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VIA HAND DELIVERY

April 29, 2013

Honorable Herb Wesson and Councilmembers
City Council of Los Angeles
200 North Spring Street
Los Angeles, CA 90012

June Lagmay
Office of the City Clerk
200 North Spring Street
Room 360
Los Angeles, CA 90012

Re: Final Environmental Impact Report for the Los Angeles International Airport Specific Plan Amendment Study – Comments of SEIU United Service Workers West

Dear Council President Wesson, Members of the City Council of Los Angeles and Clerk Lagmay:

This letter is submitted on behalf of SEIU United Service Workers West and its members living and working in the City of Los Angeles ("USWW") in support of Alliance for a Regional Solution to Airport Congestion's ("ARSAC") appeal of the February 5, 2013 City of Los Angeles Board of Airport Commissioners ("LAWA") certification of the Final Environmental Impact Report for the Los Angeles International Airport Specific Plan Amendment Study pursuant to the California Environmental Quality Act, Cal. Pub. Res. Code § 21000, et seq. (SCH # 1997061047, CPC # 2012-3357-GPA-SP, City File # AD-007-08) ("Project").

This comment letter incorporates by reference all written and oral comments submitted on the Project by any commenting party or agency.[1]

The Project is a package of airfield, terminal and ground access improvements for Los Angeles International Airport ("LAX") known as "Yellow Light" projects. As part of a 2005 settlement agreement between LAWA and the City of El Segundo, City of Inglewood, City of Culver City, County of Los Angeles and ARSAC, LAWA was required to complete the Specific

[1] We reserve the right to supplement these comments at later hearings and proceedings for this Project. *See Galante Vineyards v. Monterey Water Dist.* (1997) 60 Cal.App.4th 1109.

Plan Amendment Study prior to seeking approval for the aforementioned "Yellow Light" projects.

USWW urges the Council to vote to sustain ARSAC's appeal. The Project and its Environmental Impact Report ("EIR") should not be certified and approved at this time; instead LAWA must be ordered to revise and recirculate the Project and its environmental review.

The EIR is a product of a premature planning process, where LAWA presented the public and decisionmakers with a smorgasbord of Alternatives and possible improvements at LAX with few concrete details and little environmental analysis. No specific project was recommended until the final stage of the EIR process. Now, after a very abbreviated and surface-level environmental review, LAWA seeks to commit the City of Los Angeles to building extensive renovations at LAX with little opportunity to adequately review and study the Project. Many other clearances and approvals, including environmental review under the National Environmental Policy Act, 42 U.S.C. § 4321, et seq., and the Federal Clean Air Act, 42 U.S.C. § 7401, et seq., still are required. Many crucial details, such as the environmental impact of realigning and possibly tunneling Lincoln Boulevard, a crucial arterial road in West Los Angeles, remain unstudied.

LAWA argues that this is a program EIR, and that it can fill in the details in future approvals and studies before beginning construction of the Project. However, the fact that so many questions remain unanswered requires that LAWA not approve *any* Yellow Light project at this time. Under the circumstances, certification of the EIR and approval of the Project would commit the City of Los Angeles to a major infrastructure project with incomplete analysis in violation of governing law. A program EIR does not "decrease the level of analysis otherwise required in the EIR." *Friends of Mammoth v. Town of Mammoth Lakes* (2000) 82 Cal.App.4th 511, 534 (overturning redevelopment plan for insufficient detail and analysis). It should address "the effects of the program as specifically and comprehensibly as possible." *Id.*; 14 Cal. Code Regs. § 15168(c).

As set forth in detail in this letter, after reviewing the Project Draft ("DEIR") and Final Environmental Impact Report ("FEIR"), it is apparent that the EIR must be revised and recirculated under the California Environmental Quality Act, Public Resources Code § 21000, et. seq. ("CEQA") for the following reasons:

1) The project description is inadequate and the purported need for the project is misleading;

2) The Alternatives analysis is inadequate;

3) The DEIR/FEIR inadequately analyzes the Project's environmental baseline and impact, as it does not properly account for increases in airport and cargo capacity;

4) The FEIR does not adequately analyze or mitigate the Project's air emissions, requiring EIR recirculation;

5) The FEIR does not adequately analyze and mitigate the Project's traffic impacts;

6) The FEIR does not adequately analyze and mitigate the Project's greenhouse gas emissions;

7) The FEIR does not adequately analyze or mitigate the Project's noise impacts;

8) The FEIR does not analyze the Project's significant environmental justice concerns;

9) The FEIR does not adequately analyze and mitigate the Project's cumulative impacts; and

10) The DEIR/FEIR does not include important documents relied on in the environmental documents.

I. STANDING.

USWW, with over 40,000 members statewide and 2,000 members working at LAX, will be directly affected by the traffic, air pollution and other impacts of the proposed Project.

USWW has numerous members who live and work in the City of Los Angeles. USWW members enjoy the natural environment of the Los Angeles area. These members will be directly affected by traffic, air pollution and other impacts that will be generated by the proposed Project.

USWW advocates for programs and policies that promote good jobs and a healthy natural and working environment in order to protect the health and safety of workers and their families. An important part of the USWW's ongoing advocacy involves participating in and, where appropriate, challenging projects that would result in harmful environmental effects, or the violation of environmental laws, to the detriment of the interests of USWW's members. Workers often suffer environmental impacts that are more severe than the general population.

Workers and labor organizations have a long history of engaging in the CEQA process to secure safer working conditions, reduce environmental impacts and maximize economic benefits. The courts have held that, "unions have standing to litigate environmental claims." *Bakersfield Citizens for Local Control v. City of Bakersfield* (2004) 124 Cal. App. 4th 1184. 1198.

II. BACKGROUND ON CEQA AND THE EIR REQUIREMENT.

CEQA has two basic purposes. First, CEQA is designed to inform decision makers and the public about the potential, significant environmental effects of a project. 14 Cal. Code Regs. ("CEQA Guidelines") § 15002(a)(1). "Its purpose is to inform the public and its responsible officials of the environmental consequences of their decisions *before* they are made. Thus, the EIR 'protects not only the environment but also informed self-government.' [Citation.]" *Citizens of Goleta Valley v. Board of Supervisors* (1990) 52 Cal. 3d 553, 564. The EIR has been described as "an environmental 'alarm bell' whose purpose it is to alert the public and its responsible officials to environmental changes before they have reached ecological points of no return." *Berkeley Keep Jets Over the Bay v. Bd. of Port Comm'rs.* (2001) 91 Cal. App. 4th 1344, 1354 (*"Berkeley Jets"*); *County of Inyo v. Yorty* (1973) 32 Cal.App.3d 795, 810.

Second, CEQA directs public agencies to avoid or reduce environmental damage when possible by requiring alternatives or mitigation measures. CEQA Guidelines § 15002(a)(2) and (3). *See also, Berkeley Jets,* 91 Cal. App. 4th 1344, 1354; *Citizens of Goleta Valley v. Board of Supervisors* (1990) 52 Cal.3d 553; *Laurel Heights Improvement Ass'n v. Regents of the University of California* (1988) 47 Cal.3d 376, 400. The EIR serves to provide public agencies and the public in general with information about the effect that a proposed project is likely to have on the environment and to "identify ways that environmental damage can be avoided or significantly reduced." CEQA Guidelines § 15002(a)(2). If the project has a significant effect on the environment, the agency may approve the project only upon finding that it has "eliminated or substantially lessened all significant effects on the environment where feasible" and that any unavoidable significant effects on the environment are "acceptable due to overriding concerns" specified in CEQA section 21081. CEQA Guidelines, § 15092(b)(2)(A–B).

While the courts review an EIR using an "abuse of discretion" standard, "the reviewing court is not to 'uncritically rely on every study or analysis presented by a project proponent in support of its position.' A 'clearly inadequate or unsupported study is entitled to no judicial deference.'" *Berkeley Jets*, 91 Cal.App.4th 1344, 1355 (emphasis added) (quoting *Laurel Heights,* 47 Cal.3d at 391, 409 fn. 12). As the court stated in *Berkeley Jets*, 91 Cal. App. 4th at 1355:

> A prejudicial abuse of discretion occurs "if the failure to include relevant information precludes informed decisionmaking and informed public participation, thereby thwarting the statutory goals of the EIR process."

The preparation and circulation of an EIR is more than a set of technical hurdles for agencies and developers to overcome. The EIR's function is to ensure that government officials who decide to build or approve a project do so with a full understanding of the environmental consequences and, equally important, that the public is assured those consequences have been taken into account. For the EIR to serve these goals it must present information so that the foreseeable impacts of pursuing the project can be understood and weighed, and the public must be given an adequate opportunity to comment on that presentation before the decision to go forward is made. *Communities for a Better Environment v. Richmond (Chevron)* (2010) 184 Cal. App. 4th 70, 80 ("*CBE v. Richmond*")(quoting *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.4th 412, 449–450).

Here, the EIR is inadequate as it does not provide an adequate product description or Alternatives analysis, rendering the EIR so fundamentally inadequate that meaningful public review and comment were precluded. Moreover, this comment letter raises significant concerns about environmental baseline, air emissions, traffic, greenhouse gases, noise, and environmental justice that were not adequately addressed, analyzed or mitigated in the EIR. Finally, the EIR failed to make a number of documents incorporated by reference available to the public, requiring revision and recirculation to allow the public to review the documents.

III. THE PROJECT DESCRIPTION IS INADEQUATE, AND THE PURPORTED OBJECTIVE FOR THE PROJECT IS MISLEADING.

The EIR should be revised and recirculated as the EIR from the beginning failed to provide an adequate Project Description of LAWA's recommended Alternatives 1 and 9. These recommended Alternatives 1 and 9 were not selected until the FEIR stage. This led in the end to a too general and conclusory analysis of the recommended Project that is improper and violates CEQA. In addition, the purported safety objective for the Project misleading conceals the true reason LAWA wants the Project, which is to increase cargo capacity.

"An accurate, stable and finite project description is the sine qua non of an informative and legally adequate EIR." *County of Inyo v. City of Los Angeles* (1977) 71 Cal.App.3d 185, 192; *Berkeley Jets,* 91 Cal.App.4th at 1354; *Sacramento Old City Assn. v. City Council* (1991) 229 Cal.App.3d 1011, 1023; *Stanislaus Natural Heritage Project v. County of Stanislaus* (1996) 48 Cal.App.4th 182, 201. "[A] curtailed or distorted project description," on the other hand, "may stultify the objectives of the reporting process. Only through an accurate view of the project may affected outsiders and public decision-makers balance the proposal's benefit against its environmental costs, consider mitigation measures, assess the advantage of terminating the proposal (i.e., the "no project" alternative) and weigh other alternatives in the balance." *Id.*; *see also* CEQA Guideline § 15124; *City of Santee v. County of San Diego* (1989) 214 Cal.App.3d 1438. As one analyst has noted:

> The adequacy of an EIR's project description is closely linked to the adequacy of the EIR's analysis of the project's environmental effects. If the description is inadequate because it fails to discuss the complete project, the environmental analysis will probably reflect the same mistake. Stephen L. Kostka, Michael H. Zischke (2013) Practice Under the California Environmental Quality Act 580.

A "rigorous analysis" is required to dispose of an impact as insignificant. *Kings County Farm Bureau v. City of Hanford* (1990) 221 Cal.App.3d 692. Such a rigorous analysis is not possible if the project description is inaccurate, inconsistent, or misleading.

Here, rather than conducting environmental review on a definite and finite Project, LAWA essentially merged what is often described under CEQA as "early public consultation" or "scoping" into the later stages of the environmental review process. CEQA Guidelines § 15083 describes "early public consultation" or "scoping" as a process that occurs "[p]rior to completing the draft EIR" where the lead agency "identifies the range of actions, alternatives, mitigation measures, and significant effects to be analyzed in depth in an EIR."

Thus, the Project was described in the DEIR as a "Specific Plan Amendment Study (SPAS) that fulfills Section 7.H of the LAX Specific Plan consistent with the definition of the SPAS set forth in the LAX Master Plan Stipulated Settlement" ("Project Description"). SPAS is an early public consultation process which is meant to evaluate potential alternatives to certain projects that were previously approved as part of the LAX Master Plan Program.

The Project Description adopted for the DEIR/FEIR is inadequate as it fails to describe a CEQA project, is neither stable nor finite, does not identify a preferred Alternative in the DEIR, and misleadingly emphasizes the safety objective, when if fact the real reason LAWA wants the Project is expand cargo capacity.

A. <u>The Project Description Fails To Describe A CEQA Project.</u>

The Project Description fails to accurately describe a CEQA project. Under CEQA, a project description must describe "an activity which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment." Cal. Pub. Res. Code § 21065."

The Project Description fails to describe a CEQA project as it describes itself "as a "Specific Plan Amendment Study (SPAS) that fulfills Section 7.H of the LAX Specific Plan consistent with the definition of the SPAS set forth in the LAX Master Plan Stipulated Settlement." FEIR 2-1. Completing a study is not a CEQA project, as conducting research and drafting a study in of itself is unlikely to cause "a direct physical change . . . [or] a reasonably foreseeable indirect physical change in the environment." In reality, it is LAWA's recommended Alternatives 1 and 9 that constitute the Project here, and this needed to be identified and disclosed from the beginning, not at the end FEIR stage. This would have ensured a more thorough and complete analysis of the Project than in fact occurred here.

B. <u>The Project Description Is Inadequate As It Is Neither Stable Nor Finite.</u>

The Project Description is inadequate as the DEIR/FEIR fails to adopt a stable and finite description of the Project and the Alternatives being considered. An EIR's project description and accompanying analysis must be stable and consistent. Inconsistent description and analysis of a project prevents an EIR from serving as a vehicle for intelligent public participation in the decision-making process. *County of Inyo*, 71 Cal.App.3d at 197.

The Project Description is unstable as it provides nine separate Alternatives, including some fully integrated Alternatives, outlining airfield, terminal, and ground access improvements (Alternatives 1-4), as well as separate Alternatives outlining individual airfield, terminal, and ground access improvement projects (Alternatives 5–9). DEIR 2-8–2-42. For example, Alternative 1 is describes as a "fully-integrated alternative[] consisting of airfield, terminal, and ground access components," while Alternative 5 is described as focusing on "airfield improvements and associated termination improvement . . . compatible with the ground access improvements associated with Alternatives 1 and 2, as well as the ground access improvements associated with Alternatives 8 and 9. FEIR 2-8, 2-26. The Project Description describes this vast array of Alternatives as "interchangeable," (DEIR 2-8) and expects the public to analyze the environmental impact of each of these Alternatives by mixing and matching the environmental impacts of each individual airfield, terminal or ground access improvements.

This approach is neither stable nor finite, as it allows for a wide variety of variations on the Project beyond just the Alternatives that were reviewed within the DEIR and FEIR. Such an approach defeats the purpose of the EIR to serve as an "informational document" for the public to access the environmental impact of a project. As the Court in *County of Inyo*, 71 Cal.App.3d at 198 found "[a] curtailed, enigmatic or unstable project description draws a red herring across the path of public input."

C. **<u>The Project Description Is Inadequate As It Does Not Identify A Preferred Alternative in the DEIR.</u>**

The lack of a stable and finite project description is compounded by the fact that the CEQA process for this Project did not adopt a recommended Alternative until the FEIR was published, excluding extensive public comment and scrutiny until the very end of the decision-making process.

LAWA claims that not adopting a recommended Alternative until the FEIR stage had no meaningful impact on the public participation or decision-making process as "[n]othing would be gained had LAWA selected one of the nine Alternatives as the proposed project in the SPAS Draft EIR, and then evaluated the other options as Alternatives to the proposed project." FEIR 4-239. This is wrong.

LAWA's response highlights the fundamental problems with its approach. LAWA did not adopt any single one of the nine Alternatives proposed and analyzed in the DEIR. Instead, it opted to adopt a combination of Alternatives 1 and 9. The agency could have easily adopted any infinite number of combinations of Alternatives presented in the DEIR. LAWA, rather than conducting a thorough review of the environmental impact of a stable and finite Project as is required by CEQA, conducted surface level environmental review of each Alternative that is normally reserved for the "early public consultation" or "scoping" process. LAWA's approach prevented the thorough review of a recommended Project Alternative that is required by CEQA up until the last moment of the CEQA process. This led to inadequate analysis, as more fully described in this letter below.

D. <u>The Purported Safety Need Objective Is Misleading</u>.

LAWA consistently argues that its justification for rushing this Project through is runway safety, but this is misleading.

First, LAWA Executive Officer Lindsay admitted at the Council Committee hearing in March 2013 that he Project is at least two years away from being shovel ready so none of the projected benefits are imminent. Two years would allow ample to reissue and recirculate the EIR in line with the other federal approval processes that should be happening in tandem.

Second, a safety report issued by NASA officials and an academic panel in 2010 found that separating the runways would make the north airfield safer, but the risk of ground collisions is so low that any shift would be inconsequential. *See Attach. F hereto.*

Third, the facts show that the real objective for this Project is cargo expansion. Our understanding is that the runway alterations are needed to accommodate larger body long haul airplanes such as the Airbus 380 and Boeing 787 Dreamliner. D Weikel, "LAX Runway Proposal Advances," Los Angeles Times, December 3, 2012. These are passenger planes but they also accommodate cargo shipments, particularly international imports. or example, the Airbus 340 is touted not only for large passenger capacity but also for the fact that its holds twice the underfloor cargo capacity of comparable airliners. *See Attach.G hereto.*

The proposed improvements to accommodate large aircraft follows predicted trends in cargo traffic where air cargo traffic is expected grow at a rate of approximately 5.2% per year over the next twenty years with an increasing percentage of that cargo traffic expected to be accommodated by large freighter jets. Boeing (2012) Current Market Outlook: 2012-2031 at p. 17, *see Attach. A hereto*. More than half of the air cargo at LAX arrives and departs in the bellies of passenger aircraft; the other half is accounted for by all-cargo airlines, FedEx, and UPS. Tom Bradley International Terminal is the major cargo terminal, with airlines that accounted for one-third of all LAX freight in 2012 (excluding air mail, 20 percent of which is carried by United). *See Attach. H hereto*. Given the limited amount of airports that can accommodate these large jets, it can be expected that LAX will absorb the majority of this increase in large freighter jet traffic.

IV. <u>THE DEIR/FEIR ALTERNATIVES ANALYSIS IS INADEQUATE</u>.

Rather than providing a mixed bag of fully integrated Alternatives and individual airfield, terminal or ground access improvements, all as individual Alternatives with separate environmental impacts, LAWA should have selected a preferred Project from the beginning, and described all of the individual improvement projects as fully integrated Alternatives. The mix and match approach that was used instead violates CEQA.

A. The DEIR's Mix And Match Alternatives Analysis Violates CEQA.

The DEIR's mix and match approach violates CEQA's requirement for meaningful analysis of Alternatives. CEQA Guideline § 15126.6(f) states:

> The range of alternatives required in an EIR is governed by a "rule of reason" that requires the EIR to set forth only those alternatives necessary to *permit a reasoned choice*. The alternatives shall be limited to ones that would *avoid or substantially lessen any of the significant effects of the project*. Of those alternatives, the EIR need examine in detail only the ones that the Lead Agency determines could *feasibly attain most of the basic objectives of the project*. The range of feasible alternatives shall be selected and discussed in a manner to *foster meaningful public participation and informed decision making*. (Emphasis added).

An EIR "shall describe a range of reasonable *alternatives to the project, or to the location of the project*, which would feasibly attain most of the basic objectives of the project but would avoid or substantially lessen any of the significant effects of the project, and evaluate the comparative merits of the alternatives." CEQA Guidelines § 15126.6(a). Generally, "project alternatives typically fall into one of two categories: on-site alternatives, which generally consist of different uses of the land under consideration; and off-site alternatives, which usually involve similar uses at different locations." *Citizens of Goleta Valley v. Board of Supervisors* (1990) 52 Cal.3d 553, 566. "[T]he range of alternatives that an EIR must study in detail is defined in relation to the adverse environmental impacts of the proposed project . . . ." *Sunnyvale West Neighborhood Ass'n v. City of Sunnyvale* (2010) 190 Cal.App.4th 1351, 1376.

Here, rather than providing a easily understood set of fully integrated Alternatives, with variations of the various proposed airfield, terminal and ground access improvements proposed for LAX, LAWA opted to consider a mixed bag of some integrated and some individual airfield, terminal and ground access improvements. Many of the Alternatives violate the "rule of reason" as they do not substantially lessen any of the significant effects of the Project or feasibly attain most of the basic objectives of the Project. For example, Alternatives 5, 6 and 7, which focus on "airfield improvements and associated termination improvement," fail to attain Objective 2 of the Project which is to improve ground access systems at LAX to accommodate airport-related traffic. DEIR 2-26, 2-30, 2-33. On the other hand, Alternatives 8 and 9 which feature ground access improvements, fail to meet Objective 1 of the Project which is to provide north airfield improvements to increase the safety and efficiency of aircraft movement at LAX.

LAWA attempts to justify its "mix and match" approach to CEQA by citing *California Oak Foundation v. Regents of University of California* (2010) 188 Cal.App.4th 227, 275–77. *California Oak Foundation* involved an EIR considering a package of improvements centered on a new Athletic Center for the University of California. In that case, the University of California adopted the exact opposite approach that has been used by LAWA, as it packaged iterations of the various improvements into individual Alternatives, rather than analyzing a mix of some integrated and some related individual projects as separate, individual Alternatives. *Id.* at 274. The Court approved the University of California's "'integrated' approach, comparing each alternative, *including all of its components*, to the . . . Project[] *as a whole*." *Id.* at 276. LAWA, on the other hand, decided to mix an integrated and individual approach to its Alternatives analysis. As a result, it is virtually impossible to compare the environmental impacts of the different LAWA Alternatives to eachother, as CEQA requires, especially when the Alternatives are then combined at the last minute, as in the case with Alternatives 1 and 9.

Thus, the unorthodox mix and match approach adopted by LAWA results in conclusory analysis of the environmental impacts and differences between the Alternatives, making in unclear as to whether any of the Alternatives lessen significant effects of the Project. For example LAWA in recommending adoption of Alternatives 1 and 9 in the FEIR simply concluded that there was no significant difference in the environmental impact between the Alternatives considered, stating that "the results fall within the low and high ends of the ranges of impacts presented in the SPAS Draft EIR." This is not the meaningful Alternatives analysis that is required. More analysis is needed.

B. The FEIR Does Not Adequately Analyze The Environmentally Superior Alternative.

The FEIR does not adequately analyze as to why LAWA chose to adopt a combination of Alternatives 1 and 9 as the recommended Alternative despite earlier identifying Alternative 2 as the environmentally preferred Alternative. DEIR 1-103. CEQA requires public agencies to deny approval of a project with significant environmental impacts when feasible Alternatives, such as Alternative 2, or mitigation measures substantially lessen such effects. Cal. Pub. Res. Code § 21002.

The FEIR contains inadequate supporting data and findings to justify its failure to adopt the environmentally superior Alternative. "[I]t is the policy of the state that public agencies should not approve projects as proposed if there are feasible alternatives or feasible mitigation measures available which would substantially lessen the significant environmental effects of such projects . . . ." Cal. Pub. Res. Code § 21002. In fact, California Public Resources Code § 21081 mandates that:

> *no public agency* shall approve or carry out a project for which an environmental impact report has been certified which identifies one or more significant effects on the environment that would occur if the Project is approved or carried out unless . . . [s]pecific economic, legal, social, technological, or other considerations . . . make infeasible the mitigation measures or alternatives identified in the environmental impact report. (Emphasis added); *see also* CEQA Guidelines § 15091(a)(3).

Here, the FEIR fails to adequately explain why the designated environmentally superior Alternative 2 was not recommended by LAWA. In fact, the FEIR document provides no analysis on this point. While the FEIR document explains why LAWA recommended a combination of Alternative 1 and 9 (FEIR 2-2–2-5), the FEIR document has no analysis as to why Alternative 2 was not selected. The lack of any explanation within the main body of the FEIR document renders the FEIR facially deficient.

Only long after the FEIR was published, in response to ARSAC's appeal of LAWA's February 5, 2013 certification of the Final Environmental Impact Report for the Los Angeles International Airport Specific Plan Amendment Study did LAWA respond to this point. Los Angeles World Airports (Apr. 5 2013) Staff Report: LAX Specific Plan Amendment Study Final Environmental Impact Report (Final EIR) 9. While LAWA claims in this Staff Report that the Agency explained why Alternative 2 did not adequately meet all the Project's objectives in the CEQA Findings, Los Angeles World Airport (Jan. 2013) LAX SPAS Project CEQA Findings 105–08, the analysis in this document is cursory, insufficient and in any case, came far too late, as it should have been included in the FEIR to allow for public comment and scrutiny.

Moreover, LAWA's response *directly contradicts* claims made in the FEIR. While LAWA claims that Alternative 1 would better meet objectives to improve runway safety and efficiency, in fact the FEIR states that "the average delay and unimpeded taxi times for Alternative 1 are slightly greater than those for Alternative 2. The benefit of having access to the centerfield taxiway is overshadowed by the increased taxi time needed to get in from Runway 24R under Alternative 2." FEIR 4-178. Moreover, the FEIR concludes that "Alternative 2 provides lower aircraft emissions under good weather VFR conditions." *Id.*

LAWA did not conduct adequate analysis as to why the FEIR recommended Alternatives 1 and 9 instead of Alternative 2. LAWA attempts to correct its mistake in this regard only after the FEIR was published by providing cursory analysis that is directly contradicted by the FEIR itself. The court is not to "uncritically rely on every study or analysis presented by a project proponent in support of its position. A clearly inadequate or unsupported study is entitled to no judicial deference." *Laurel Heights,* 47 Cal.3d at 309 n12.

C. <u>The EIR Does Not Properly Identify A "No Project" Alternative.</u>

The EIR does not properly identify a "no project" Alternative. CEQA Guideline § 15126.6(e)(1) requires that an EIR evaluate a "no project" Alternative describing either "existing conditions . . . or . . . what would be reasonably expected to occur in the foreseeable future if the project were not approved . . . ." If the Project is a "revision of an existing . . . plan . . . the 'no project' Alternative will be the continuation of the existing plan, policy or operation into the future . . . . the projected impacts of the proposed plan or alternative plans would be compared to the impacts that would occur under the existing plan." *Id.* § 15126.6(e)(3)(A).

The "no project" Alternative is misidentified as Alternative 3. DEIR 2-17. Alternative 3 includes all previously approved portions of the LAX Master Plan, as well as the original "Yellow Light" projects which were, according to the Settlement, to be replaced with other similar projects. The DEIR incorrectly identifies Alternative 3 as the "no project" Alternative, as the "Yellow Light" project included were not expected to go forward absent additional approvals pursuant to the terms of the Settlement.

Oddly enough, Alternative 4 (which only includes all previously approved portions of the LAX Master Plan) is not designated as the "no project" alternative; yet, it is described as "what would reasonably be expected to occur if an ongoing and reasonably foreseeable non-Yellow Light improvements identified in the LAX Master Plan (i.e. "Alternative D") were to be implemented, and none of the Yellow Light Projects . . . were constructed or implemented." DEIR 2-22. Moreover, the DEIR utilizes Alternative 4 as the benchmark of analysis for future conditions without the Project, stating "[o]f the nine alternatives, Alternative 4 has the least amount of improvements and most closely represents a future (2025) 'no Yellow Lights Projects' scenario . . . ." DEIR 4-121.

Thus, the EIR should be revised and recirculated to designate and better analyze Alternative 4 as the "no project" Alternative.

V. THE FEIR INADEQUATELY ANALYZES THE PROJECT'S ENVIRONMENTAL BASELINE AND IMPACT, AS IT DOES NOT PROPERLY ACCOUNT FOR INCREASES IN AIRPORT CAPACITY.

The FEIR inadequately analyzes the Project's environmental baseline and impact by claiming that LAX will be forced to accommodate a practical capacity of 78.9 million passengers per year regardless of improvements at the facility. Notwithstanding the fact that this places the utility of the Project into serious question, this approach serves to minimize the differences in environmental impact between the Alternatives and skews the baseline calculations of the FEIR. The court is not to "uncritically rely on every study or analysis presented by a project proponent in support of its position. A clearly inadequate or unsupported study is entitled to no judicial deference." *Laurel Heights,* 47 Cal.3d at 409 n12; *see also American Canyon v. City of American Canyon* (2006) 145 Cal.App.4th 1062, 1081 (rejecting "naked assertion" concerning Wal-Mart traffic); *Berkeley Keep Jets,* 91 Cal.App.4th at 1381 (CEQA analysis inadequate when expert testimony demonstrated methods for evaluating impacts were insufficient). The FEIR should be revised and recirculated to analyze the difference between airport passenger capacities among the Alternatives.

The FEIR should not be certified without a comprehensive analysis of the capacity enhancing improvements of the various Alternatives being considered. As stated in the North Airfield Safety Study, "runway reconfiguration can be justified on capacity grounds . . . capacity and operational efficiency can be further studied to estimate the economic operational costs and benefits of various airfield configurations." FEIR, Attach. 5, SPAS-PC00149.

The FEIR inadequately analyzes airport capacity as it fails to analyze increased traffic from Category VI New Large Aircraft and cargo traffic. Moreover, the FEIR's approach to calculating "practical capacity" violates FAA regulations to determining the capacity of an airport facility and improperly relies upon an unenforceable forecast of 78.9 million passengers per year.

The FEIR should be revised and recirculated to analyze increased air passenger capacity at LAX.

A. <u>The FEIR Fails To Analyze The Impact of Increased Traffic From Category 6 New Large Aircraft.</u>

LAWA recommends Alternative 1, which includes increased runway separation, eastward extension of the north runways, and the addition of centerline taxiways and high speed runway exits is almost certain to increase the capacity of LAX, because the Project is intended to improve access for large Category 6 aircraft that are currently unable to utilize the North Airfield where the Project proposes to improve. The FEIR itself states that "one of the project objectives pertaining to the north airfield improvements is to lengthen the primary departure runway (Runway 6R/24L), which is currently too short for certain large aircraft (e.g. fully-loaded Boeing 747-400) on long-haul flights." FEIR 4-268.

Despite this admission, LAWA claims that this Project will not allow for increased numbers of large Category 6 aircraft to access the airport by arguing that the approaches for large aircraft will not be changed as a result of the Project. However, these claims directly contradict the express descriptions of the Project in the FEIR. As the FEIR states, the Project will:

> Relocate the service road that currently lies between Taxiway E and Taxilane D to a location 142 feet south of Taxilane D centerline to increase the separation between the two taxiways to *allow for simultaneous operations with larger aircraft than currently accommodated*. . . . FEIR 2-7.

The Project will almost inevitably allow for increased operations of large aircraft, as presently the two northern runways, 6L/24R and 6R/24L, "are treated as a single runway because the spacing between the two runways." FEIR 4-248.

The overwhelming weight of evidence within the administrative record demonstrates that the proposed Alternatives would significantly increase passenger capacity at LAX. For example, the South Coast Air Quality Management District ("SCAQMD") concluded that the Project will cause "a significant increase of air passenger capacity at the project site." Moreover, as the Los Angeles County Board of Supervisors concluded, all proposed Alternatives "include improvements to the north airfield . . . designed to increase aircraft flow and safety. . . . increas[ing] the peak hour Instrument Flight Rules (IFR) capacity of the north airfield. FEIR 4-247. This has to be better analyzed in the EIR

B. The FEIR Fails To Account For Increased Cargo Capacity.

Moreover, the FEIR fails to take into account the Project's increased cargo handling capacity. The FEIR bases its calculations of environmental impacts on LAX accommodating a practical capacity of 78.9 million passengers per year, but it ignores the impact that the North Runway improvements would have on traffic on large planes that carry bigger cargo loads. As noted earlier, the Project will increase the capacity for LAX to accommodate large jets.

The impact of increased cargo capacity is not insubstantial. Ground transportation for passengers and cargo along with the use of ground transportation equipment together account for more than half of all nitrogen oxides – a precursor to smog – produced at LAX. [C Callahan, The Plane Truth: Air Quality Impacts of Airport Operations and Strategies for Sustainability: A Case Study of Los World Airports, Commissioned by the Clean Air Coalition, June, 2010. *See Attach. I hereto.*

The FEIR nonetheless ignores these trends by entirely failing to account for the traffic and air quality impacts from increased cargo handling capacity, cargo handling equipment, and trucks that will be needed to handle the large amounts of cargo that will go through LAX.

C. The FEIR's Practical Capacity Approach Violates FAA Regulations.

LAWA's reliance upon its figure of 78.9 million annual passengers ("MAP") "practical capacity" is based upon "market conditions . . . . expected physical characteristics of the various functional elements of the airport . . . [and] how the market is likely to respon[d] to and use LAX." FEIR 4-243. The FEIR's approach is at odds with FAA regulations concerning airport capacity in long range planning. While LAWA repeatedly claims that all Alternatives assume a practical capacity of 78.9 MAP, the FAA requires that capacity be measured based upon the "maximum number of aircraft operations which can be accommodated on the airport or airport component in an hour," annual service volume, and aircraft mix. Federal Aviation Administration, Advisory Circular 150/5060-5 (1983) 1-2.

The FEIR neglects to calculate its environmental impact based upon its actual capacity, and instead claims that all Alternatives are only capable of serving a practical capacity of 78.9 MAP, failing to account for the maximum number of aircraft operations as well as the aircraft mix that will utilize the improved runway facilities at LAX. The court is not to "uncritically rely on every study or analysis presented by a project proponent in support of its position. A clearly inadequate or unsupported study is entitled to no judicial deference." *Laurel Heights,* 47 Cal.3d at 309 n12.

Let us also reiterate that many federal clearances and approvals, including environmental review by the FAA under the National Environmental Policy Act, 42 U.S.C. § 4321, et seq., and the Federal Clean Air Act, 42 U.S.C. § 7401, et seq., still are required.

D. <u>The DEIR/FEIR Improperly Relies Upon An Unenforceable Practical Capacity Of 78.9 MAP</u>.

Despite indications to the contrary, the DEIR/FEIR assumes that every Alternative analyzed within the DEIR/FEIR for the Project has a "practical capacity" of 78.9 MAP. Essentially, LAWA asks that the public to take it as a given that LAX will serve no more than 78.9 MAP, not to mention cargo, in spite of indications that LAX would be theoretically capable of efficiently accommodating even higher levels of usage after implementing the proposed improvements in the Project.

The FEIR casts doubt upon whether 78.9 MAP is a realistic appraisal of how much air traffic LAX's facilities can absorb, stating that "LAWA may not restrict access to the airport and may not impose any 'cap' on aircraft operations, nor regulate or legally control in any way what operations the airlines might wish to undertake at any particular airport." FEIR 4-143. The FEIR even tacitly admits that any project aimed towards addressing operational and safety concerns, as here, also increases capacity, stating "[t]he FAA . . . promotes permanent solutions to operational concerns and inefficiencies through capacity improvements." FEIR 4-242–4-243

Given that LAWA admits that it cannot impose any actual control upon the number of passengers or cargo that utilize its facility, LAWA argues that its "forecast" of 78.9 MAP is reasonable based upon the limited number of gates at LAX and a commitment to seek "regionalization" of air traffic once the airport reaches 75 MAP. FEIR 4-243.

However, LAWA provides no data to justify the ratio of passengers to gates used to arrive at its forecast of 78.9 MAP based upon 153 gates being built under all Alternatives. The FEIR itself states that there is "no apparent correlation . . . between the number of passenger gates and passenger capacity without assessing multiple contributing factors, most of which are very specific to each airport." FEIR 4-245.

Moreover, the "passenger to gate ratios" differ significantly between the various Alternatives proposed in the DEIR. Alternatives 1, 3, 5, and 7 all propose different gate configurations (FEIR 2-10, 2-21, 2-29–2-30) which may significantly influence passenger capacity. FEIR 4-246.

Finally, LAWA's commitment to seek regionalization of air traffic is both vague and seriously doubtful. The FEIR contains no concrete, specific, or enforceable proposals as to how LAWA will be able to "regionalize" air traffic once LAX usage reached 75 MAP. Moreover, LAWA's commitment to a "regional" solution to air traffic is in serious question given that two separate lawsuits have recently been filed by parties (ARSAC, Ontario) alleging that LAWA has purposely avoided regionalizing air traffic in violation of various settlement and joint-power agreements.

VI. THE DEIR/FEIR DOES NOT ADEQUATELY ANALYZE OR MITIGATE THE PROJECT'S AIR EMISSIONS.

The DEIR/FEIR also fails to adequately analyze the air pollutant emissions that will be generated by the Project. In particular, the FEIR fails to include two recent air quality studies conducted at LAX or adequately analyze air emissions that will be generated by the Project. Moreover, the FEIR shows that approving the Project would violate California's State Implementation Plan under the Federal Clean Air Act, and the FEIR fails to demonstrate adequate mitigation measures to address its impact on air quality. Finally, the FEIR adopts an improper baseline for calculating air quality emissions and needs to better characterize cargo emissions. The FEIR should be revised and recirculated to properly analyze and mitigate the Project's air emissions. A program EIR does not "decrease the level of analysis otherwise required in the EIR." *Friends of Mammoth,* 82 Cal.App.4th at 534 (overturning redevelopment plan for insufficient detail and analysis). It should address "the effects of the program as specifically and comprehensibly as possible." *Id.*; 14 Cal. Code Regs. § 15168(c).

A. The Project Should Not Be Approved Until Airport Emissions Are Properly Evaluated By The Froines and LAX Air Quality and Source Apportionment Study. In This Circumstance Recirculation Is Needed.

The DEIR and FEIR do not analyze two recent studies concerning air pollution at LAX. In 2007, a study commissioned by the California Air Resources Board found elevated levels of black carbon and ultrafine particles near LAX caused by aircraft takeoffs and landings. John Froines, et al (2007) Monitoring and Modeling of Ultrafine Particles and Black Carbon at the Los Angeles International Airport. Moreover, in spring of 2013, LAWA is expected to release the results of its LAX Air Quality and Source Apportionment Study (AQSAS), the publication of which was part of the LAX Master Plan Community Benefits Agreement.

The Project should not be approved without taking into account the results of the Froines and AQSAS studies as both of them are intended to help guide future development at LAX. SCAQMD, in its comments, emphasized the importance of these studies, stating that "[a]s both of these studies were conducted to help the public and decision makers for this project evaluate potential air quality impacts from this facility, a robust description should be included in the Final EIR." FEIR 4-114.

Failure to include and analyze the studies in the DEIR and FEIR, and their subsequent insertion into the administrative record by SCAQMD, requires revision and recirculation here. The California Supreme Court in *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.4th 412, 447 has described the recirculation requirement as follows:

> [Public Resources Code] Section 21092.1 provides that when a lead agency adds "significant new information" to an EIR after completion of consultation with other agencies and the public (see §§ 21104, 21153) but before certifying the EIR,

> the lead agency must pursue an additional round of consultation. In *Laurel Heights II* . . . we held that new information is "significant," within the meaning of section 21092.1, only if as a result of the additional information "the EIR is changed in a way that deprives the public of a meaningful opportunity to comment upon a *substantial* adverse environmental effect of the project or a feasible way to mitigate or avoid such an effect." Recirculation is not mandated under section 21092.1 when the new information merely clarifies or amplifies the previously circulated draft EIR, but is required when it reveals, for example, a new substantial impact or a substantially increased impact on the environment. We further held the lead agency's determination that a newly disclosed impact is not "significant" so as to warrant recirculation is reviewed only for support by substantial evidence. (Citations removed).

B. The FEIR Fails to Adequately Analyze Emissions That Will Be Generated By The Project.

The FEIR fails to adequately analyze air pollutant emissions that will be generated by the Project. The FEIR should be revised and recirculated as the FEIR does not adequately assess air quality emissions for all Alternatives, and fails to account for background and reverse thrust emissions.

1. The DEIR/FEIR Does Not Adequately Assess Air Quality Emissions For All Alternatives Considered In The EIR.

The DEIR/FEIR fails to analyze or provide adequate air quality modeling data to assess the differences in environmental impacts of each Alternative. An EIR must "include sufficient information about each Alternative to allow meaningful evaluation, analysis, and comparison with the proposed project." CEQA Guidelines § 15126.6(d). Information sufficient to allow an informed comparison of the impacts of the Project with those of the Alternatives should be provided. *Kings County Farm Bureau,* 221 Cal.App.3d at 733.

The DEIR/FEIR only includes air quality modeling data for Alternatives 1 through 4, omitting modeling for Alternatives 5 through 7 for budgetary reasons. LAX Specific Plan Amendment Study Report, Appx. F-2, 1.

Moreover, the data that the DEIR/FEIR does provide is inadequate to assess the air quality impacts of Alternatives 1 through 4, failing to present aircraft, ground support equipment, and auxiliary power unit emissions by operation mode.

LAWA is required to adequately analyze and compare the environmental impacts of *all* Alternatives considered in the EIR process. The DEIR/FEIR only analyzes the air quality impact of some, but not all, Alternatives. The EIR should be revised and recirculated with modeling data for all Alternatives.

2. <u>The FEIR Inadequately Analyzes Background Emissions</u>.

The DEIR/ FEIR fail to adequately analyze background emissions near the airport.

LAWA's approach is to calculate airport-related emissions associated with each Alternative (but not combined Alternatives such as the recommended Alternatives 1 and 9), perform a dispersion analysis, superimpose the predicted concentration upon the background, and then compare the combined exposure to acceptable incremental thresholds to ambient air quality standards.

However, the DEIR and FEIR fail to provide information concerning background ambient air quality in the communities directly east of the freeway, relying upon background measurements taken in Westchester, north of the airport. SCAQMD recommended including background measurements set at the eastern property boundary near the 405 Freeway to determine background concentrations in communities lying east of LAX. LAWA, in response, stated that there are no monitoring stations located in the communities east of LAX and that the nearby monitoring station in Westchester was the closest monitoring station available to monitor emissions in those communities. As a result, the environmental review grossly underestimates major air pollution sources such as the 405 Freeway. An EIR "necessarily involves some degree of forecasting," but "an agency must use its best efforts to find out and disclose all that it reasonably can." 14 Cal. Code Regs. § 15144. That did not happen here.

Incomplete information, such as the lack of ambient air quality measurements in communities east of LAX, and the failure to include emissions generated by the 405 Freeway, highlight the problems caused by the FEIR failing to include important, relevant studies such as the Froines and AQSAS studies. The court is not to "uncritically rely on every study or analysis presented by a project proponent in support of its position. A clearly inadequate or unsupported study is entitled to no judicial deference." *Laurel Heights,* 47 Cal.3d at 309 n12.

3. <u>The FEIR Omits Reverse Thrust Emissions</u>.

The FEIR air pollutant emissions analysis fails to include reverse thrust emissions. Reverse thrust emissions must be included in emission calculations as "[r]everse thrust is . . . considered by EPA as an official mode and should be included in calculation procedures as a sixth operation mode . . . ." Federal Aviation Association (1997) Air Quality Procedures for Civilian Airports and Air Force Bases, Appx. D, D-5.

While LAWA claims to have included reverse thrust emissions into its emission calculations, the public has been unable to verify this as LAWA has not made its model algorithms and data sets available to the public. Nonetheless, our review indicates that the emission calculations in the DEIR and FEIR are far lower than is typically expected for calculations including reverse thrust emissions, casting serious doubt on the accuracy of those calculations.

4. The EIR Needs To Better Characterize Cargo Handling Emissions.

Air emissions at airports are produced by vehicular traffic, air traffic, ground service equipment (GSE) and emergency generators. All of these produce emissions with different operational characteristics. To the extent that increased cargo truck traffic and use of GSE would result from increased cargo handling capacity generated by the Project, this impact requires further analysis.

For example, SCAQMD, in its comments, noted that the Draft EIR does not contain any description of how emission sources were treated in the dispersion model. Without this key description of the modeling exercise, the public is not able to confirm the validity of the dispersion modeling analysis. Key parameters that require additional clarification include source type, placement strength, dispersion parameters, etc. SQAQMD Comments, p 8: Dispersion Modeling Source Treatment.

Toxic air pollutants, are known or suspected to cause cancer or other serious health effects such as birth and reproductive effects. Many toxic air pollutants are emitted in the form of volatile organic compounds (VOC) or particulates. Specific examples include benzene, which is found in gasoline, diesel particulate matter, which is emitted by diesel powered trucks. *See Attach I hereto*. Particulate pollution emitted from the combustion of diesel fuel is especially problematic in terms of health impacts. In 1998, the California Air Resources Board identified diesel particulate matter as a toxic air contaminant, linking it to increased cancer risk. Particulate matter exposure also has been linked to asthma and other respiratory diseases as well as cardiovascular disease in adults. *Id.* p. 40.

SCAQMD, in its comments also noted that it is unclear how emissions were calculated for vehicles accessing the project site. For example, Table 56 of Attachment 2 of Appendix of the Draft EIR presents estimates of Vehicle Miles Traveled (VMT) for different speed bins and different vehicle types for the baseline scenario. However there are several parameters that are not clear from Table 56, including how the different vehicle classes (at least 6 classes of vehicles likely travel to LAX) were weighted down to the two classes presented. The EIR should include a more thorough explanation of how emission calculations were performed. SQAQMD Comments, p 8: Emissions Inventory Calculations for Vehicles.

C. The FEIR Shows That Approval Of the Project Would Violate Both State And Federal Law As Construction and Operational Emissions From the Project Would Violate State and Federal Ambient Air Quality Standards.

Approving the Project and certifying the FEIR would violate both the Federal and California Clean Air Act as the FEIR itself demonstrates that construction and operation emissions would result in violations of the National ("NAAQS") and California Ambient Air Quality Standards ("CAAQS"). FEIR 2-42; Approval, construction and operation at the Project would violate California's State Implementation Plan under the Federal Clean Air Act, exposing

California to additional sanctions under Federal law as well as placing the health and safety of local residents at risk.

Let us reiterate that many federal clearances and approvals, including environmental review under the National Environmental Policy Act, 42 U.S.C. § 4321, et seq., and the Federal Clean Air Act, 42 U.S.C. § 7401, et seq., still are required. It is readily apparent that LAWA wants to rush through the municipal approvals for the Project and CEQA, but in truth all this analysis, including of the federal requirements, is more properly done together, and should be studied and disclosed now.

The Project's operational emissions would result in violations of the National and California AAQS. FEIR 2-42. The FEIR states that "[i]mplementation of the LAWA Staff-Recommended Alternative would exceed the 1-hour NAAQS for NO_2, the 1-hour CAAQS for NO_2, and the SCAQMD significance thresholds for PM_{10}." *Id.*

Construction emissions generated by the Project would also result in similar violations. FEIR 2-31. The FEIR finds that "construction concentrations for the LAWA Staff-Recommended Alternative would exceed the 1-hour NO_2 CAAQS and NAAQS. *Id.*

Approving the Project would be in direct violation of the both National and State clean air laws. The EIR should be revised and recirculated with additional mitigation, such as the purchase of emission offsets, to avoid violating clean air laws and protect the health and safety of California residents.

D. <u>The Project Fails To Adequately Mitigate For Its Construction and Operational Emissions.</u>

LAWA is required to adopt additional mitigation measures before approving and implementing the Project to mitigate emissions that would violate the State Implementation Plan. CEQA Guidelines § 15126.4 requires that an FEIR describe mitigation measures to mitigate significant adverse impacts. Mitigation measures should be capable of "avoiding the impact altogether," "minimizing impacts," "rectifying the impact," or "reducing the impact." CEQA Guidelines § 15370. Importantly, mitigation measures must be "fully enforceable through permit conditions, agreements, or other measures" so "that feasible mitigation measures will actually be implemented as a condition of development." *Federation of Hillside & Canyon Ass'ns v. City of Los Angeles* (2000) 83 Cal.App.4th 1252, 1261.

However, it is clear the mitigation measures that the FEIR proposed for the Project are insufficient. The FEIR does not appear to mitigate significant air pollutant emissions and violations of the NAQS and CAAQS, as set forth above. The FEIR fails to quantify emission reductions credited to its mitigation measures, as the FEIR admits that of the 34 mitigation actions adopted for the Project; <u>*only 3 of them have quantifiable emission reductions*</u>. FEIR 4-271.

LAWA therefore is required to revise and recirculate the EIR with additional quantifiable mitigation measures for the Project's significant air pollutant emissions.

E. The FEIR Adopts An Inadequate Baseline In Analyzing Air Emissions That Will Be Generated By The Project.

The FEIR adopts an improper baseline for calculating air quality emissions. In response to comments from SCAQMD, the FEIR analyzed a future baseline of total airport emissions in 2025 under Alternative 4 compared to the emissions generated under the Staff Recommended Alternatives 1 and 9 in addition to prior analysis in the DEIR based upon existing baseline (2009) conditions. FEIR 2-38, 4-110–4-111.

It is unclear exactly why LAWA opted to base the future baseline on the year 2025 as the Project is expected to have completed construction and begin operation prior to 2025. The FEIR should be revised and recirculated to analyze the Project's environmental impact over current and future baseline during construction, as well as upon when the Project is completed and begins operation.

Every CEQA document must start from a "baseline" assumption. The CEQA "baseline" is the set of environmental conditions against which to compare a project's anticipated impacts. *CBE v. SCAQMD*, 48 Cal. 4th at 321. Section 15125(a) of the CEQA Guidelines (14 C.C.R., § 15125(a)) states in pertinent part that a lead agency's environmental review under CEQA:

> …must include a description of the physical environmental conditions in the vicinity of the project, as they exist at the time [environmental analysis] is commenced, from both a local and regional perspective. This environmental setting will normally constitute the baseline physical conditions by which a Lead Agency determines whether an impact is significant. *Save Our Peninsula Committee v. County of Monterey* (2001) 87 Cal.App.4th 99, 124–125.

Using a skewed baseline "mislead(s) the public" and "draws a red herring across the path of public input." *San Joaquin Raptor Rescue Center v. County of Merced* (2007) 149 Cal.App.4th 645, 656; *Woodward Park Homeowners v. City of Fresno* (2007) 150 Cal.App.4th 683, 708-711.

VII. THE FEIR DOES NOT ADEQUATELY ANALYZE AND MITIGATE FOR THE PROJECT'S TRAFFIC IMPACTS.

The FEIR does not adequately analyze and mitigate for traffic impacts that will occur during constructions and after the Project is completed. In fact, LAWA has so thoroughly ignored its obligations to mitigate the impacts of the Project that it has raised concerns of "Endless Carmagaddeon among some critics of the Project. Stop Endless LAX Carmageddon," http://www.stopendlesscarmageddon.com (last visited Apr. 23, 2013).

The FEIR should be revised and recirculated as the FEIR fails to adequately mitigate traffic impacts and analyze construction and traffic impacts, particularly in connection with the Lincoln Boulevard Realignment Project.

A. <u>The FEIR Does Not Adequately Mitigate for Traffic Impacts Within Los Angeles County</u>.

The FEIR fails to adequately mitigate impacts to nine County intersections that will be impacted by Staff Recommended Alternatives 1 and 9. CEQA Guidelines § 15126.4 requires that an FEIR describe mitigation measures to mitigate significant adverse impacts. Despite the fact that the Project will severely impact the intersections of La Cienega Boulevard & Century Boulevard, Hawthorne Boulevard & Lennox Boulevard, Inglewood Avenue & Lennox Boulevard, La Brea Avenue/Overhill Drive & Stocker Street, La Brea Avenue & Slauson Avenue, La Cienega Boulevard & Stocker Street, La Cienega Boulevard & West 120th Street, Ocean Avenue/Via Marina & Washington Boulevard, and Western Avenue & Imperial Highway, the FEIR opts to adopt partial mitigation measures for only <u>*one*</u> of these intersections. FEIR 4-253.

LAWA is required to adopt all feasible mitigation measures for the traffic impacts that the Project will have throughout the County. California Public Resources Code § 21002 requires that "public agencies should not approve projects as proposed if there are feasible alternatives or feasible mitigation measures available which would substantially lessen significant environmental effects of such projects . . . ." *See also* Cal. Pub. Res. Code § 21081.

LAWA deemed most of the possible traffic mitigations infeasible on the basis that traffic mitigation is outside their agency authority. FEIR 4-228. However, the mere fact that LAWA cannot by itself adopt traffic mitigation measures does not render traffic mitigation legally infeasible. While LAWA may not impose mitigation measures on streets outside of their authority, "responsible agenc[ies], or a[ny] public agency having jurisdiction over natural resources affected by the project" may submit "mitigation measures which would address the significant effects on the environment . . . ." Cal. Pub. Res. Code § 21081.6(c); CEQA Guidelines § 15086(d).

In fact, LAWA refuses to adopt additional mitigation despite suggestions and support for additional mitigation from the Los Angeles County Department of Public Works ("LADPW"), the responsible agency with authority to impose traffic mitigations. As a responsible agency, LADPW has the right to request additional mitigation measures. Cal. Pub. Res. Code § 21081.6(c); CEQA Guidelines § 15086(d).

Despite a number of specific proposed traffic mitigation measures from LADPW, LAWA continues to ignore its obligation to mitigate the Project's substantial environmental impact. FEIR 4-228, 4-256. Mitigation measures should be capable of "avoiding the impact altogether," "minimizing impacts," "rectifying the impact," or "reducing the impact." CEQA Guidelines § 15370. Importantly, mitigation measures must be "fully enforceable through permit conditions, agreements, or other measures" so "that feasible mitigation measures will actually be implemented as a condition of development." *Federation of Hillside & Canyon Ass'ns,* 83 Cal.App.4th at 1261.

LAWA's claim that it is not required to mitigate the Project's traffic impacts since it is outside its agency authority highlights the rushed nature of the Project's CEQA process. FEIR 4-228. CEQA Guidelines §§ 15083 and 15086 requires that LAWA consult with the County prior to publication of the DEIR. LAWA did not consult with the Los Angeles County Department of Public Works prior to publication of the DEIR, despite conducting a limited number of other early consultations with other agencies. FEIR, Appx. B, i.

B. <u>The DEIR/FEIR Does Not Adequately Analyze The Construction and Traffic Impacts Of the Lincoln Boulevard Realignment Project</u>.

The FEIR does not analyze the environmental impacts that would occur with the relocation and tunneling of Lincoln Boulevard (California State Highway 1), under the runway realignment proposed under Staff Recommended Alternative 1. FEIR 4-445.

The FEIR is required to analyze and the environmental impacts of this Project. However, the FEIR evades analyzing the realignment, claiming that a more detailed analysis will be conducted in the future. FEIR 4-59–4-60. LAWA claims that it is not required to conduct environmental analysis at this time since it the FEIR is a program-level document.

However, certification of the FEIR and approval of the Project requires thorough analysis of the environmental impacts of the Lincoln Boulevard realignment, regardless of whether the FEIR is considered a program-level document. CEQA requires LAWA to prepare and "certify the completion of, an environmental impact report on any project which they *propose to carry out or approve* that may have a significant effect on the environment." Cal. Pub. Res. Code § 21100(a) (emphasis added); *see also* Cal. Pub. Res. Code § 21151. "'Approval' means the decision by a public agency which commits the agency to a definite course of action in regard to a project intended to be carried out by any person." CEQA Guidelines § 15352(a). Postponing the preparation of an EIR until after the City has committed to realigning Lincoln Boulevard undermines CEQA's goal of transparency in environmental decision-making. Besides informing the decision makers themselves, the EIR is intended "to demonstrate to an apprehensive citizenry that the agency has in fact analyzed and considered the ecological implications of its action." *No Oil, Inc. v. City of Los Angeles* (1974) 13 Cal.3d 68, 86.

Certification of the FEIR commits LAWA to realigning Lincoln Boulevard without having conducted sufficient environmental review on the project. CEQA environmental review is required to be conducted early enough to serve, realistically, as a meaningful contribution to public decision." *Save Tara v. City of West Hollywood* (2008) 45 Cal.4th 116, 134. "The level of specificity of an EIR is determined by the nature of the project and the 'rule of reason' rather than any semantic label accorded to the EIR." *Al Larson Boat Shop, Inc. v. Board of Harbor Commissioners* (1993) 18 Cal.App.4th 729, 741–42.

Under the circumstances, the FEIR should be revised and recirculated to analyze the environmental impacts of realigning Lincoln Boulevard.

VIII. THE DEIR/FEIR DOES NOT ADEQUATELY ANALYZE AND MITIGATE THE PROJECT'S GREENHOUSE GAS EMISSIONS.

The FEIR does not adequately address greenhouse gas emissions that will be generated by the Project. The FEIR does not propose *any* mitigation measures for greenhouse gas emissions despite the fact that the FEIR finds that the Project's greenhouse gas emissions are significant. FEIR 2-276. This violates CEQA.

The FEIR should be revised and recirculated to take into account its impact on greenhouse gas emissions as the EIR's greenhouse gas methodology is flawed and fails to adopt adequate mitigation.

A. The FEIR's Greenhouse Gas Methodology Is Flawed.

The FEIR adopts a flawed methodology for estimating greenhouse gas emissions. The FEIR adopts its own methodology for estimating greenhouse gas emissions at odds with numerous international and nationally accepted protocols.

The FEIR greenhouse gas methodology improperly excludes greenhouse gas emissions. The FEIR included only greenhouse gas emissions emitted below the average mixing height of 1,806 feet above sea level. FEIR 4-119. While 1,806 feet above sea level is the standard average mixing height for criteria pollutants, *id.* it is inappropriate to adopt this guideline for pollutants with little to no localized impacts such as greenhouse gases.

Moreover, the FEIR does not adequately justify the use of its greenhouse gas methodology. In adopting its own methodology, LAWA ignores numerous national and international protocols developed by EPA, International Energy Agency and even the Intergovernmental Panel on Climate Change (adopted by the California Air Resources Board) with little justification. U.S. Envt'l Prot. Agency (2011) Emission Factors for Greenhouse Gas Inventories; Int'l Energy Agency (2012) CO_2 Emissions From Fuel Combustion; Int'l Panel on Climate Change (2008) Special Report on Aviation and the Global Atmosphere. *See Attachs. C-E hereto*. The FEIR should be revised and recirculated with a revised greenhouse gas methodology.

B. The FEIR Does Not Adequately Mitigate for Greenhouse Gas Emissions.

The FEIR does not describe mitigation measures for greenhouse gas emissions. CEQA Guideline § 15126.4(c) requires lead agencies to "consider feasible means . . . [to] mitigat[e] the significant effects of greenhouse gas emissions . . . [including] [m]easures in an existing plan or mitigation program for the reduction of emissions . . . [r]eductions in emissions resulting from a project through implementation of project features, project design ., . . [o]ffsite measures, including offsets that are not otherwise required, to mitigate a project's emissions . . . [and] sequester [of] greenhouse gases . . . ."

The FEIR does not describe any mitigation measures for greenhouse gases or provide any rationale for its failure to do so. Mitigation measures should be capable of "avoiding the impact altogether," "minimizing impacts," "rectifying the impact," or "reducing the impact." CEQA Guidelines § 15370. Importantly, mitigation measures must be "fully enforceable through permit conditions, agreements, or other measures" so "that feasible mitigation measures will actually be implemented as a condition of development." *Federation of Hillside & Canyon Ass'ns,* 83 Cal.App.4th at 1261. The FEIR should be revised and recirculated to include mitigation measures for greenhouse gases.

IX. THE FEIR DOES NOT ADEQUATELY ANALYZE OR MITIGATE THE PROJECT'S NOISE IMPACTS.

The FEIR does not adequately analyze or mitigate noise impacts of the Project. The FEIR should be revised and recirculated as it does not adequately analyze or mitigate noise impacts.

A. The FEIR Does Not Adequately Analyze Noise Impacts.

The FEIR does not adequately analyze noise impacts in the neighborhoods surrounding LAX as it relies purely upon modeling data. FEIR 4-264. LAWA should utilize both measured and modeled data in its noise analysis as the City of Los Angeles CEQA Thresholds Guide (2006) I.1-4 (*see Attach. B hereto)* requires that noise levels be determined utilizing field measures, presumed ambient noise levels, or a noise monitoring program.

The FEIR should be revised and recirculated to provide environmental analysis based upon both measured and modeling data.

B. The FEIR Does Not Adequately Mitigate Noise Impacts.

The FEIR does not adequately mitigate for the Project's noise impacts as the Airport Noise Mitigation Program ("ANMP") as the Project does not provide a timeframe before implementation of the mitigation program is to occur and is vague as it does not specify eligibility criteria for the ANMP program.

The FEIR fails to adequately mitigate the Project's noise impacts as it does not provide a timeframe for implementation. CEQA requires that the mitigation measures be "capable of being accomplished in a successful manner within a reasonable period of time." Cal. Pub. Res. Code § 21061.1. Mitigation measure MM-LU-1, Implement Revised Aircraft Noise Mitigation Project provides that LAWA shall "mitigate land uses that would be rendered incompatible by noise impacts associated with implementation . . . . [by providing] adequate acoustic performance (sound insulation) to ensure an interior noise level of 45 CNEL ["Community Noise Equivalent Level"] or less." FEIR 4-268. However, the FEIR states that despite the new program "significant and unavoidable interim noise impacts would be experienced over an indeterminate period of time." FEIR 2-167.

The lack of a specified timeframe for implementation of the measure violates CEQA as mitigation measures must both be enforceable and "committed . . . to a specific performance standard." CEQA Guideline 15126.4(a)(2); *Gray v. County of Madera* (2008) 167 Cal.App.4th 1099, 1119.

Moreover, the mitigation measure is vague as it is leaves eligibility for the ANMP program unclear. While LAWA states that any home with an interior noise level below 45 CNEL is ineligible for mitigation under the ANMP program, FAA Program Guidance Letter 12-09 provides completely different grounds for eligibility. Program Guidance Letter 12-09 states that an impacted structure must have an average noise level across all habitable rooms of greater than 45 dB in order to be eligible for the ANMP program. Federal Aviation Admin. (2012) Action: Program Guidance Letter 12-09 Eligibility and Justification Requirements for Noise Insulation Projects. It is unclear based upon the FEIR what rooms will be eligible for the ANMP program.

The FEIR should be revised and recirculated to adopt a specific timeframe for the ANMP program as well as to clarify eligibility.

X. THE FEIR DOES NOT ANALYZE THE PROJECT'S SIGNIFICANT ENVIRONMENTAL JUSTICE CONCERNS.

The FEIR does not adequately analyze environmental justice concerns raised by the Project. Air quality and noise impacts are underestimated for the neighboring communities, including Lennox, a disadvantaged, minority community. For example, Lennox is the only residential neighborhood around LAX with homes in the 75 dB Community Noise Equivalent Level.

LAWA claims that the FEIR is not required to conduct an environmental justice analysis, FEIR 4-268, incorrectly citing CEQA Guideline Section 15131 which in fact states that:

> "Economic, social and particularly housing factors *shall be considered* by public agencies together with technological and environmental factors in deciding whether changes in a project are feasible to reduce or avoid the significant effects on the environment identified in the EIR. If information on these factors is not contained in the EIR, the information must be added to the record in some other manner to allow the agency to consider the factors in reaching a decision on the project." (Emphasis added).

In truth, the CEQA Guidelines define "Significant Environmental Impacts" to include "***health and safety problems*** caused" by the project. CEQA Guidelines § 15126.2(a) (emphasis added). The CEQA Guidelines require a ***mandatory*** finding of significance if a project will have impacts on human health. The Guidelines state:

> a lead agency shall find that a project may have a significant effect on the environment and thereby require an EIR to be prepared for the project where . . . the environmental effects of a project will cause ***substantial adverse effects on human beings, either directly or indirectly***. 14 Cal. Code Regs. 15065(d) (emphasis added). See also, CEQA Guidelines, App. G. Section XVIII (c) ("mandatory finding of significance" required if "the project [will] have environmental effects which will cause substantial ***adverse effects on human beings, either directly or indirectly***." (emphasis added)).

CEQA case law has uniformly interpreted the above provisions of law to require that an EIR include an analysis of human health impacts of a proposed project. An agency abuses its discretion and fails to proceed in a manner required by law if it refuses to analyze human health impacts of a proposed project in an EIR despite being presented with substantial evidence that such impacts may occur. *Bakersfield Citizens for Local Control v. City of Bakersfield* (2004) 124 Cal.App.4th 1184, 1219-20 ("*Bakersfield Citizens*").

In *Bakersfield Citizens*, the court held that it was necessary in an EIR for two proposed Wal-Mart projects to "correlate adverse air quality impacts to resulting adverse health impacts." (*Id.* at 1219-20) The Wal-Mart EIRs admitted that both projects would result in significant unmitigated air pollution impacts. However, the EIRs contained no analysis of the human health implications of that increased air pollution. The court held:

> Guidelines section 15126.2, subdivision (a) requires an EIR to discuss, inter alia, "health and safety problems caused by the physical changes" that the proposed project will precipitate. Both of the EIRs concluded that the projects would have significant and unavoidable adverse impacts on air quality. It is well known that air pollution adversely affects human respiratory health. (See, e.g., Bustillo, Smog Harms Children's Lungs for Life, Study Finds, L.A. Times (Sept. 9, 2004).) Emergency rooms crowded with wheezing sufferers are sad but common sights in the San Joaquin Valley and elsewhere. . . Yet, neither EIR acknowledges the health consequences that necessarily result from the identified adverse air quality impacts. Buried in the description of some of the various substances that make up the soup known as "air pollution" are brief references to respiratory illnesses. However, there is no acknowledgement or analysis of the well-known connection between reduction in air quality and increases in specific respiratory conditions and illnesses. After reading the EIR's, the public would have no idea of the health consequences that result when more pollutants are added to a nonattainment basin. On remand, ***the health impacts resulting from the adverse air quality impacts must be identified and analyzed in the new EIR's.*** *Id.* 1219-20

> (emphasis added); see also, *Woodward Park Homeowners Assn., Inc. v. City of Fresno*, 150 Cal.App.4th 683, 731-732 (2007) ("air pollution discussion is inadequate for another reason . . . there is no disclosure and analysis whatsoever of the correlation of 'the identified adverse air quality impacts to resultant adverse health effects.'")

Similarly, in *Berkeley Keep Jets*, 91 Cal. App. 4th at 1367-1368 (2001), the court held that the "public health impact" of an airport expansion had to be analyzed in the EIR despite the absence of an accepted scientific methodology. The court held that the Port failed to assess the health effect of toxic air contaminants ("TACs") from mobile sources on persons who live in close proximity to the Airport.

The FEIR should be revised and recirculated in order to analyze and mitigate air quality and noise impacts on Lennox, and provide a semi-equal balance of north/south runway selection similar to a mitigation measure for airfield operations as a means of protecting Lennox and other unincorporated, environmental justice communities from even greater air quality and noise impacts.

XI. <u>THE FEIR DOES NOT ADEQUATELY ANALYZE AND MITIGATE THE PROJECT'S CUMULATIVE IMPACTS.</u>

The FEIR fails to adequately analyze or mitigate for cumulative impacts. The EIR should be revised and recirculated to include data from previously certified EIRs, including the LAX Master Plan, as well as describe additional mitigation measures to mitigate its cumulative impact. An EIR "necessarily involves some degree of forecasting," but "an agency must use its best efforts to find out and disclose all that it reasonably can." 14 Cal. Code Regs. § 15144. That did not happen here.

A. <u>The EIR Does Not Adequately Analyze Previously Certified EIRs.</u>

The EIR should take into consideration previously approved LAX plans and environmental review documents, including the LAX Master Plan and accompanying environmental impact report and environmental impact. Los Angeles World Airports (2004) Los Angeles International Airport Master Plan; Los Angeles World Airports (2004) LAX Master Plan Final EIS/EIR. CEQA Guidelines § 15130(d) allows cumulative impact analysis to incorporate "[p]revious approved land use documents, including, but not limited to . . . previously certified EIRs."

The FEIR does not analyze or incorporate the 2004 LAX Master Plan documents. The EIR should be revised and recirculated with cumulative analysis including data from the LAX Master Plan documents. "The inadequate cumulative analysis prevented the Commission from gaining a true perspective on the consequences of approving these projects." *San Franciscans for Reasonable Growth v. City and County of San Francisco* (1984) 151 Cal.App.3d 61, 80 (rejecting findings in statement of overriding considerations).

B. The FEIR Does Not Mitigate Cumulative Impacts.

The FEIR fails to describe or adopt mitigation measures, despite finding that the Project will have significant cumulative impacts on air quality, greenhouse gases, noise, and traffic. FEIR 2-266, 2-276, 2-286, 2-295. CEQA Guidelines § 15130(b)(5) requires an EIR to "examine reasonable, feasible options for mitigating or avoiding the project's contribution to any significant cumulative effects."

The FEIR does not describe or adopt any mitigation measures for air quality, greenhouse gases, noise, or traffic. The EIR should be revised and recirculated with mitigation for the Project's cumulative impacts.

XII. THE DEIR/FEIR FAILS TO INCLUDE IMPORTANT CEQA DOCUMENTS INCORPORATED BY REFERENCE.

The DEIR/FEIR fails to make documents incorporated by reference available to the public. CEQA Guideline § 15150 states that while an EIR may "incorporate by reference all or portions of another document . . . [the] document shall be made available to the public." Moreover, the "EIR . . . shall state where the incorporated documents will be available for inspection . . . [and] briefly summarized." *Id.*

Despite this, the FEIR fails to include or make available to the public:

- Los Angeles/El Segundo Dunes Habitat Restoration Plan, FEIR 2-62;
- LAX Wildlife Hazard Management Plan, FEIR 2-62;
- Long Term Habitat Management Plan for Los Angeles Airport/El Segundo Dunes, FEIR 2-68;
- Survey Guidelines referenced in:
    - MM-BIO (SPAS)-3. Conservation of Floral Resources: Lewis' Evening Primrose, FEIR 2-63;
    - MM-BIO (SPAS)-4. Conservation of Floral Resources: California Spineflower, FEIR 2-63;
    - MM-BIO (SPAS)-5. Conservation of Floral Resources Mesa Horkelia, FEIR 2-64;
    - MM-BIO (SPAS)-6. Conservation of Floral Resources: Orcutt's Pincushion, FEIR 2-64; and
    - MM-BIO (SPAS)-7. Conservation of Floral Resources: Southern Tarplant, FEIR 2-65.
- Visual Flight Rules and Instrument Flight Rules data, FEIR 4-178;
- Air Quality Modeling Data, FEIR 4-177;
- Aircraft Engine Assignments, FEIR 4-182; and
- Airspace Redesign, FEIR 4-456.

XIII. CONCLUSION.

USWW appreciates the opportunity to comment on the Project. USWW strongly supports ARSAC's appeal of LAWA's certification of the FEIR and urges the Council to recommend revision and recirculation of the EIR to provide time for environmental review and public comment on the Project.

The EIR is a product of a premature planning process, where LAWA presented the public and decisionmakers with a smorgasbord of Alternatives and possible improvements at LAX, with few concrete details and little environmental analysis. This violates CEQA, and the LAX communities and workers deserve better.

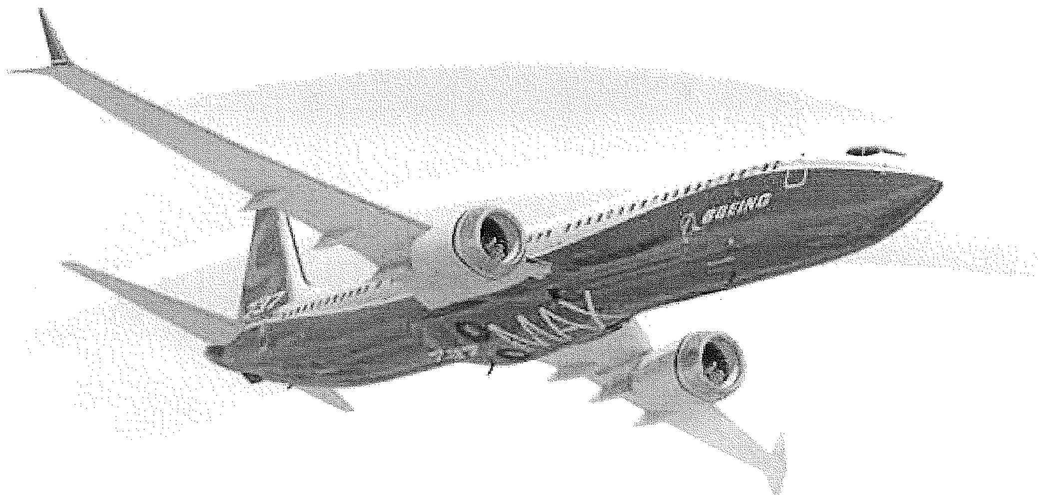
Please put the undersigned on the service list for all notices in connection with the Project and please include this letter and all attachments in the record of proceedings for this Project.

Sincerely,

Gideon Kracov
Attorney for SEIU USWW

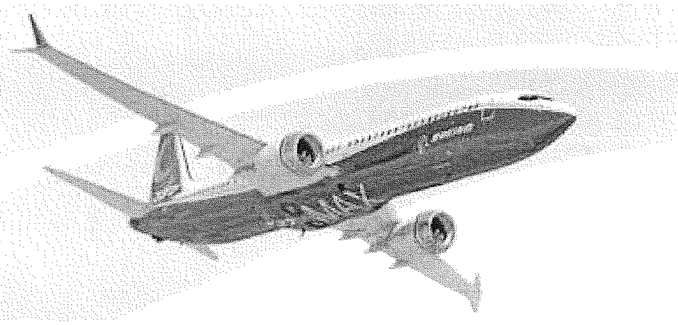
Attachs.

EXHIBIT A

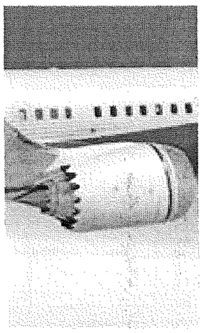


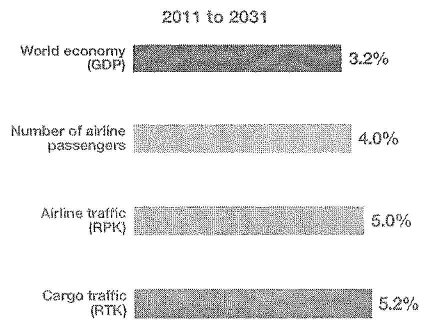
Current Market Outlook
2012-2031

Outlook on a Page

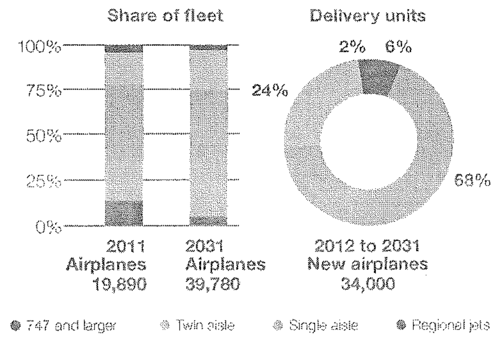


World regions
Market growth rates





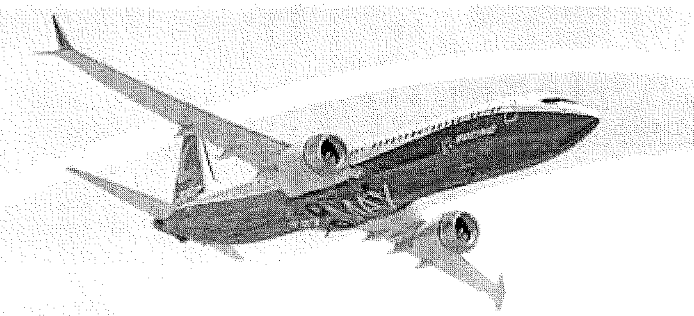
World regions
Market value: $4,470 billion



World regions
Key indicators and new airplane markets

Growth measures Regions		Asia Pacific	North America	Europe	Middle East	Latin America	CIS	Africa	World
World economy	(GDP) %	4.6	2.6	1.9	3.9	4.1	3.4	4.4	3.2
Airline traffic	(RPK) %	6.4	2.8	4.1	6.4	6.6	4.7	5.6	5.0
Cargo traffic	(RTK) %	5.9	4.5	4.6	5.7	5.9	5.0	5.8	5.2
Airplane fleet	%	5.5	1.4	3.2	4.8	5.1	1.7	3.4	3.5
Market size									
Deliveries		12,030	7,290	7,760	2,370	2,510	1,140	900	34,000
Market value	($B)	1,700	820	970	470	260	130	120	4,470
Average value	($M)	140	110	130	200	100	110	130	130
Unit share	%	35	22	23	7	7	3	3	100
Value share	%	38	18	22	10	6	3	2	100
New airplane deliveries									
Large		320	40	200	190	0	30	10	790
Twin aisle		3,230	1,320	1,440	1,100	340	250	270	7,950
Single aisle		7,990	5,040	5,800	1,060	2,080	700	570	23,240
Regional jets		490	890	320	20	90	160	50	2,020
Total		**12,030**	**7,290**	**7,760**	**2,370**	**2,510**	**1,140**	**900**	**34,000**
Market value (2010 $B, catalog prices)									
Large		110	10	70	70	0	20	2	280
Twin aisle		860	340	370	310	80	50	70	2,080
Single aisle		720	440	520	80	170	50	50	2,030
Regional jets		10	30	10	10	10	10	2	80
Total		**1,700**	**820**	**970**	**470**	**260**	**130**	**120**	**4,470**
2011 fleet									
Large		340	120	190	70	0	60	10	790
Twin aisle		1,080	1,030	680	470	140	170	140	3,710
Single aisle		3,170	3,730	3,160	470	1,020	650	410	12,610
Regional jets		120	1,770	410	60	110	200	110	2,780
Total		**4,710**	**6,650**	**4,440**	**1,070**	**1,270**	**1,080**	**670**	**19,890**
2031 fleet									
Large		460	110	230	170	0	50	10	1,030
Twin aisle		3,490	1,740	1,630	1,170	440	310	330	9,110
Single aisle		9,230	6,090	6,120	1,320	2,850	970	850	27,430
Regional jets		490	890	340	50	160	170	110	2,210
Total		**13,670**	**8,830**	**8,320**	**2,710**	**3,450**	**1,500**	**1,300**	**39,780**

Market values above 5 have been rounded to the nearest 10.



Long-Term Market

Purpose of the forecast

The *Current Market Outlook* is our long-term forecast of air traffic volumes and airplane demand. The forecast has several important practical applications. It helps shape our product strategy and provides guidance for our long-term business planning. We have shared the forecast with the public since 1964 to help airlines, suppliers, and the financial community make informed decisions.

Each year we start new, so we can factor the effects of current business conditions and developments into our analysis of the long-term drivers of air travel. The forecast details demand for passenger and freighter airplanes, both for fleet growth and for replacement of airplanes that retire during the forecast period. We also project the demand for conversion of passenger airplanes to freighters.

Air travel continues to be resilient

The remarkable resilience of air travel is amply documented in nearly 50 years of published editions of the Boeing *Current Market Outlook*.

Commercial aviation has weathered many downturns in the past. Yet recovery has followed quickly as the industry reliably returned to its long-term growth rate of approximately 5 percent per year. Despite uncertainties, 2011 passenger traffic rose 6 percent above 2010 levels. We expect this trend to continue over the next 20 years, with world passenger traffic growing 5 percent annually. Air cargo traffic has been moderating after a high period in 2010. Air cargo contracted by 2.4 percent in 2011. Expansion of emerging-market economies will, however, foster a growing need for fast, efficient transport of goods. We estimate that air cargo will grow 5.2 percent annually through 2031.

The shape of the market

We forecast a long-term demand for 34,000 new airplanes, valued at $4.5 trillion. These new airplanes will replace older, less efficient airplanes, benefiting airlines and passengers and stimulating growth in emerging markets and innovation in airline business models. Approximately 23,240 airplanes (68 percent of new deliveries) will be single-aisle airplanes, reflecting growth in emerging markets, such as China, and the continued expansion of low-cost carriers throughout the world. The twin-aisle segment will also increase, from a 19 percent share of today's fleet to a 23 percent share in 2031. The 7,950 new twin-aisle airplanes will allow airlines to continue expansion into more international markets.

Current Market Outlook
2012–2031

UPDATED!
Randy Tinseth introduces the Asia Pacific subregions

Airplanes in service
2011 and 2031

Size	2011	2031
Large	790	1,030
Twin aisle	3,710	9,110
Single aisle	12,610	27,430
Regional jets	2,780	2,210
Total	**19,890**	**39,780**

Demand by size
2012 to 2031

Size	New airplanes	Value ($B)*
Large	790	280
Twin aisle	7,950	2,080
Single aisle	23,240	2,030
Regional jets	2,020	80
Total	**34,000**	**4,470**

*$ values throughout the CMO are catalog prices

Key indicators
2011 to 2031

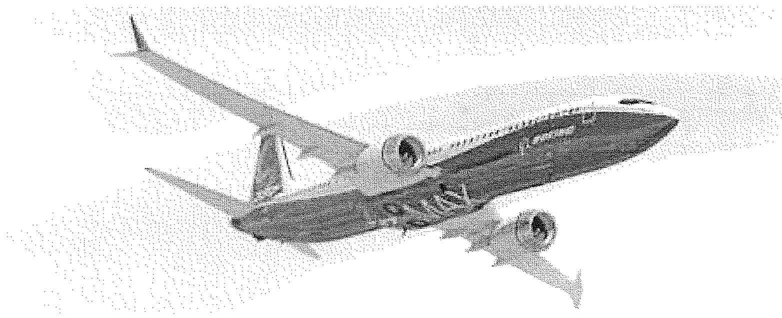
Growth measures	
World economy Gross domestic product (GDP)	**3.2%**
Airplane fleet	**3.5%**
Number of passengers	**4.0%**
Airline traffic Revenue passenger-kilometers (RPK)	**5.0%**
Cargo traffic Revenue tonne-kilometers (RTK)	**5.2%**

Demand by region
2012 to 2031

Region	New airplanes	Value ($B)
Asia Pacific	12,030	1,700
Europe	7,760	970
North America	7,290	820
Middle East	2,370	470
Latin America	2,510	260
CIS*	1,140	130
Africa	900	120
Total	**34,000**	**4,470**

*Commonwealth of Independent States.

Market Developments



Airlines responding and adapting

Boeing factors a wide variety of market forces and influences into the long-term forecast that the company produces each year. At the broadest level, global economic growth is expected to average 3.2 percent over the next 20 years, fostering 5.0 percent annual growth in passenger traffic and 5.2 percent annual growth in cargo traffic.

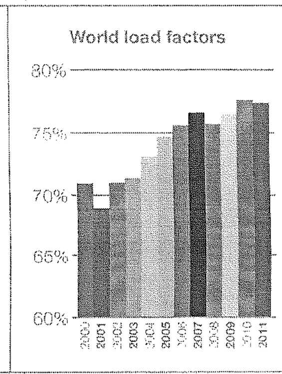
In response to market pressures, airlines are deploying capacity more strategically to help boost yields and cover higher fuel expenses. Airlines are optimizing airplane utilization more closely to seasonal demand fluctuations, and passenger load factors remain near historic highs. The number of new-generation airplanes in the parked fleet remains low, indicating that airlines are shifting utilization to their most efficient assets. These activities are projected to help the global airline industry achieve a profitable year, despite below-average economic growth and oil prices that are likely to average in the triple digits for the full year—a scenario that would have seemed unbelievable just a decade ago.

Dynamic industry

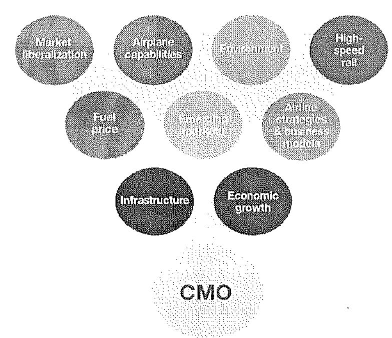
The industry continuously adapts to varied market forces, including fuel price, economic growth and development, environmental regulation, infrastructure, market liberalization, airplane capabilities, other modes of transport, business models, and emerging markets. Each of these forces can have both positive and negative impacts on the industry. For example, on the negative side, rising fuel prices have become a major component of airline costs. On the positive side, the rise in fuel prices has prompted manufacturers to produce more fuel-efficient airplanes, such as the 787 and 737 MAX. High fuel costs have also encouraged airlines to explore cost-cutting opportunities and new sources of revenue to help offset the effects of fuel prices. Impacts such as these inform our analysis of aviation market developments.

Market developments
World passenger load factors at historic highs

Source: ICAO



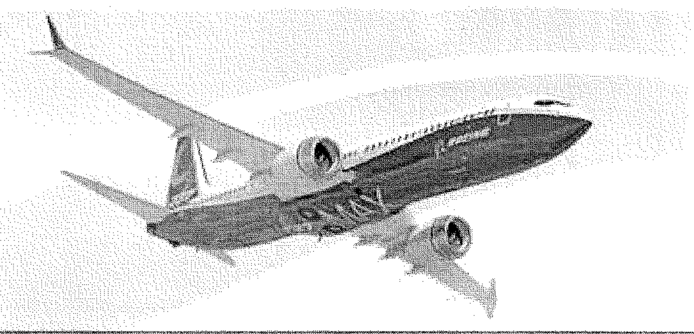
Market developments
Key indicators



Market developments
Airline traffic growth rates

2011 to 2031

	Africa	Latin America	Middle East	Europe	North America	Asia Pacific
Asia Pacific	7.4%	5.4%	7.2%	5.7%	4.8%	6.7%
North America	6.0%	5.1%	6.4%	3.6%	2.2%	
Europe	4.8%	4.6%	5.1%	3.5%		
Middle East	6.9%	–	5.1%			
Latin America	8.3%	6.5%				
Africa	6.2%					



Market Developments
Business Environment

Continued passenger demand growth

With first-quarter data in hand, 2012 appears to be another challenging year for the airlines. Economic forecasters expect that the European debt crisis will tip Europe into recession and reduce growth in other regions. Global economic growth is projected to lag behind the long-term average into 2013.

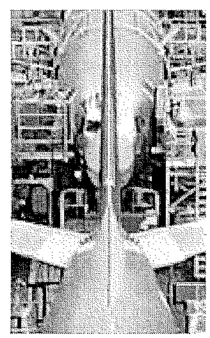
Despite the sub-par economic outlook, air passenger demand is forecast to grow at close to the long-term average rate of 5 percent in 2012. Trends that drove above-average passenger growth in 2011 have continued into 2012: economic growth and expanding middle classes in emerging markets; liberalization and new airline business models that stimulate demand; and corporate focus on revenue growth, which bolsters demand for business-class travel.

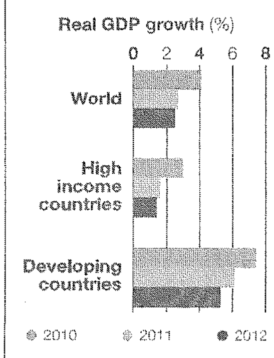
Air cargo traffic growth, on the other hand, has loitered below the long-term average since 2011, weighed down by weak economic growth, spiking fuel prices, and supply chain shocks. Historically, air cargo traffic has been a reasonable indicator of current economic health, rather than of future economic performance or global passenger trends. Air cargo traffic correlates well with long-haul passenger traffic, while the strong demand for short-haul travel has made overall passenger traffic resilient to the challenges that have recently faced air cargo.

Oil price pressures easing

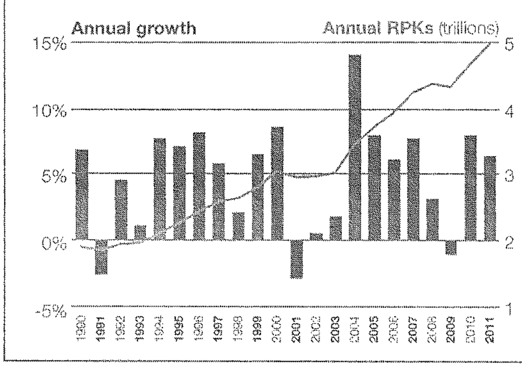
Beyond the weak economic environment, the key external challenge for airlines has been volatile oil prices. After spiking in early 2012 in response to Middle East supply concerns, Brent crude oil prices dropped below $100 per barrel for the first time since early 2011 as a result of fluctuations in both demand and supply outlooks. On the demand side, projections are declining as economists cut near-term global economic growth forecasts to reflect the impacts of the Eurozone debt crisis. Investor demand for oil and other commodities is also dropping as investors move from commodities to safer assets like US treasury bonds. On the supply side, projections are increasing as OPEC and US production rises. In the long term, energy forecasters are reassessing supply projections and, in some cases, moderating future price projections, to reflect improving North American oil shale prospects. Lower jet fuel prices will bolster near-term airline profitability outlooks, despite the uncertain economic outlook.

Business environment
Near-term economic challenges
Source: World Bank June 2012 forecast

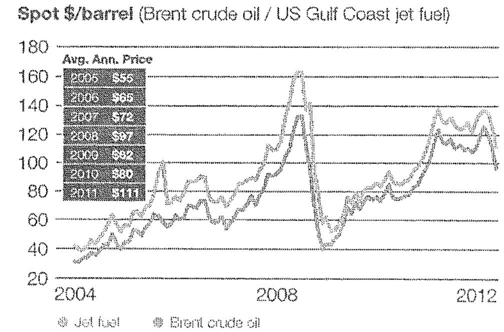


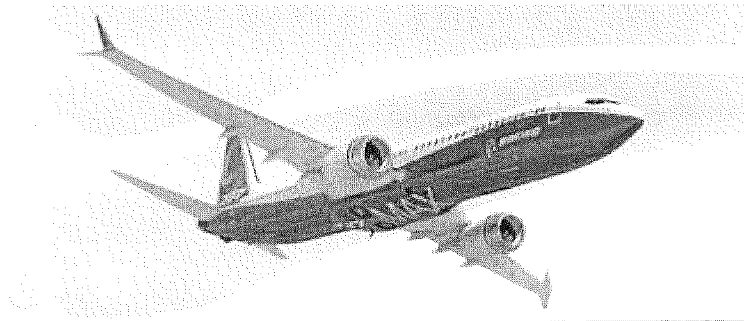


Business environment
Passenger traffic resilient
Source: ICAO



Business environment
Oil and jet fuel prices elevated and volatile
Source: EIA





Market Developments
Today's Fleet

Historical fleet

Before looking at today's fleet, let's take a step back for some historical perspective. Before the deregulation of the US aviation industry, the world jet fleet in 1977 comprised approximately 6,500 airplanes, the majority of them single aisle. Boeing and McDonnell Douglas provided 65 percent of the fleet, mainly 707s and 727s. There were roughly 290 airlines, with the top ten having more than a 50 percent fleet share. The top ten airlines were very similar: all large network carriers, the majority located in North America, providing both domestic and international service. Today, three of those top ten airlines--Eastern, TWA, and Pan Am--are no longer in service.

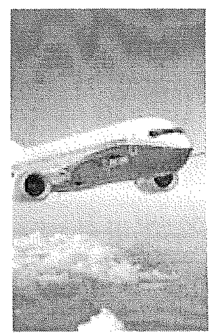
Current trends

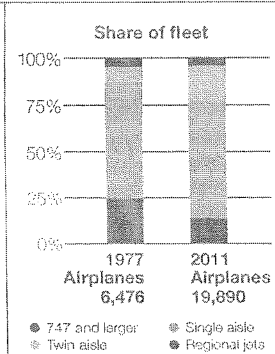
Today there are more than 900 airlines in operation. Boeing is still the dominant manufacturer, with 50 percent of the in-service jet fleet. The airlines with the largest fleets are a diverse mix, including low-cost carriers and cargo carriers, as well as airlines originating outside North America.

Single-aisle airplanes still comprise an overwhelming majority of the fleet, reflecting little change in share percentage, having risen to 63 percent of the fleet in 2011, compared to 62 percent in 1977. The number of single-aisle airplanes, however, has grown by 200 percent to more than 12,600 airplanes from 4,000 during the same period. The number of twin-aisle airplanes rose 600 percent to 3,700 from 518. Only the regional jet category reported a large percentage decline, down 11 percentage points, although the number of regional jets has increased by 1,100 since 1977.

At year end 2011, at least 30 percent of the installed commercial fleet was based in the United States. The second largest share belongs to China, with 9 percent. Russia, the United Kingdom, and Germany, at a combined 12 percent share, split the third largest share about evenly. Commercial airplane backlogs indicate that the geographical diversity of the order base is growing. The United States and China retain their respective top two positions as new entrants, including India, the United Arab Emirates, Malaysia, and Indonesia, gain a significant presence. Russia also has a sizable backlog of aircraft on order and will remain a large base for the commercial aviation industry.

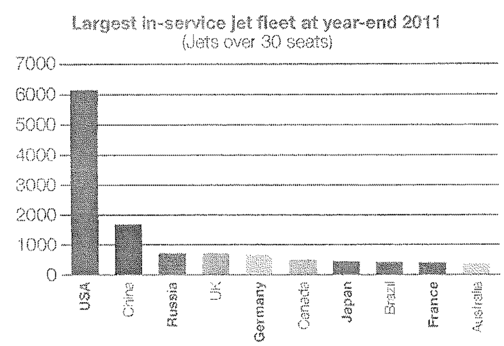
Today's fleet
Tripled since 1977





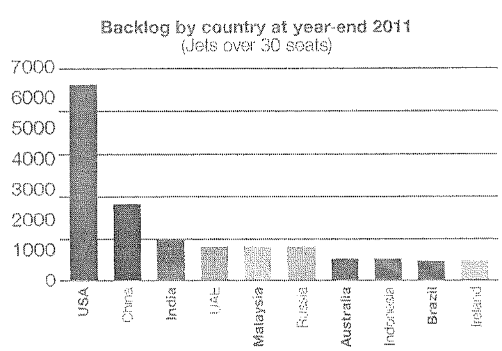
Today's fleet
In-service fleet: 19,890

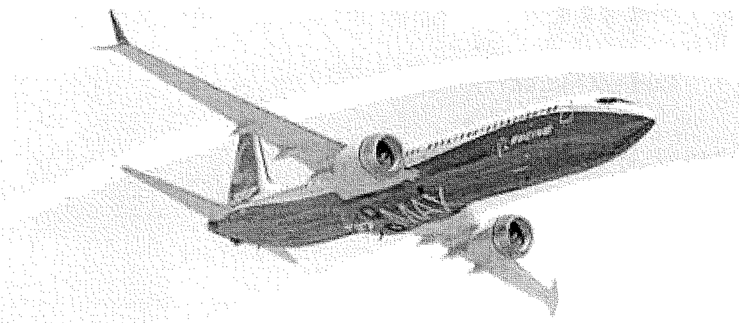
Source: Ascend



Today's market
Backlog year-end 2011: 9,230

Source: Ascend





Market Developments
Infrastructure

Infrastructure investment remains crucial
Sustained investment in aviation infrastructure is crucial to the continuing growth of commercial aviation. Airports, national airspace management agencies, and airlines share challenges and opportunities of aviation growth.

Boeing analysis indicates that projected commercial air traffic growth will increase congestion at certain airports around the world as demand for takeoffs and landings reaches or surpasses airport capacity over the next 20 years. The world's busiest airports, such as London's Heathrow, have already reached their limits for hourly airplane movements, even with slot controls.

Many airports have capacity to meet projected traffic growth. Other airports have the capacity to handle demand efficiently during off-peak hours, but are constrained during morning and/or evening hours when demand is highest. Continued infrastructure investment is particularly important in regions, such as China, Northeast and Southeast Asia, India, and Latin America, where aviation growth outpaces planned infrastructure development.

Capital improvements
Airport authorities around the world are investing in large capital projects, including new or improved runways, terminal expansions, and entirely new airports. These investments can significantly increase airport capacity, but are substantial, and development times typically extend more than a decade from initial planning to completion of construction. Community noise and environmental concerns often stretch development times further and may limit the scope of expansion.

Airspace management enhancements
Many national and regional airspace management agencies are engaged in programs to overhaul airspace systems. For example, the United States is implementing the NextGen program to help airports run smoother and avoid long takeoff lines on the runway. This type of program is implemented gradually, and the improvements in airport efficiency will be realized over time.

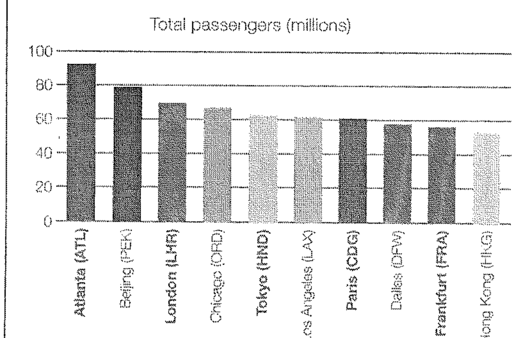
Airlines have implemented a number of approaches to manage airport crowding. In particular, airlines have replaced smaller airplanes such as regional jets with larger single-aisle airplanes, helping to ease demand for takeoff and landing slots during peak periods. Creating secondary hubs and expanding service to secondary airports also can ease congestion at the busiest airports. Airline alliances have proven effective in allowing airlines to expand route systems without duplicating services that would add to congestion.

In sum, although airports and governmental air services agencies will need to continue investing in infrastructure improvements, and airlines will need to evolve strategic responses at some airports, congestion will not be a major limiting factor to commercial air traffic growth during the forecast period.

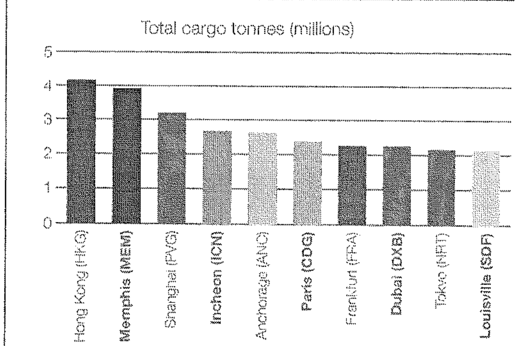
Infrastructure
Infrastructure is crucial to growth

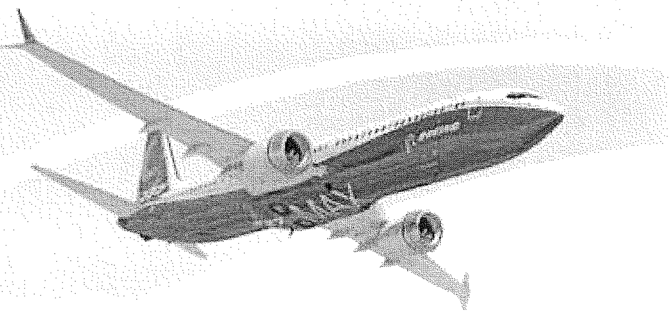
Investment in infrastructure is key to growth

Infrastructure
2011 busiest airports by passengers
Source: ACI www.airports.org



Infrastructure
2011 busiest airports by cargo
Source: ACI www.airports.org





Market Developments
High-Speed Rail

Limited competition with commercial aviation
Our long-term forecast considers the impact that other technologies, including high-speed rail (HSR), have on air travel. In 2010, worldwide railways carried 45 percent less passenger traffic, but 45 times more cargo traffic than commercial aviation. The total distance covered by railway networks was a mere 2.5 percent that of the aviation network. Analysis of the data shows that (1) railways are well suited for carrying passengers over relatively short distances (terrain permitting), whereas aviation excels for longer journeys; (2) railways are an efficient mode for overland cargo transport; and (3) aviation is very effective for creating large transportation networks without heavy investment in infrastructure.

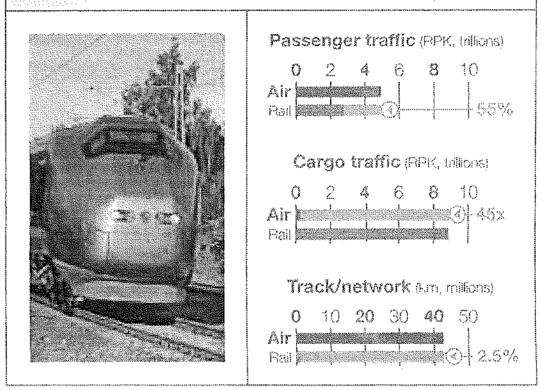
It has been almost 50 years since Japan introduced the world's first modern HSR service between Tokyo and Osaka. By the end of 2012, China will be operating 13,000 kilometers of HSR--more than the rest of the world combined. Yet, HSR still accounts for less than 2 percent of the world's railway lines, and only six nations have HSR networks with tracks longer than 1,000 kilometers.

Capital intensive, sizable life-cycle carbon footprint
China's unprecedented HSR program entailed a 2-trillion-RMB investment in a 13,000-kilometer network. In addition to the large capital investment, the infrastructure construction had significant impact on the environment. In 2009 alone, China's HSR program consumed 20 million tonnes of steel and 120 million tonnes of concrete. The carbon emissions associated with just the raw materials amounted to approximately 150 million tonnes of CO_2--roughly equivalent to a quarter of the annual CO_2 emissions for all the world's airlines. Yet, Boeing analysis shows that passenger traffic on the 2012 HSR network would account for less than 2 percent of the domestic revenue passenger-kilometers flown by Chinese carriers in 2009.

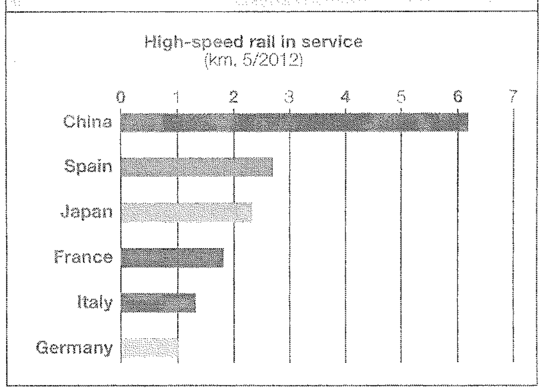
Intermodal strategies
HSR could compete with some airlines in high-volume, high-yield markets. Yet, the relatively short routes where HSR excels represent only a small portion of the market served by commercial aviation. Airline assets are highly flexible, because airplanes can be easily redeployed to more lucrative markets. In addition, the infrastructure investment for a comprehensive aviation network is much lower than for ground modes of transport. Aviation's network connectivity simply cannot be replicated by ground-based modes. Opportunities to develop intermodal solutions can potentially combine the advantages of both HSR and aviation.

High-speed rail
Rail[1] vs. air[2]

Source:
[1]2010 UIC members
[2]2010 ICAO/Boeing

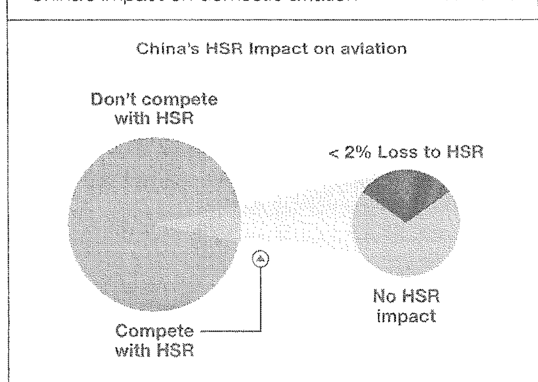


High-speed rail
Top high-speed rail countries

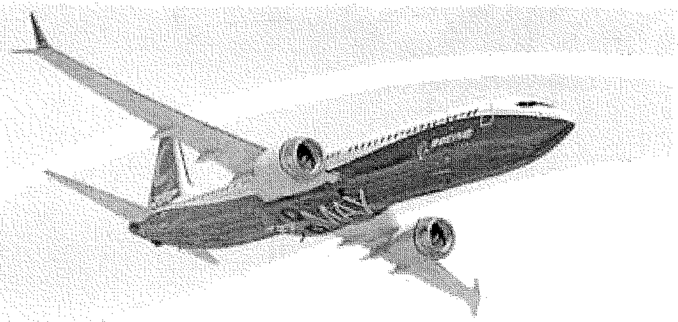


High-speed rail
China's impact on domestic aviation

Source:
2009 Domestic
RPK CAAC



Market Developments
Environment



Environmental challenges for the airplane market

For both economic and environmental reasons, airline customers demand ever-increasing fuel efficiency. Boeing and the aviation industry have committed to ambitious CO_2 emissions targets to achieve carbon-neutral aviation growth beyond 2020 and halve net carbon emissions by 2050 (compared to 2005). Boeing is playing a leadership role in leveraging technology and innovation in support of the industry's strategy by

- Improving the performance of current jetliners and introducing new airplanes, such as the 787 Dreamliner, 747-8, and 737 MAX, that are significantly more efficient than the airplanes they replace.
- Enabling greater operational efficiency through improved airline operations and advocating for global air traffic management system infrastructure modernization.
- Championing the commercialization of sustainable aviation fuels that produce 50 percent or lower life-cycle CO_2 emissions than conventional fuels.

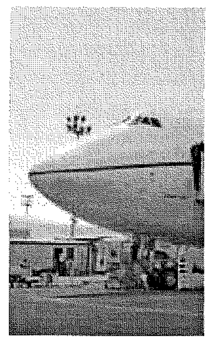
Sustainable aviation fuels

Sustainable aviation fuel received a significant boost in the past year when the ASTM international standards organization approved the commercial use of fuel blends. Since that approval, conventional jet fuel blends with up to 50 percent biofuel derived from sources such as jatropha, camelina, algae, and other oils have been used on more than 1,500 commercial flights. Increasing the availability of sustainable aviation fuel is a critical component of aviation's strategy to reduce life-cycle emissions by 50 percent compared to conventional fuels. Meeting airline fuel demand at price points comparable to those of petroleum-based fuels requires continued investment and government policy support. Boeing will continue to be a catalyst and advocate in both arenas.

Airport environment and growth

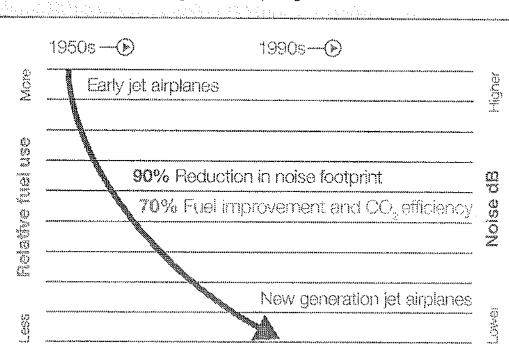
The *Current Market Outlook* projects a doubling of the commercial airplane fleet by 2031. This will require many constrained airports to increase capacity. In some regions of the world, particularly Europe, airport communities have expressed concerns about the environmental effects of increased operations and airport expansion. Finding the appropriate balance between growth and community concerns takes time and can slow or limit progress in a region's capacity planning. The combination of new, cleaner and quieter airplanes like the 787, and innovative operational procedures that take advantage of Required Navigational Performance (RNP) and other technologies, holds the potential to improve the environment around airports while enabling airports to sustain regional economic growth.

Environment
747-8 Freighter Biofuel flight



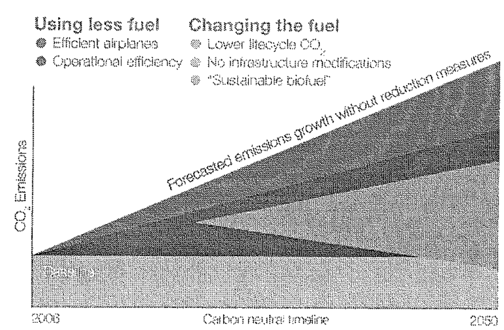
Meeting aviation's environmental challenge

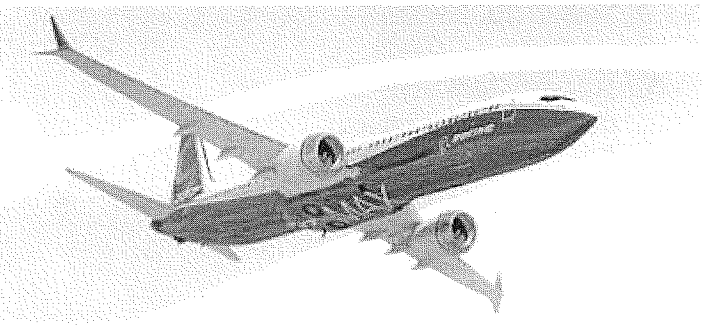
Environment
Track record of significant progress



Noise footprint based on 85 dBa

Environment
The commercial aviation challenge–carbon neutral growth





Market Developments
Global Trends

Industry growth amid economic uncertainty

Boeing's business analysis includes extensive study of global geopolitical dynamics that influence commercial aviation. This research focuses on current events as well as long-term trends. The analysis helps to determine risk and opportunity in the commercial aviation market as a whole, and in specific regions around the world.

Recent global events, including regional political turmoil, energy price volatility, and debt crises, have dampened global economic growth. Although growth is expected to return, albeit slowly, the risks of persistent high oil prices and debt contagion could have lasting effects. A slowdown of trade liberalization could constrain economic growth in some regions, prolonging and delaying the recovery, which would adversely affect demand for air travel and new airplanes.

Level playing field and aviation liberalization

Government assistance for civil aircraft development remains a concern. Recent World Trade Organization rulings have made clear that such government support must be provided on commercial terms. In the area of export finance, the recent reauthorization of the US Export-Import Bank charter helps level the playing field for aircraft manufacturers and airlines.

Liberalization of aviation services stimulates competition, giving passengers more choices and generally reducing ticket prices, which in turn increases demand for air travel. Unlike trade liberalization, air services liberalization has not slowed significantly, despite continued resistance from some governments. This resistance stems primarily from concern about allowing increased levels of foreign ownership in domestic airlines.

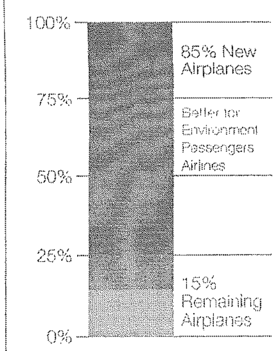
Infrastructure, security, and environment

The *Current Market Outlook* projects that the global large commercial airplane fleet will double by the year 2031. The resultant global air traffic growth will necessitate infrastructure investments, as initiatives to modernize air traffic management provide crucial enhancements to both system capacity and efficiency.

While significant improvements in aviation security have been made globally since 9/11, constant vigilance is still required. Security concerns will continue to affect commercial aviation operations.

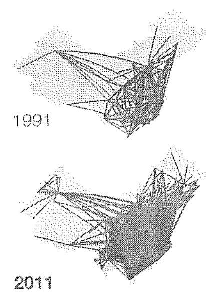
The aviation industry is addressing environmental challenges with a three-pronged strategy of designing more efficient and safer aircraft, improving operational procedures, and developing sustainable biofuels. Moreover, governments around the world are aligning with the industry's strategies to reduce emissions and achieve carbon-neutral growth. This approach will allow the industry to continue strong growth over the long term, despite anticipated regulatory constraints.

Global trends
20 years in the future



Global trends
China domestic frequencies

Source: August OAG

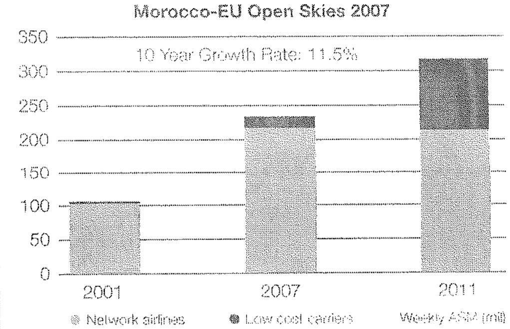


	1991	2011
Total weekly ASKs*	508	11,395
Weekly frequencies	2,165	47,791
Total airport pairs	170	1,085
Airplane size (seats)	147	149

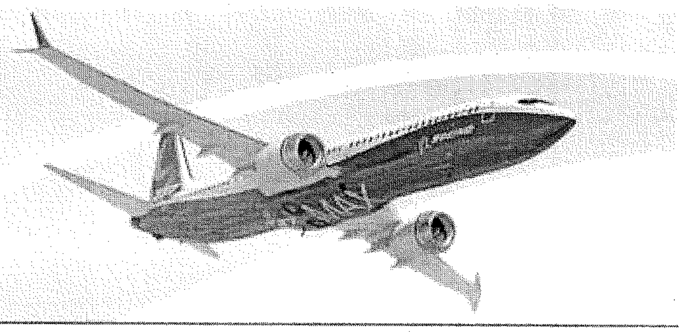
*Available seat-kilometers.

Global trends
Liberalization has stimulated service

Source: August OAG



Methodology



Practical value for Boeing and the industry

The long-term forecast contained in Boeing's *Current Market Outlook* guides product strategy and provides the basis for business plan development. We have shared the forecast with the public since 1964 to help airlines, suppliers, industry organizations, academia, and financiers make informed business decisions and benchmark other forecasts or analyses.

Air travel demand is resilient

Global and regional economic cycles profoundly affect air travel demand, so it is essential to take the current phase of the economic cycle into account in developing the long-term forecast. Historically, declines in economic activity are often associated with unexpected events. The resilience of air travel demand to a disruptive event depends on the nature of the event and the extent to which the event affects air travel, directly or indirectly. For example, events related to personal safety, such as pandemic, war, or threats against aircraft, have a greater effect than commercial or political events. Perturbations from the long-term demand trend are typically relatively short lived, lasting around 12 months. The role air travel plays in the fabric of society is key to its resilience. Air travel is an essential part of personal and business life for many travelers. The Internet, mobile connectivity, and social media are increasingly integrated into daily life, including how we research, discuss, plan, and book travel. At the same time, improved airplane technology and efficiency are allowing airlines to make air travel more affordable, so airfares generally represent a smaller portion of total trip costs.

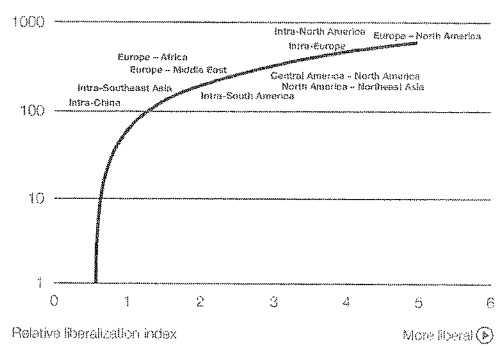
Development process for air travel demand outlook

Our air travel demand forecast is developed by constructing and matching top-down and bottom-up analyses. Bottom-up analysis involves forecasts of traffic between and within individual countries, based on economic predictions, growth momentum, historical trends, travel attractiveness, and projections of the relative openness of air services and domestic airline regulation. Additionally, government statistics on inbound and outbound visitors and tourism receipts are included to identify and cross-check trends. Countries are grouped into geographical regions that generate air traffic flows between and within the regions. In the top-down approach, global and regional markets are similarly projected on aggregated variables. The bottom-up and top-down projections are then reconciled, allowing for the effects of industry and airline business model developments. Further, positive or negative region-specific developments, including population dynamics, shifts toward or away from other modes of transport, and emergence of new air services, are factored in. The resulting regional traffic forecasts are used in developing the airplane demand forecast.

Methodology
2012 traffic outlook

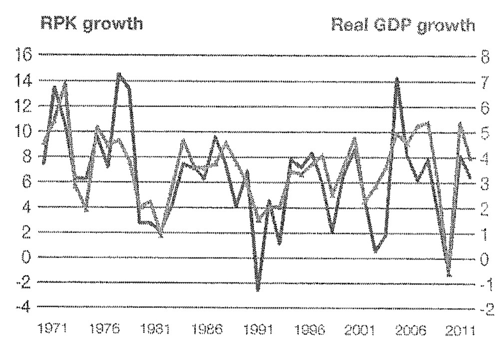
EXPLORE!
The methodology behind the 2012 traffic outlook

Methodology
Relative liberalization and traffic

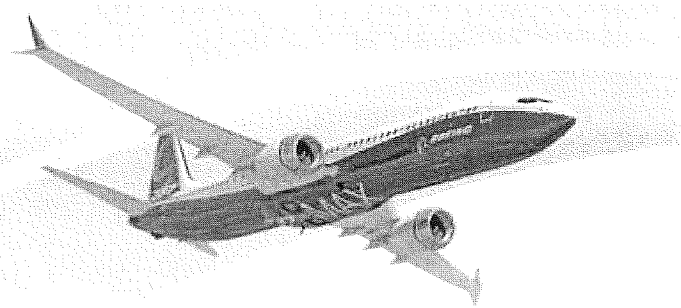


Methodology
World passenger traffic growth vs. GDP

Source: ICAO GDP–IMF



Methodology—continued



Philosophy behind the forecast

Growth in air travel, measured in revenue passenger-kilometers (RPK), has historically outpaced economic growth, represented by GDP. At the global level, the relationship is

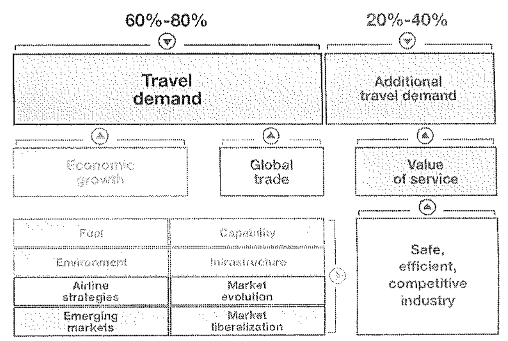
$$RPK_{(growth)} = GDP_{(growth)} + f(t)$$

where f(t) is a time-varying function that typically centers around 2 percent.

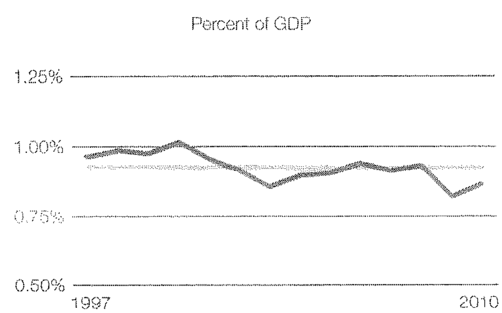
This leads us to conclude that, at the regional level, about 60 to 80 percent of air travel growth can be attributed to economic growth, which in turn is driven by trade. This conclusion is consistent with the observation that countries whose economies are tied to trade tend to have higher rates of air travel. Air travel revenues consistently average about 1 percent of GDP in countries around the world, regardless of the size of the national economy. Globally, air travel has consistently tended toward this historical share of GDP. With a few exceptions, most countries move toward the general trend over the long term. The time-varying function f(t) accounts for the 20 to 40 percent of air travel growth that is not directly associated with GDP growth. This component of growth derives from the value travelers place on the speed and convenience that only air travel can offer. For example, the value travelers place on choice of arrival and departure times, routings, nonstop flights, choice of carriers, service class, and fares stimulates increased aviation services.

Liberalization is the primary driver of value creation in the global air transport network, typically spurring a "bump" in traffic demand. Studies suggest that as the relative openness of a country's bilateral air service rises from the 20th to the 70th percentile, the resulting increase in traffic can boost air travel demand by 30 percent. Often, improved air services directly and indirectly stimulate economic growth, creating a virtuous circle that leads to further air transport growth, which in turn leads to added economic growth, and so on. The percentage of air transport growth that comes from economic development compared to the percentage that comes from the value of air travel services is an indicator of the maturity of an air travel market. Although individual regions may exhibit signs of slowing due to maturing markets, other regions continue or begin to grow vigorously. Current global percentages do not indicate that the world aviation market is nearing maturity in aggregate.

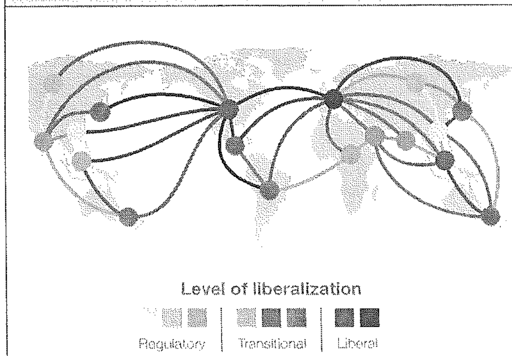
Methodology
Drivers of air travel



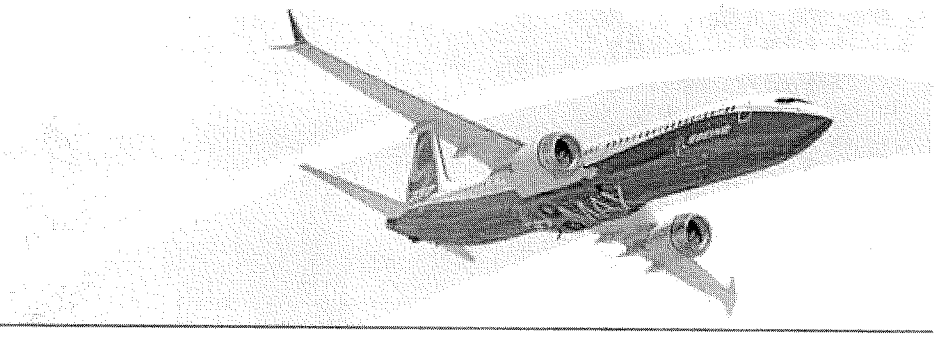
Methodology
World airline revenues
Source: ICAO, IATA IHS Global Insight nominal GDP



Methodology
Levels of liberalization
Source: World Economic Forum Travel & Tourism Report 2009



Forecast Indicators



New airline business models and emerging economies

Each year, we begin our analysis for the *Current Market Outlook* by examining key industry indicators, including fuel, market liberalization, airline capabilities, airline strategies, emerging markets, economic growth, high-speed rail, and the environment. Worldwide economic activity is the most powerful driver of commercial air transport growth and the resulting demand for airplanes. The global gross domestic product (GDP) is projected to grow 3.2 percent per year for the next 20 years, driving worldwide air passenger traffic to average 5.0 percent and air cargo traffic to average 5.2 percent annual growth over the same period.

Global growth spurred by emerging economies

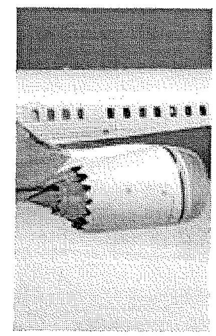
Emerging economies are projected to grow 5 percent per year over the next 20 years, outpacing developed economies, which will average 2 percent growth.

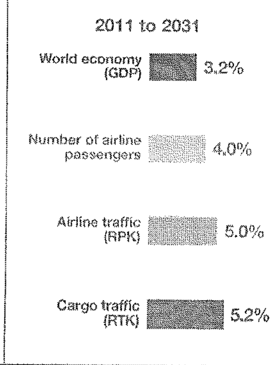
Emerging and developing economies will account for 72 percent of global growth between 2011 and 2031. Their share of real global GDP will increase from 30 percent to 44 percent over the same period. The fastest growing economies include Asia Pacific (projected 4.6 percent growth), the Middle East (projected 3.9 percent growth), and Latin America (projected 4.1 percent growth). Household income will grow and consumption patterns will change as educated labor forces expand, investment in physical and social infrastructure increases, urbanization progresses, and the relative importance of economic sectors shifts within the world's emerging economies. With urbanization, the labor force shifts toward the industrial and service sectors, which spurs median incomes to progress towards the income levels of developed economies. The emerging global middle class will expect to enjoy standards of living comparable to those in developed economies. As demand for international goods and services rises and leisure time increases, appetite for travel will grow.

Business models and airline strategies

Airline strategies and business models help determine the types of airplanes that airlines purchase and, as a result, the types of airplanes that manufacturers produce. Low-cost carriers drive the strong demand for new single-aisle airplanes. Their share of the market is expected to grow from 14 percent to 19 percent by 2031. There is a need for 23,240 new single-aisle airplanes, 36 percent of which will replace older airplanes and 64 percent will expand the fleet. International expansion of network carriers is driving demand for 7,950 new twin-aisle airplanes, including 940 freighters, primarily large freighters such as the 747-8F and 777 Freighter.

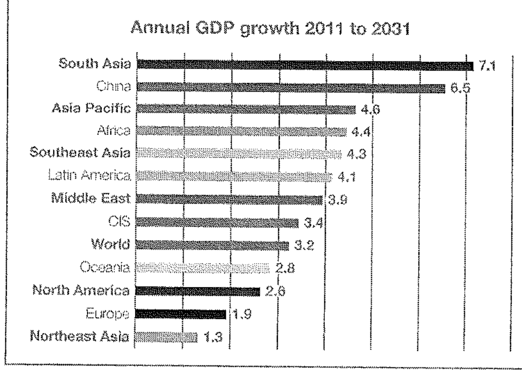
Forecast indicators
Growth rates



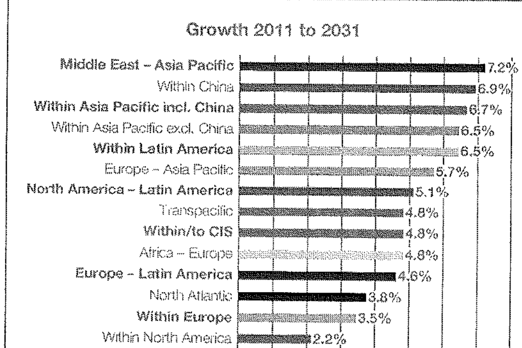


Forecast indicators
Emerging markets driving economic growth

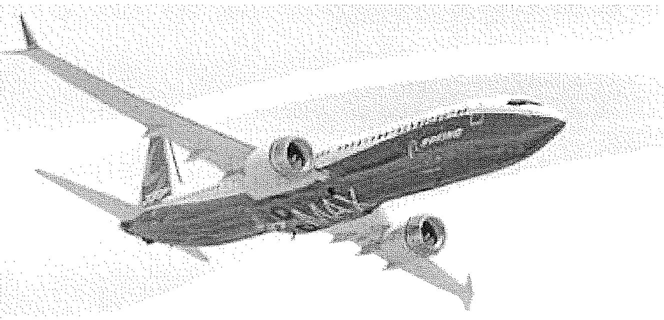
Source: IHS Global Insight



Forecast indicators
Annual traffic growth



Fleet Development



Fleet size will double

The in-service commercial fleet will grow an average 3.5 percent per year to double in size from 19,890 airplanes today to 39,780 by 2031. Over the next 20 years, the airline industry will need 34,000 new airplanes, of which 41 percent will replace older, less efficient airplanes; 59 percent of the new deliveries will reflect growth in emerging markets and evolving business models.

Single-aisle airplanes to predominate

Single-aisle airplanes continue to dominate the world's fleet. In 2011, the single-aisle category comprised 63 percent of the world's fleet. By 2031, we estimate that share will rise to 69 percent. Of the forecast demand for 23,240 new airplanes, valued at $2.0 trillion, 36 percent will replace older airplanes, while 64 percent will expand the fleet. Emerging markets are driving demand for single-aisle airplanes. The Asia Pacific region is expected to need 7,990 new airplanes to expand its single-aisle fleet from 3,170 to 9,230 airplanes by 2031. Latin America, which is expected to take delivery of 2,080 new single-aisle airplanes, and the Middle East, which is expected to take delivery of 1,060 new airplanes, also generate strong demand. Low-cost carriers, whose business models focus on fleet commonality, also drive demand for single-aisle airplanes.

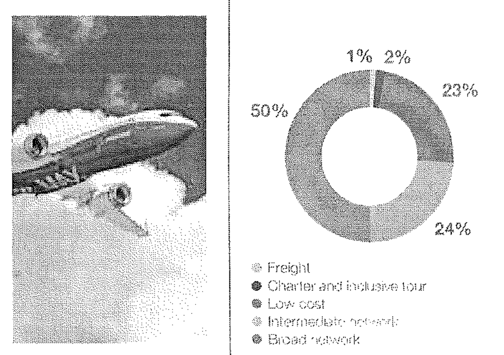
Expanding international markets increase demand

Traffic on long-haul routes is forecast to grow 5.2 percent annually over the next 20 years, creating demand for 7,950 new twin-aisle airplanes. The largest twin-aisle markets are Asia Pacific, Europe, North America, and the Middle East, which will take nearly 90 percent of all new deliveries.

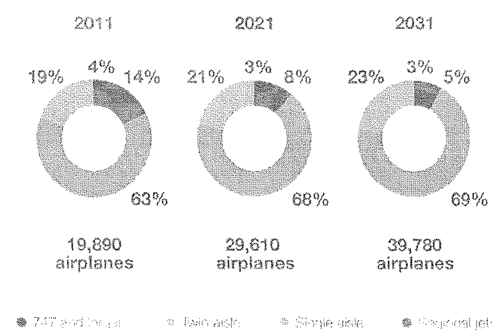
Efficiencies of the fleet

Increased airline costs, specifically increased fuel costs, are driving airlines to operate the most efficient aircraft available. Consequently, we foresee a modest increase in the average size of airplanes in operation. Airlines are replacing small regional jets with larger regional jets. This trend continues in the single-aisle category. Airlines that have ordered 737-700s are ordering 737-800s, and airlines that ordered 737-800s are ordering 737-900ERs. In the twin-aisle fleet, it is the medium twin-aisle category, represented by the 777, that is growing. In 2011, this size category made up 50 percent of the twin-aisle fleet. By 2031, it will make up 59 percent of the twin-aisle fleet. Current orders reflect this trend. In 2011, there were 202 orders placed for 777s, an increase of 165 percent compared to 2010.

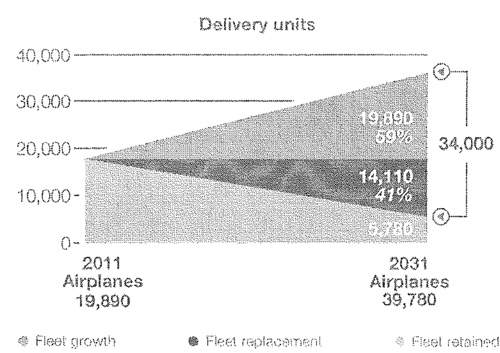
Fleet developments
Market share by business models



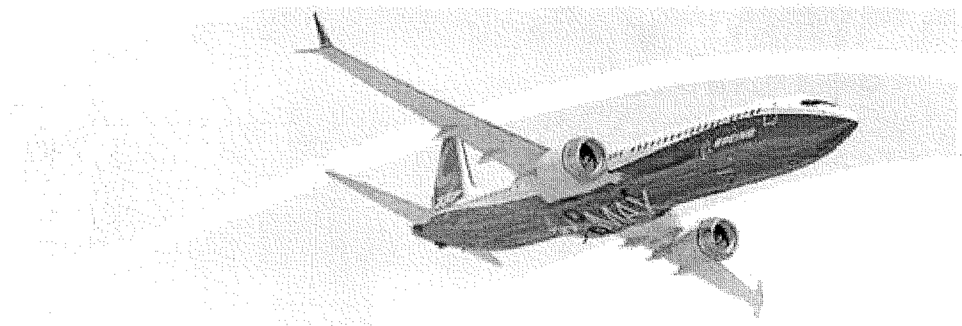
Fleet developments
World fleet will double by 2031



Fleet developments
Over half of new deliveries are for growth



New Airplanes



Single-aisle aircraft remain pivotal

Over the next 20 years, we project that 23,240 single-aisle airplanes will be delivered, representing nearly 70 percent of commercial airplane deliveries and 45 percent of total delivery value. Most commonly used for shorter distance travel, single-aisle airplanes will find new applications in emerging markets as passenger demand continues to grow. Airlines will continue to rely on single-aisle airplanes to connect adjacent regions, such as North America to South America and Oceania to Southeast Asia. Asia Pacific will receive 34 percent of the new single-aisle aircraft, while Europe and North America will take 25 percent and 22 percent, respectively. In the mature markets, new single-aisle airplanes will replace aging airplanes, such as MD-80s, 737 Classics, and older A320s. As more new 737 MAX and A320neo airplanes enter service, overall fleet efficiency will improve and the more capable airplanes will be able to serve new markets.

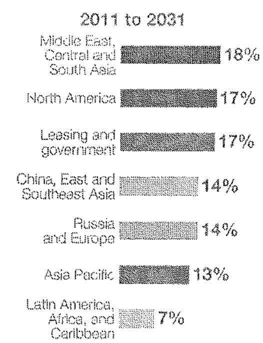
International traffic creates twin-aisle demand

The twin-aisle airplane segment is the highest valued segment of the long-term forecast, valued at US$2.1 trillion over the next 20 years. Entry into service of airplanes such as the Boeing 787 Dreamliner, and later, the Airbus A350 is allowing airlines to create new point-to-point international service. These new airplane families will help foster traffic growth between regions by allowing airlines to supplement current service provided by the Boeing 777 and the Airbus A330. Twin-aisle airplanes account for 24 percent of forecast deliveries, which is 47 percent of the projected delivery value. Over the next 20 years, the vast majority of twin-aisle airplanes currently flying will be retired. By 2031, new airplanes will account for 87 percent of the twin-aisle fleet.

Demand for large airplanes focused in key regions

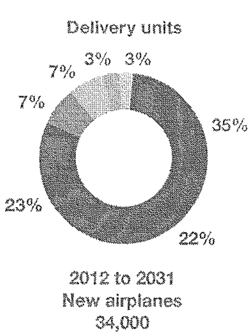
Asia Pacific, Europe, and the Middle East account for more than 90 percent of large-airplane demand in the 20-year forecast. These airplanes will serve as passenger jetliners on high-traffic trunk routes, as well as dedicated commercial freighters. The forecast 790 deliveries are valued at US$280 billion, or 6 percent of the total delivery value. The Asia Pacific region will receive 41 percent of these deliveries, while Europe will take 25 percent and the Middle East will take 24 percent. While medium-size twin-aisle airplanes will take a growing share of long-haul traffic over the next 20 years, large airplanes will remain an important part of the commercial airline fleet.

New airplanes
Boeing order backlog: $308B

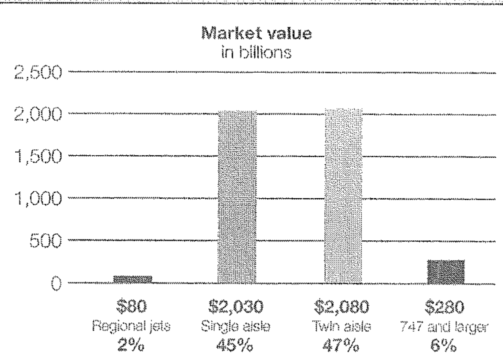


New airplanes
Deliveries by region

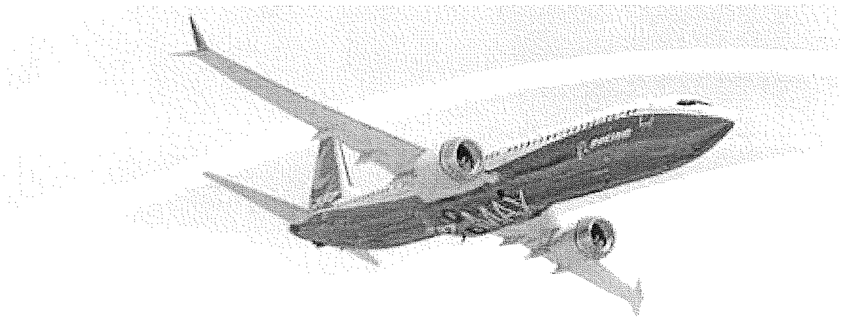
Region	New airplanes
Asia Pacific	12,030
North America	7,290
Europe	7,760
Middle East	2,370
Latin America	2,510
CIS	1,140
Africa	900
Total	**34,000**



New airplanes
Market value: $4.5 trillion



Air Cargo Market



Resilient demand for air cargo

While surface transport accounts for the majority of the world's freight traffic, air cargo remains indispensable for industries that transport perishables, such as seafood or flowers; high-value, low-weight goods, such as consumer electronics or pharmaceuticals; and time-critical goods such as just-in-time inventory items. Lately, with rising fuel prices, shippers have settled for slower modes of transport. But the speed advantage of air cargo ensures air freight's role in the global economy.

Air cargo can be carried in the lower hold of passenger flights or on dedicated freighters. Capacity on passenger flights has been expanding, especially as greater numbers of highly cargo-capable airplanes, such as the 777-300ER, enter the fleet. Lower-hold cargo can generate extra profit for passenger airlines, taking advantage of dense passenger networks. But freighters, with larger payloads and routes and frequencies optimized for cargo, carry the majority of traffic—about 60 percent.

Air cargo traffic growth, measured in revenue tonne-kilometers (RTK), is projected to average 5.2 percent over the next 20 years. Global economic growth and the need to replace aging airplanes will create a requirement for 2,760 freighter deliveries over the same period. About 1,820 of these will be passenger airplane conversions. The remaining 940 airplanes, valued at $250 billion, will be new. The freighter fleet will nearly double in size, from 1,740 airplanes in 2011 to 3,200 in 2031.

Most standard-body freighters to be conversions

Boeing forecasts a requirement for 1,120 standard-body freighters, nearly all of which will be passenger conversions. The low capital cost of converted airplanes makes them attractive for the low-demand routes typically flown in standard-body operations.

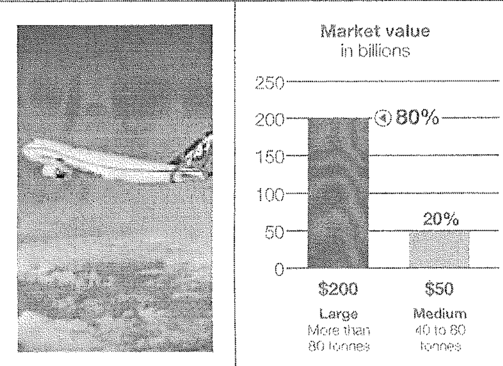
Express carriers drive medium widebody market

Of the 710 medium widebody freighters delivered during the forecast period, 260 will be new purpose-built freighters. This market segment is driven by express carriers, which value the balance between the lower cost per tonne achieved by larger airplanes and the schedule flexibility of smaller airplanes.

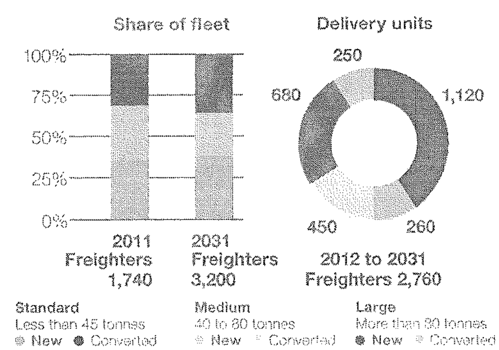
Intercontinental operations favor new, large freighters

Although purchase prices for converted large freighters are attractive, the performance and reliability advantages of new, purpose-built freighters outweigh this consideration—particularly for intercontinental cargo operations, where larger payloads and extended ranges are crucial. Of the 930 large freighter deliveries, 680 will be new airplanes.

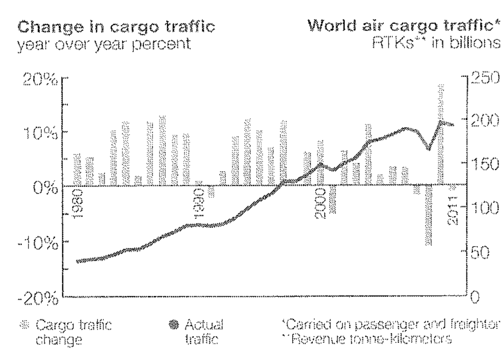
Air cargo market
Market value: $250 billion

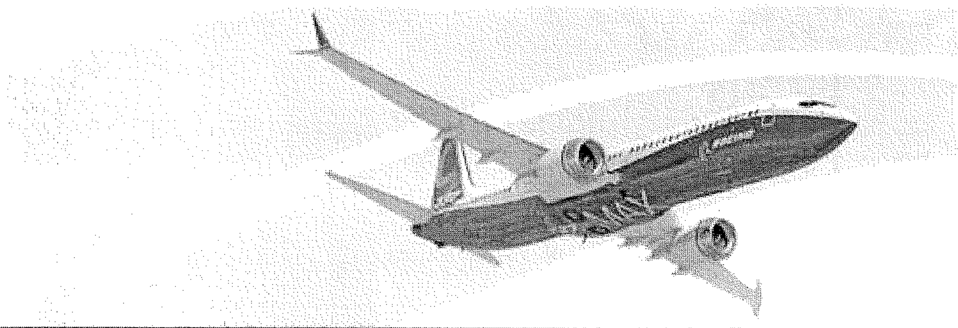


Air cargo market
940 new and 1,820 converted



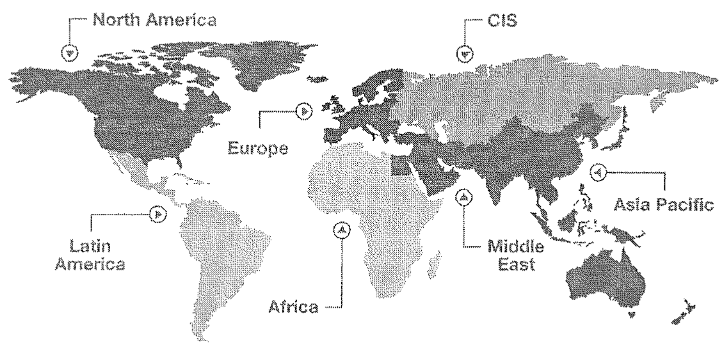
Air cargo market
Annual growth: 5.5% since 1980





World Regions

World regions
New airplane market by region



Globalized demand

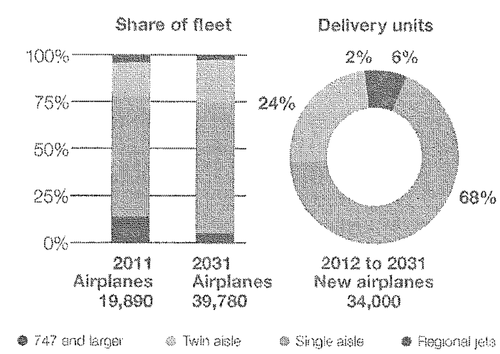
The number of airplanes in the world fleet grows an average 3.5 percent each year as passenger traffic, measured in revenue passenger-kilometers, grows 5.0 percent per year. Cargo traffic, measured in revenue tonne-kilometers, grows 5.2 percent a year. Over the next 20 years, this will create a need for 33,060 passenger airplanes and 940 freighter airplanes. Increasing demand for new airplanes from airlines in emerging markets around the globe drives this expansion and significantly increases the industry's resilience to regional economic fluctuations.

Regional focus

Air transport markets and airline business models evolve at different rates from region to region. Airplane demand therefore varies across the globe. As new airlines emerge, established airlines seek to preserve and boost their share of the passenger market by increasing frequency of service, expanding the number of city pairs served, offering new products, and introducing new business and premium passenger services—all while staying true to the airline's brand image.

Each region's unique market characteristics affect its demand for airplanes. For example, the markets in North America and Europe are shaped by aggressive growth of low-cost carriers and the need to replace aging airplanes in the fleets of established network carriers. Demand is strongest for single-aisle airplanes in these markets. In the Middle East, on the other hand, airline business models concentrate on long-haul international services, which favor twin-aisle jetliners. The Asia Pacific region is seeing markets surge for both domestic and international services, creating demand for a more even mix of single- and twin-aisle airplanes.

World regions
Market value: $4,470 billion



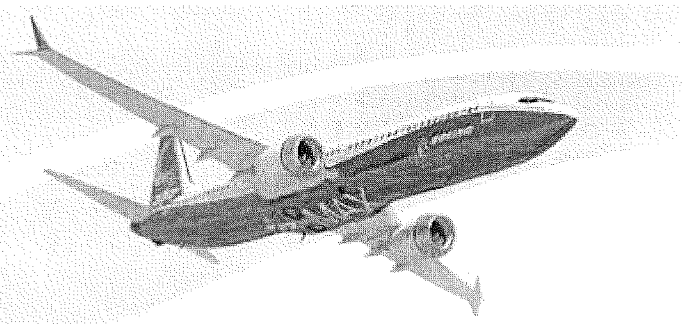
World regions
Key indicators and new airplane markets

Growth measures	
Economy (GDP)	3.2%
Traffic (RPK)	5.0%
Cargo (RTK)	5.2%
Airplane fleet	3.5%

	New airplanes	Share by size
Large	790	2%
Twin aisle	7,950	24%
Single aisle	23,240	68%
Regional jets	2,020	6%
Total	**34,000**	

Market size	
Deliveries	34,000
Market value	$4,470B
Average value	$130M

	2011 Fleet	2031 Fleet
Large	790	1,030
Twin aisle	3,710	9,110
Single aisle	12,610	27,430
Regional jets	2,780	2,210
Total	**19,890**	**39,780**



World Regions
Asia Pacific

Growing markets

The vibrant economies in the Asia Pacific region continue to lead the world economic recovery. Intrinsic strength, progressive trade agreements among the region's countries, and recovering global demand helped most economies in the region maintain growth through the downturn. China and India will lead the region's economic growth with 4.6 percent growth per year for the next 20 years, significantly outpacing the world's average growth rate. The region's share of world GDP will expand from 28 percent today to 36 percent by 2031.

Rising traffic levels

During the next 20 years, nearly half of the world's air traffic growth will be driven by travel to, from, or within the Asia Pacific region. Total traffic for the region will grow 6.4 percent per year. Fueled by national economic growth and the increasing accessibility of air transport services, traffic within the region will grow faster than traffic to and from other regions. Domestic and international travel within the region will grow 6.7 percent per year.

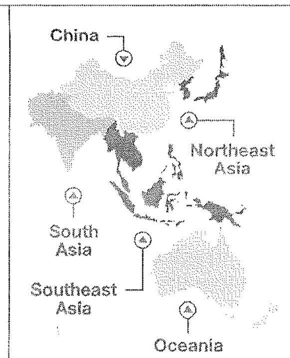
Air cargo plays a critical role in the region's economy, transporting goods over difficult terrain and vast stretches of ocean. Some of the world's largest and most efficient cargo operators are located in Asia. Air cargo will grow 5.9 percent per year during the next 20 years. Carriers within the region are expected to take 330 new freighters, with an additional 450 conversions.

Asia Pacific airlines will need 12,030 new airplanes, valued at $1.7 trillion, over the next 20 years. The number of airplanes in the Asia Pacific fleet will nearly triple, from 4,710 airplanes in 2011 to 13,670 airplanes in 2031. New low-cost carriers and demand for short-haul flying have spurred a substantial increase in single-aisle aircraft. In the past 8 years, single-aisle capacity has doubled and will likely double again in the coming decade.

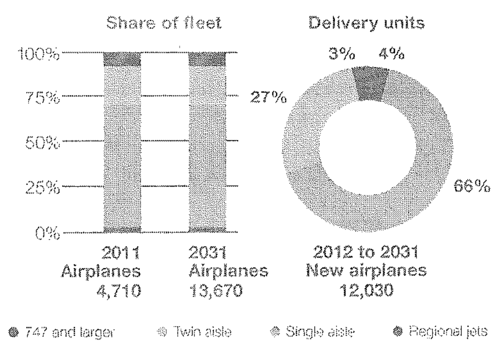
Liberalization expands markets

The structure of the Asia Pacific airline industry is changing as regulations are liberalized and carriers expand beyond national boundaries. The impact of liberalization is particularly dramatic in the case of low-cost carriers, which are increasing air travel by lowering fares and opening new markets. Established airlines are forming low-cost units to compete, often as joint ventures with high-profile, low-cost brands within the region. This competition is rapidly improving the affordability and accessibility of air travel, which will stimulate demand in established markets and meet the emergent travel needs of the rising middle class.

Asia Pacific
New airplanes: 12,030



Asia Pacific
Market value: $1,700 billion



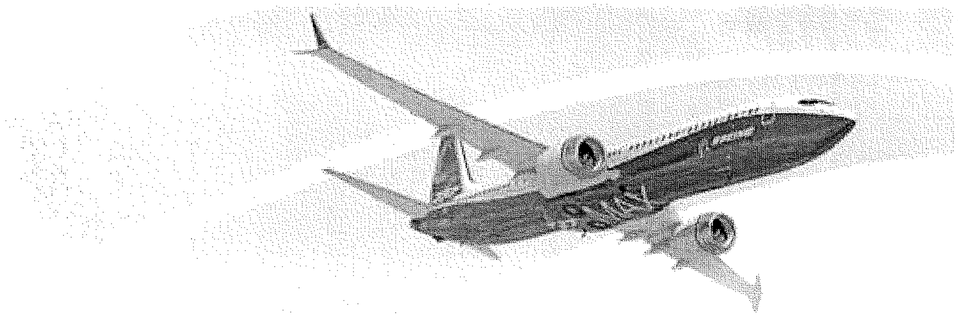
Asia Pacific
Key indicators and new airplane markets

Growth measures	
Economy (GDP)	4.6%
Traffic (RPK)	6.4%
Cargo (RTK)	5.9%
Airplane fleet	5.5%

	New airplanes	Share by size
Large	320	3%
Twin aisle	3,230	27%
Single aisle	7,990	66%
Regional jets	490	4%
Total	**12,030**	

Market size	
Deliveries	12,030
Market value	$1,700B
Average value	$140M

	2011 Fleet	2031 Fleet
Large	340	460
Twin aisle	1,080	3,490
Single aisle	3,170	9,230
Regional jets	120	490
Total	**4,710**	**13,670**



World Regions
China

40 years of working together
Boeing is celebrating 40 years of working together with China's aviation industry. In 1972 CAAC placed an order for China's first Boeing airplanes--ten 707s. Mainland Chinese airlines have since ordered more than 900 Boeing airplanes. More than 6,000 people currently work at Boeing-related businesses and tens of thousands more support Boeing suppliers. This partnering will continue.

Continued growth
With GDP forecast to rise 6.5 percent annually over the next 20 years, China will continue to serve as a growth engine for the global economy. China's share of world GDP will continue to increase over the next several decades. As Chinese incomes converge toward those in the historical industrialized nations, an expanding middle class will expect to enjoy a comparable standard of living and consumption patterns.

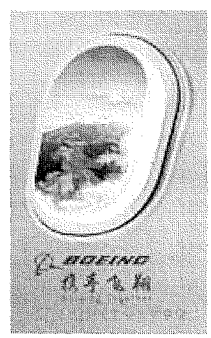
Traffic continues to be robust, rising 12.1 percent in 2011 compared to 2010. Growth will moderate toward 7.0 percent, which will nonetheless drive a need for 5,260 new airplanes valued at $670 billion.

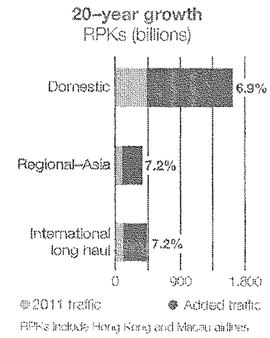
A projected 230 airports will be available for commercial use by 2015 as domestic travel continues to grow. Airlines will also look for opportunities to expand, particularly in regional and long-haul markets. The number of new international markets has doubled over the past 10 years. Over the next 20 years, intra-Asia and long-haul traffic are both expected to grow 7.2 percent, driving the future fleet mix. Single-aisle airplanes will be preferred for newly opening markets within China. Within Asia, a mix of single-aisle and twin-aisle airplanes will be needed, while long-haul flying will rely on airplanes like the 787, 777, and 747-8 Intercontinental.

Cargo market
The Chinese cargo market is one of the world's largest and fastest growing. Domestically, it has grown 15.5 percent annually since 1990. China's airlines are forecast to grow 6.2 percent annually over the next 20 years, outpacing all other regions. This growth suggests a need for 120 new freighters and 230 freighter conversions. Chinese cargo airlines now number among the world's top cargo airlines, and we expect their market share will continue to increase.

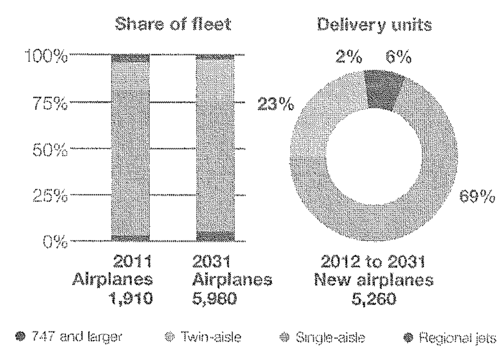
Adapting business models
Historically, the majority of airlines in Europe and North America were large network airlines. Today a mix of network carriers, low-cost carriers, charter airlines, and air cargo operators meets consumer needs. As aviation continues to grow in China, airlines will adapt and evolve their business models to meet the needs of their customers.

China
Chinese airline expansion in Asia and long haul routes





China
Market value: $670 billion



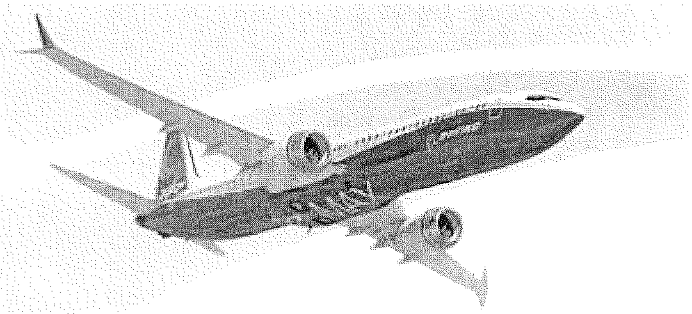
China
Key indicators and new airplane markets

Growth measures	
Economy (GDP)	6.5%
Traffic (RPK)	7.0%
Cargo (RTK)	6.2%
Airplane fleet	5.9%

Market size	
Deliveries	5,260
Market value	$670B
Average value	$130M

	New airplanes	Share by size
Large	110	2%
Twin aisle	1,190	23%
Single aisle	3,650	69%
Regional jets	310	6%
Total	**5,260**	

	2011 Fleet	2031 Fleet
Large	80	140
Twin aisle	280	1,310
Single aisle	1,490	4,220
Regional jets	60	310
Total	**1,910**	**5,980**



World Regions
Northeast Asia

Modest economic growth
Northeast Asia's gross domestic product is forecast to grow 1.35 percent annually over the next 20 years. This modest growth projection reflects the slender growth of the dominant Japanese economy over the past decade. Although Japan's economy is forecast to grow as it recovers from the recent earthquakes and tsunami, low birth rates and a declining working-age population will moderate the long-term growth rate. South Korea's broadening industrial base is forecast to drive its economy to grow faster than Japan's.

Northeast Asia's air capacity grew more than 50 percent in the 1990s. Over the past decade, however, air travel growth slowed to 5 percent in the wake of a series of economic disruptions, including the Asian financial crisis, SARS epidemic, slumping global economy, natural disasters, and the restructuring of a major carrier. To keep pace with the economic growth and increasing air travel of neighboring nations, Japan and South Korea are executing new trade agreements, reducing traditional travel barriers, and potentially privatizing portions of infrastructure to spur domestic and inbound travel growth.

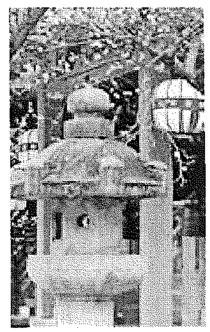
Easing operating restrictions to promote growth
Northeast Asia's air travel is forecast to grow 3.7 percent annually over the next 20 years. Expanded operations agreements with the United States, Europe, China, the Middle East, and other Asia Pacific nations are encouraging global network carriers and low-cost airlines to expand services and open new markets. Liberalization and the rapid growth of economic ties with neighboring regions are driving brisk growth in passenger traffic with other Asia Pacific countries. Low-cost carriers spurred substantial growth in travel to South Korea from neighboring nations in 2012, and three new low-cost carriers in Japan are also expected to stimulate domestic and short-haul demand.

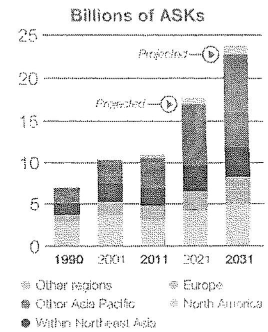
Airport capacity will continue to increase, particularly at Tokyo's Haneda and Narita airports. Improved market access, airport development, increased competition, and expanded low-cost service to, from, and within Northeast Asia will nurture continued air travel growth.

Fleet modernization continues
Network carriers in Northeast Asia are restructuring, renewing fleets, forming joint ventures, and introducing new products. Airlines in Japan and South Korea continue to modernize their fleets and grow their international networks, creating a need for 1,270 new airplanes over the next 20 years.

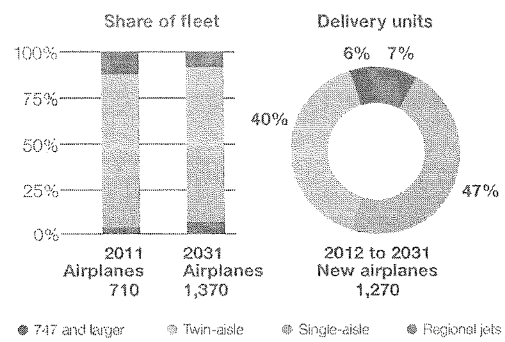
The number of regional jets, including the anticipated Mitsubishi Regional Jet (MRJ), is forecast to grow slightly. Single-aisle airplanes will account for 47 percent of new deliveries. New twin-aisle airplanes will account for 40 percent of new deliveries, while the number of large airplanes will remain relatively constant.

Northeast Asia
Capacity growth





Northeast Asia
Market value: $220 billion



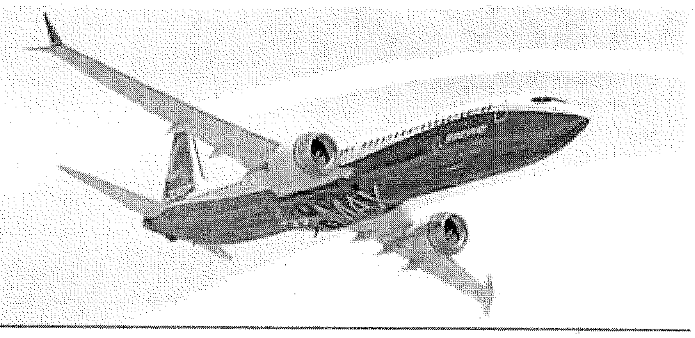
Northeast Asia
Key indicators and new airplane markets

Growth measures	
Economy (GDP)	1.3%
Traffic (RPK)	3.7%
Cargo (RTK)	5.8%
Airplane fleet	3.3%

Market size	
Deliveries	1,270
Market value	$220B
Average value	$170M

	New airplanes	Share by size
Large	70	6%
Twin aisle	510	40%
Single aisle	600	47%
Regional jets	90	7%
Total	1,270	

	2011 Fleet	2031 Fleet
Large	80	120
Twin aisle	300	580
Single aisle	300	580
Regional jets	30	90
Total	710	1,370



World Regions
South Asia

Robust traffic growth

South Asian air travel is expected to grow 8.4 percent per year over the next 20 years, outpacing all other regions in our long-term forecast. Traffic will remain focused on the Asian continent, with the largest flows comprising domestic travel and travel within South Asia and flights to and from the Middle East and Southeast Asia.

Economic development and socioeconomic shifts are leading to rapid economic growth and expansion of air travel. A growing share of South Asia's large population (totaling 1.65 billion in 2011) is entering the workforce for the first time, boosting economic activity and incomes. Real gross domestic product (GDP) grew 7.3 percent per year from 2001 to 2011. Emerging markets averaged only 6 percent growth during the same period. Incomes increased even faster, with GDP per capita growing by about 10 percent per year. With continued government support of economic policy liberalization, market reform, and investment, India could become the world's fourth-largest economy within 20 years.

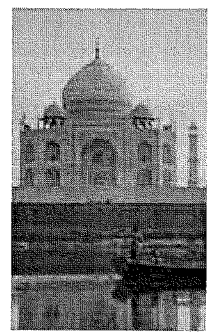
South Asia's airlines have been helped by liberalization in key markets, including the domestic Indian market, and flights between India and the Middle East. Liberalization allows airlines to open routes, add frequencies, and try new business models. As a result, air transport has become more convenient and less expensive throughout South Asia.

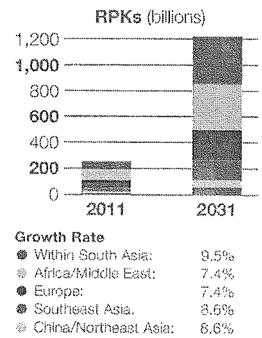
Consolidation and reform in India

Indian carriers recently suffered record-breaking financial losses, but there are reasons to hope for profitable future growth. Kingfisher's contraction in 2011 and 2012 reduced capacity in the market, allowing healthier airlines to take international and domestic market share, even as they implemented much-needed fare increases.

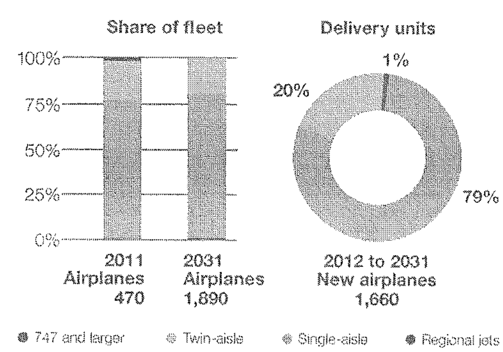
The Government of India is helping with targeted reforms. Air India has long held a right of first refusal for international traffic rights. Exercise of this right has been detrimental to other Indian carriers, but not to foreign carriers. The Government's priorities having changed in early 2012, full utilization of traffic rights by Indian airlines will now be encouraged. The Government also allowed reform in airline fuel purchasing. This will offer some relief to Indian airlines, which face some of the highest fuel prices in the world. Further opportunities include a proposal to allow foreign airlines to acquire 49 percent of Indian airlines. The proposal has languished for years, but support for action is building. For Indian carriers with weakened balance sheets, foreign direct investment would be a welcome source of funds.

South Asia
South Asia traffic varies by market





South Asia
Market value: $210 billion



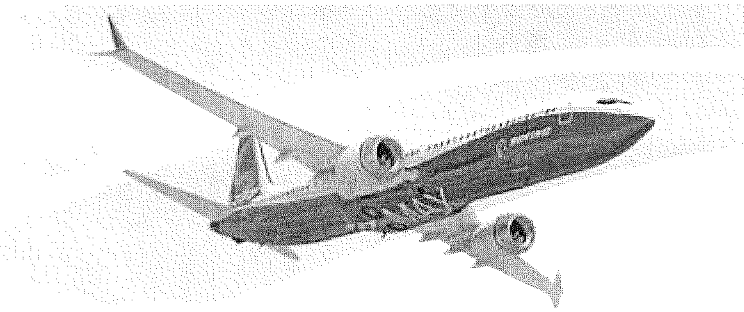
South Asia
Key indicators and new airplane markets

Growth measures	
Economy (GDP)	7.1%
Traffic (RPK)	8.4%
Cargo (RTK)	5.9%
Airplane fleet	7.2%

	New airplanes	Share by size
Large	–	–
Twin aisle	340	20%
Single aisle	1,300	79%
Regional jets	20	1%
Total	1,660	

Market size	
Deliveries	1,660
Market value	$210B
Average value	$130M

	2011 Fleet	2031 Fleet
Large	10	–
Twin aisle	100	370
Single aisle	360	1,500
Regional jets	–	20
Total	470	1,890



World Regions
Southeast Asia

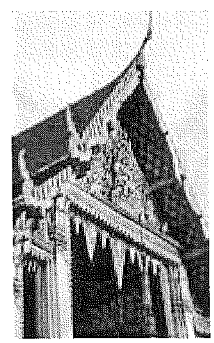
Airlines expand operations
Airlines have grown strongly as Southeast Asia continues to develop economically. Low-cost carriers are expanding and gaining market share as their attractive fares and new routes stimulate demand. Legacy carriers have restructured their operations and finances to become more competitive and grow. Some have launched subsidiaries or partnered with low-cost airlines to expand product offerings in the quickly evolving market. Rapid market growth will continue as the Association of Southeast Asian Nations (ASEAN) strengthens business and leisure travel ties within ASEAN and with China and Taiwan. Travelers are increasingly likely to book multi-stop itineraries as low fares and network integration make this more attractive. New, efficient airplanes with improved capabilities and lower operating costs are key to airline business strategies. Orders for new airplanes have dramatically increased to meet growing demand and enable new, direct, long-range markets.

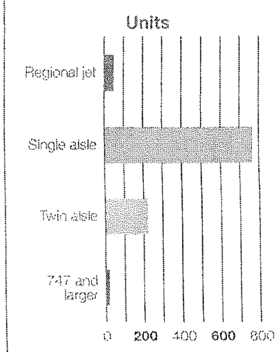
Liberalization opens routes
Regulatory changes and infrastructure improvements are crucial to air travel expansion. Many traditional barriers to growth have fallen as ASEAN countries relax market regulation within Southeast Asia and across the strait with Taiwan and China. For example, more than 700 passenger flights per week are now scheduled between Taiwan and China, where service had been limited to charter flights. Increased service between ASEAN capital cities signals a transition toward a unified regional aviation market. Not waiting for liberalization, several carriers are aggressively expanding into new markets by acquiring or partnering with other Southeast Asian carriers to operate as a combined fleet on a single extended network. Governments and airport authorities are eager to expand their aviation infrastructures and capitalize on increased trade and tourism.

Airlines bolster economic growth
Economic relationships and collaboration among Southeast Asian countries continue to strengthen. Air transportation is vital to the region's above-average GDP growth projection of 4.8 percent annually over the next 10 years. For example, more affordable air travel options have spurred growth throughout the services sector, including tourism and financial services. Air cargo operations enable the efficient shipment of manufactured goods. Overall, air travel to, from, and within Southeast Asia is projected to grow at an average annual rate of 6.5 percent over the next 20 years. Traffic within Southeast Asia is expected to grow at a rate of 7.6 percent per year. More than half of new airplane deliveries will be single-aisle airplanes, needed to serve Southeast Asian routes.

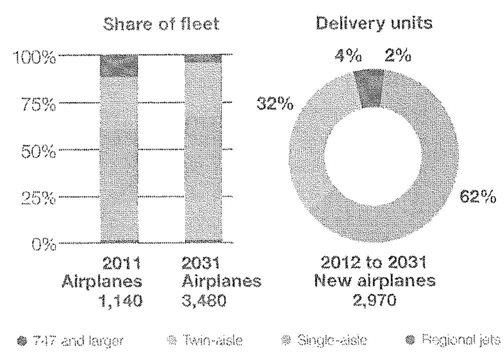
Southeast Asia
Backlog: 1,050 aircraft

Source: Ascend January 2012





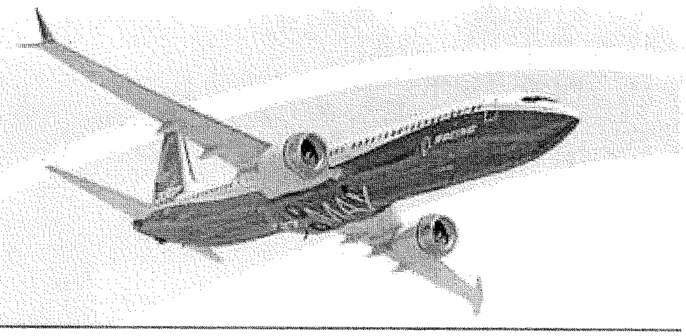
Southeast Asia
Market value: $470 billion



Southeast Asia
Key indicators and new airplane markets

Growth measures			New airplanes	Share by size
Economy (GDP)	4.3%	Large	110	4%
Traffic (RPK)	6.5%	Twin aisle	950	32%
Cargo (RTK)	5.7%	Single aisle	1,840	62%
Airplane fleet	5.7%	Regional jets	70	2%
		Total	**2,970**	

Market size			2011 Fleet	2031 Fleet
Deliveries	2,970	Large	130	150
Market value	$470B	Twin aisle	310	980
Average value	$160M	Single aisle	680	2,280
		Regional jets	20	70
		Total	1,140	3,150



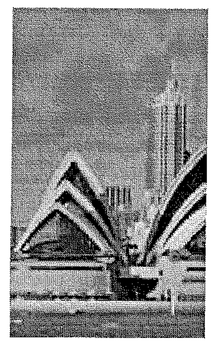
World Regions
Oceania

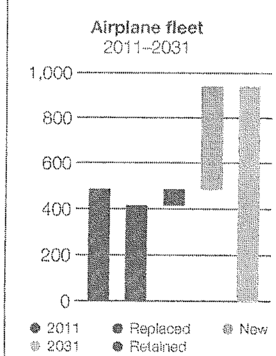
A thriving market
With roughly 40 million people--only 0.5 percent of the world's population--Oceania still accounts for 14 percent of the world's air traffic today. Total Oceania air traffic is forecast to maintain 5 percent annual growth over the next 20 years as connections with the Asia Pacific region and the rest of the world continue to strengthen. Traffic to and from Oceania will grow faster than internal traffic, which will grow 4 percent per year. Capacity between Oceania and Southeast Asia is forecast to increase 5 percent per year as this flow continues to be the primary gateway to the rest of the world. In addition, new flights and markets will open as trade and tourism with North America, the Middle East, and China expand. Annual traffic growth between the Middle East and Oceania is forecast to grow most quickly at 7 percent per year, primarily as a result of Middle East carriers operating sixth freedom flights connecting Oceania and Europe, Africa, and the Middle East.

Oceana's airlines continue to adapt
The market in Oceania changed dramatically during the past decade as airlines redefined themselves during economic uncertainty. Qantas successfully countered the rise of the low-cost carrier business model by introducing its own LCC, Jetstar. Virgin Blue sought to compete against Qantas by creating a spinoff airline, V Australia. In 2012, however, Virgin Blue unified its product by rebranding all its airlines as Virgin Australia. Air New Zealand has continued to differentiate its product with the introduction of the Boeing 777-300ER and its unique custom-designed Economy Skycouch seats. In addition, market liberalization is boosting international competition from foreign airlines carrying passengers to and from Oceania.

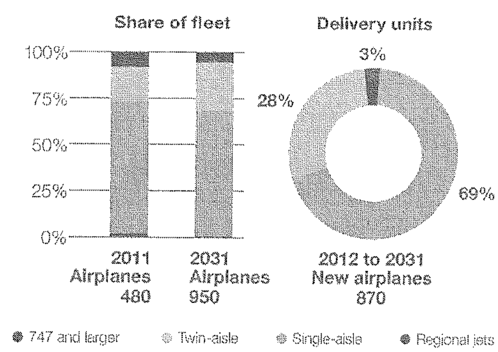
New airplane requirement
As traffic increases and airlines evolve and expand, there will be a continued need for new airplanes in Oceania. Over the next 20 years, it is expected that Oceania will need 870 new airplanes. Of those, 600 will be single-aisle airplanes needed to transport people within Oceania or to nearby Southeast Asia. In addition, 240 twin-aisle and 30 large airplanes will be needed for long-range travel across the globe. This new generation of airplanes will enable airlines to open long, thin routes that would not be economical to serve using the previous generation of airplanes. The increasingly interconnected world will create a strong demand in Oceania for small- to medium-size twin-aisle airplanes, such as the 787.

Oceania
460 new airplanes required over next 20 years





Oceania
Market value: $130 billion



Oceania
Key indicators and new airplane markets

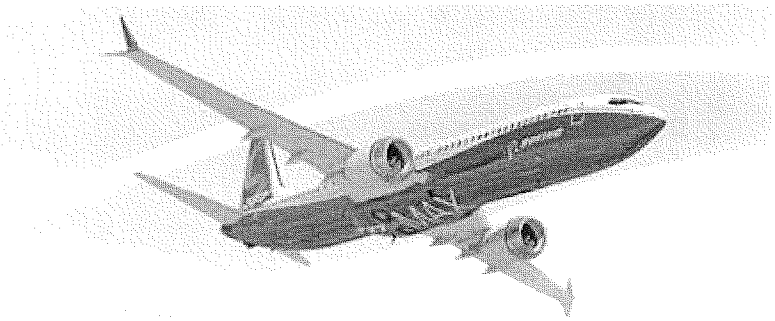
Growth measures	
Economy (GDP)	2.8%
Traffic (RPK)	4.9%
Cargo (RTK)	5.4%
Airplane fleet	3.5%

	New airplanes	Share by size
Large	30	3%
Twin aisle	240	28%
Single aisle	600	69%
Regional jets	–	–
Total	**870**	

Market size	
Deliveries	870
Market value	$130B
Average value	$150M

	2011 Fleet	2031 Fleet
Large	40	50
Twin aisle	90	250
Single aisle	340	650
Regional jets	10	–
Total	**480**	**950**

World Regions
North America



Growth moderating in third year of improvement

The North American commercial airline industry posted its third year of traffic and capacity growth amid sustained profitability. Capacity and traffic both grew 2 percent, year over year, with varying results for network and low-cost carriers. Network carriers reported a 1 percent rise in both capacity and traffic, contributing to an 83 percent passenger load factor. The low-cost carrier segment continues to grow at a faster rate, with capacity growing 6 percent and traffic growing 7 percent, contributing to a 1 percent boost in passenger load factor to 82 percent.

The two largest Canadian airlines are also growing faster than US network carriers. Combined available seat-miles and traffic increased at the same 5 percent rate, while passenger load factor remained flat at 81 percent.

Fleet replacement accelerates

High fuel prices are intensifying the need for new fuel-efficient airplanes, prompting several airlines in the United States to accelerate their fleet renewal programs. At least 900 new fuel-efficient single-aisle airplanes were ordered in 2011, with deliveries beginning in the middle of this decade. American, Delta, and Southwest have announced plans to replace some of their older, less efficient airplanes with Next-Generation 737s or the new 737 MAX.

Boeing 787-8 increasing market fragmentation

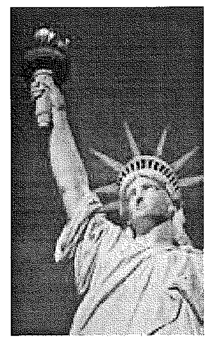
Several new routes have been announced since the Boeing 787-8 took to the sky. Boston and San Diego are the first cities to celebrate new routes (initially to Tokyo) enabled by the new airplane's state-of-the-art economics and capabilities. Additional routes to and from North America will be announced as 787 deliveries continue.

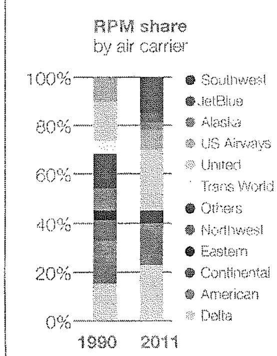
Fleet outlook

The long-term outlook for the North American airline industry is for modest growth through the forecast period. Network carriers will maintain strict capacity discipline. Low-cost carriers will continue to outpace network carrier growth to accommodate increased demand and fill niches abandoned by network carriers. Financial stability also will be a key indicator of future growth. Several airlines have indicated growth planning to be executed when returns are sufficient to fund their strategic goals.

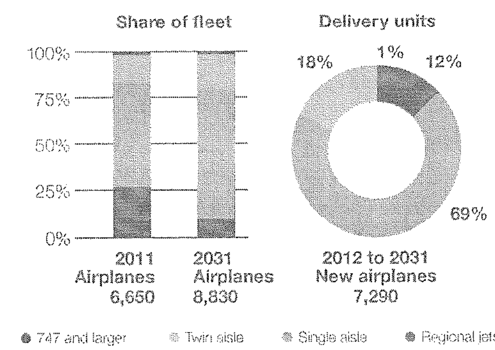
In consideration of these trends, we forecast the region's demand to be 7,300 new airplanes to accommodate an average 2 percent annual traffic growth. Single-aisle airplanes account for the bulk of demand, which is forecast to exceed 5,000 new airplanes.

North America
Changing market share 1990–2011





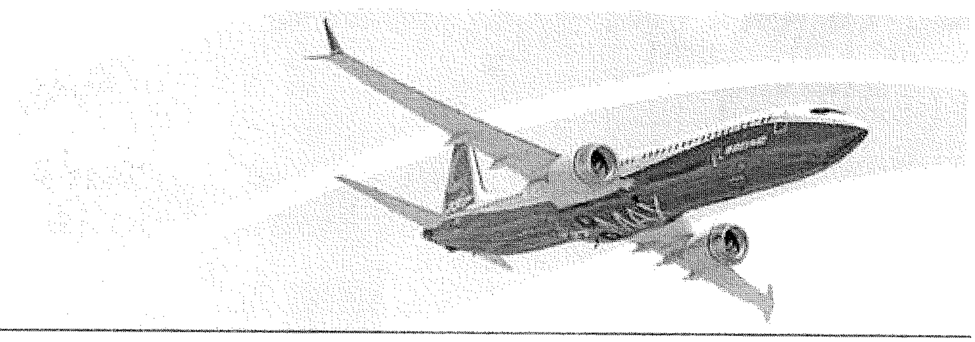
North America
Market value: $820 billion



North America
Key indicators and new airplane markets

Growth measures			New airplanes	Share by size
Economy (GDP)	2.6%	Large	40	1%
Traffic (RPK)	2.8%	Twin aisle	1,320	18%
Cargo (RTK)	4.5%	Single aisle	5,040	69%
Airplane fleet	1.4%	Regional jets	890	12%
		Total	7,290	

Market size			2011 Fleet	2031 Fleet
		Large	120	110
Deliveries	7,290	Twin aisle	1,030	1,740
Market value	$820B	Single aisle	3,730	6,090
Average value	$110M	Regional jets	1,770	890
		Total	6,650	8,830



World Regions
Europe

Strength despite uncertainty

The European aviation market remained strong in 2011, despite uncertainties from the sovereign debt crisis and the lingering threat of recession. Europe's GDP increased by 1.8 percent in 2011 compared to 2010. The Association of European Airlines reports that member airlines carried 9.3 percent more passengers in 2011. Members of the European Low Fares Airline Association (ELFAA) reported a 6.1 percent increase in passengers. European airlines acquired more than 330 new airplanes that year, of which more than 80 percent were single aisle.

Aviation growth is expected to persist over the next 20 years, with European airlines forecast to acquire 7,760 new airplanes valued at $970 billion. Single-aisle airplanes will account for the majority of deliveries, representing a 75 percent share.

Although aviation growth in Europe is not as rapid as in the world's emerging economies, the region's large installed base of airplanes (more than 4,400 units) sustains a substantial demand for replacement airplanes. This demand will account for 50 percent of Europe's new-airplane market.

Europe is economically diverse, with both mature economies and newer high-growth economies. Though uncertainties remain for some European economies, the region's GDP is expected to grow 1.9 percent annually during the forecast period, spurred by growth exceeding 3.6 percent in the rapidly developing economies. European Union transport liberalization efforts contribute to this growth, with negotiations taking place with Turkey, Brazil, India, Korea, and other countries.

Leading strategic change

Airline operations continue to evolve with the launch of new ventures and new business models. The next 20 years are expected to bring additional mergers and acquisitions, along with increased collaboration with alliance partners around the world.

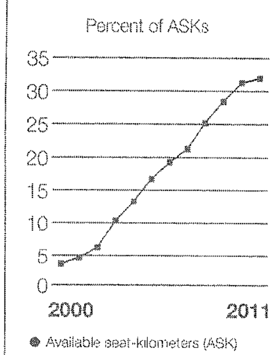
Large network airlines are tending to shift focus away from short-haul routes that are targeted by low-cost carriers (LCC) and toward longer haul routes. LCCs have continued to add service in short-haul markets, with ELFAA members providing 32 percent of capacity on intra-Europe flights in 2011. Smaller flag carriers and charter airlines will be challenged to adapt to a competitive environment where LCCs dominate short-haul, point-to-point service, and large network carriers and their alliance partners exploit the cost advantages of mega-hubs for long-haul traffic.

Environment

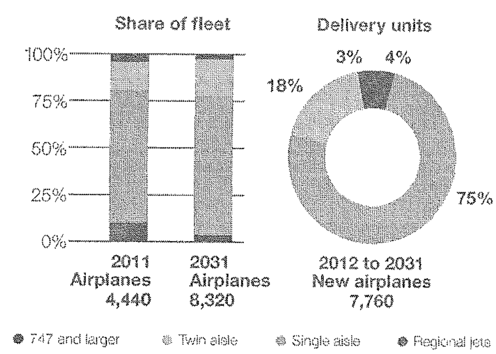
European airlines continue to reduce their environmental impact by replacing older, less efficient airplanes with newer technology planes, like the 787. By 2031, more than 93 percent of planes operated by European airlines will have been delivered since 2011.

Europe
LCC share of Intra-Europe short-haul service

Source: OAG



Europe
Market value: $970 billion



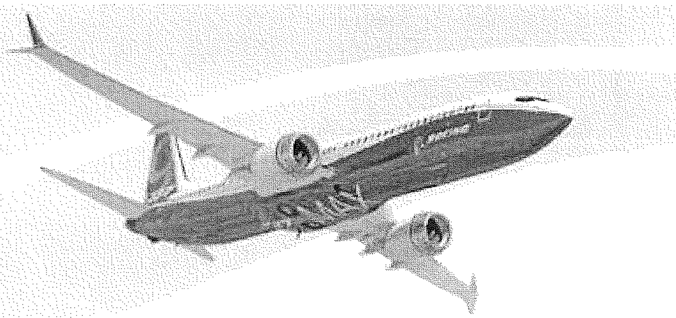
Europe
Key indicators and new airplane markets

Growth measures	
Economy (GDP)	1.9%
Traffic (RPK)	4.1%
Cargo (RTK)	4.6%
Airplane fleet	3.2%

Market size	
Deliveries	7,760
Market value	$970B
Average value	$130M

	New airplanes	Share by size
Large	200	3%
Twin aisle	1,440	18%
Single aisle	5,800	75%
Regional jets	320	4%
Total	**7,760**	

	2011 Fleet	2031 Fleet
Large	190	230
Twin aisle	680	1,630
Single aisle	3,160	6,120
Regional jets	410	340
Total	**4,440**	**8,320**



World Regions
Middle East

Long-haul, short-haul, and domestic markets grow

Middle East airline traffic is projected to grow 6.4 percent, compounded annually, during the next 20 years. Revenue passenger-kilometers will more than triple by 2031, supported by healthy development of long-haul, short-haul, and domestic travel.

The "Gulf 3"—Emirates, Qatar Airways, and Etihad Airways—provide the largest part of the region's long-haul service, operating under "sixth freedom" agreements to connect two foreign countries via a stop in the carrier's home country. Favorably placed to connect Asia, Africa, and Europe, the Middle East is relatively new to the sixth freedom business model, which has been proven by both European and Asian carriers.

The Middle East also generates its own long-haul origin and destination traffic, with business and leisure hubs in Dubai, historical and resort sites in Egypt, beaches and natural wonders in Oman, and growing Hajj pilgrim traffic to Saudi Arabia. Guest workers from South Asia and other regions also boost traffic to the region.

Low-cost carriers, with simplified networks and operations—often flying a single, narrowbody airplane type—are taking an increasing share of the region's short-haul traffic. The single-aisle fleets of airlines like Air Arabia and flydubai can reach many destinations in South Asia, Europe, the CIS, and Africa.

Fleet renewal a priority

Middle East carriers often prefer to renew their fleets on a 15-year cycle, a shorter cycle than the global average. Thus, of the 2,370 forecast airplane deliveries to the region, about 30 percent will replace older airplanes, leaving 70 percent for the region's fleet growth.

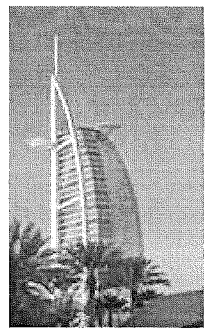
Policy and infrastructure crucial to growth

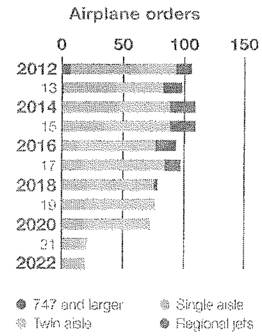
Infrastructure development is a long-term concern for the region's carriers. Although the region's airspace is not yet crowded, large areas of airspace remain under military control, limiting the airspace available for commercial traffic. At smaller airports, the capacity of immigration areas and check-in desks is not well aligned with services that airlines aim to provide.

Middle East governments are moving toward coordinated aviation policy and market liberalization. The UAE, for example, makes funding and political support available for infrastructure and airport development; aviation is not heavily taxed, and visas are easy to obtain. Saudi Arabia is moving toward market liberalization, with plans to privatize Saudi Arabian Airlines. In 2011, the Kingdom's General Authority of Civil Aviation (GACA) began soliciting bids from foreign carriers to operate domestic services. Additional opportunities include relaxing the price controls on domestic airfares.

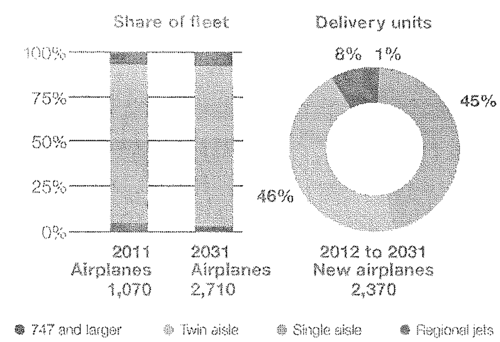
Middle East
Large backlog, spread over the decade

Source: Ascend





Middle East
Market value: $470 billion



Middle East
Key indicators and new airplane markets

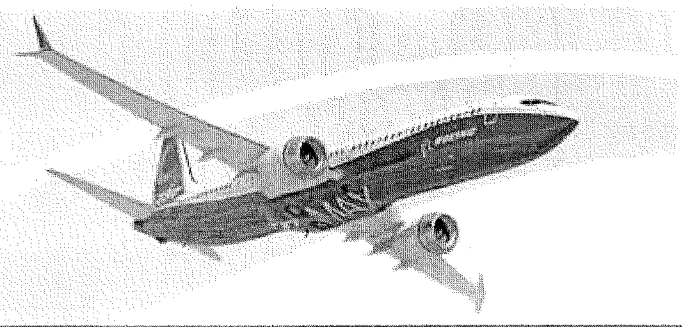
Growth measures	
Economy (GDP)	3.9%
Traffic (RPK)	6.4%
Cargo (RTK)	5.7%
Airplane fleet	4.8%

	New airplanes	Share by size
Large	190	8%
Twin aisle	1,100	46%
Single aisle	1,060	45%
Regional jets	20	1%
Total	**2,370**	

Market size	
Deliveries	2,370
Market value	$470B
Average value	$200M

	2011 Fleet	2031 Fleet
Large	70	170
Twin aisle	470	1,170
Single aisle	470	1,320
Regional jets	60	50
Total	**1,070**	**2,710**

World Regions
Latin America



Stability fosters economic growth

The Latin America region's increasing political stability creates a favorable context for economic growth. Regional economies have weathered the 2008-09 financial crises well. Their recovery has been faster than in other regions of the world, including Organisation for Economic Co-operation and Development (OECD) economies. Within the region, South America has outperformed Central America, Mexico, and the Caribbean. The global economy continues to be the main source of uncertainty for Latin America and the Caribbean. Although inflation remains a concern, the region is forecast to enjoy a growth rate of 3.6 percent, well above the world average of 2.6 percent.

International and domestic aviation on the upswing

The natural barriers of the Andes Mountains and the Amazon rainforests present formidable obstacles to rail and road development. The region therefore relies heavily on aviation for domestic transport. Airspace, airport, and ground infrastructure are all struggling to keep pace with growing aviation demand. The anticipated increase in international traffic from the 2014 World Cup and the 2016 Olympics in Brazil highlight the need for investment. The greatest opportunity for growth is within the region. For example, air travel is beginning to overtake bus travel in Mexico and Brazil. In 2011, the number of domestic air travelers in Brazil rose above the number of bus passengers for the first time, as 8.7 million passengers took their first commercial airplane flight. Regional growth has spurred the rise of low-cost carriers (LCC) such as Viva, Interjet, Azul, and Volaris. As LCCs drive growth and stimulate demand, they are entering partnerships to extend their reach globally.

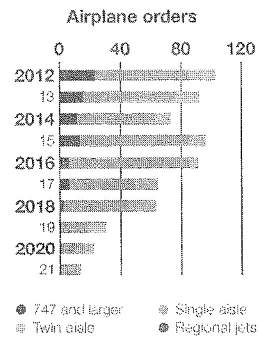
The dynamic nature of Latin American aviation has produced a healthier, more competitive marketplace and encouraged new airline business models. The region's largest airlines have led the way with mergers, including Avianca/TACA, TRIP/Azul, and LAN/TAM, that streamline networks and introduce new efficiencies. Well run and profitable, with access to capital, the top carriers in the region can compete with any airline in the world.

Regional fleet expanding strongly

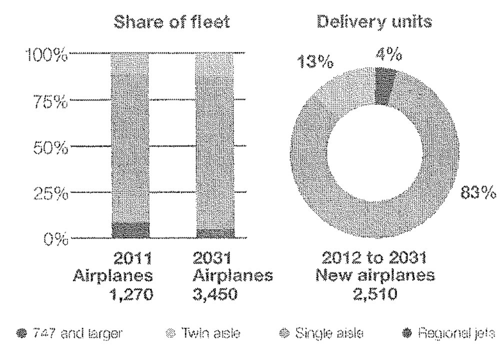
The installed fleet is expected to grow 5.1 percent annually to comprise 3,450 airplanes, including 2,510 new deliveries valued at $260 billion. Most of these will be single-aisle airplanes, spurred by intense regional traffic growth. The twin-aisle fleet will expand to 340 airplanes as regional carriers compete more strongly on routes traditionally dominated by foreign operators.

Latin America
Incredible growth in airplane orders

Source: Ascend



Latin America
Market value: $260 billion



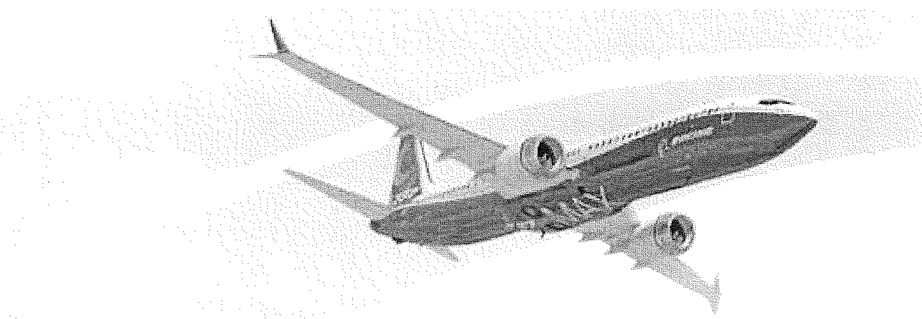
Latin America
Key indicators and new airplane markets

Growth measures	
Economy (GDP)	**4.1%**
Traffic (RPK)	**6.6%**
Cargo (RTK)	**5.9%**
Airplane fleet	**5.1%**

	New airplanes	**Share by size**
Large	–	–
Twin aisle	340	**13%**
Single aisle	2,080	**83%**
Regional jets	90	**4%**
Total	**2,510**	

Market size	
Deliveries	**2,510**
Market value	**$260B**
Average value	**$100M**

	2011 Fleet	**2031 Fleet**
Large	–	–
Twin aisle	140	440
Single aisle	1,020	2,850
Regional jets	110	160
Total	**1,270**	**3,450**



World Regions
CIS

Younger, more efficient fleet

The outlook for aviation demand in the Commonwealth of Independent States (CIS) continues to grow. The region is forecast to take delivery of a total of 1,140 new airplanes over the next 20 years, valued at $130 billion. CIS airplane orders were strong in 2011, both for models from western manufacturers and for new Russian models, such as the Sukhoi Superjet 100 that entered service in 2011 and the developmental Irkut MS-21. The current CIS order backlog accounts for 41 percent of forecast deliveries.

Economy recovering

The economies of the CIS region grew moderately in 2011. GDP expanded at a rate of 4.3 percent in 2011, in line with GDP growth of 4.5 percent in 2010. Overall, regional growth is expected to continue, with GDP growing 3.4 percent annually over the next 20 years. Russia's economy continues to be the region's largest, accounting for more than 70 percent of the region's GDP in 2011. The economies of Ukraine and Kazakhstan follow Russia in size.

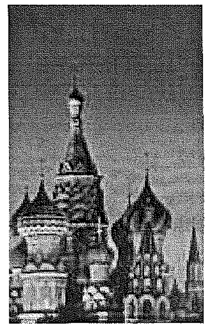
The Russian Transport Ministry's Federal Air Transport Agency reported that Russian airports serviced 112.4 million passengers in 2011, an increase of 12.9 percent compared to 2010. Over the next 20 years, Boeing forecasts that air traffic to and from the CIS region will grow at a rate of 4.7 percent annually.

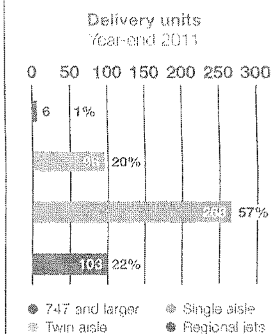
Strong demand for twin-aisle airplanes

Long-haul international traffic is expected to grow at an annual rate of 4.8 percent through 2031. The Russian Transport Ministry's Federal Air Transport Agency reported nearly 47 million passengers on international routes in 2011, a 14.9 percent increase compared to 2010. Driven by increasing international traffic, twin-aisle service will remain an important component of the region's market, creating demand for 250 new fuel-efficient twin-aisle airplanes and 30 large twin-aisle aircraft. The region's geographical size and diverse terrain make airline travel an attractive transportation option. Air travel will increase over the coming 20 years as personal incomes rise and liberalization of air transport regulations makes aviation services more available and affordable.

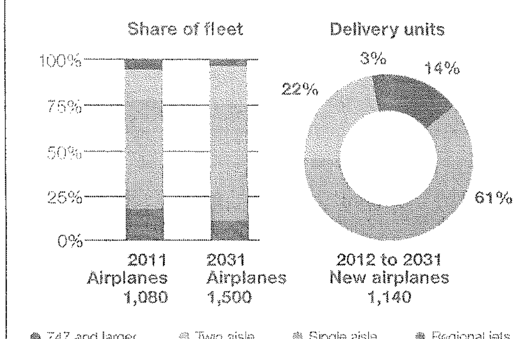
CIS
Strong backlog of 473 airplanes

Source: Ascend





CIS
Market value: $130 billion



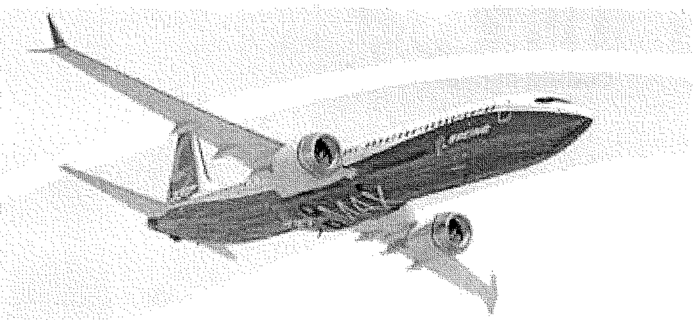
CIS
Key indicators and new airplane markets

Growth measures	
Economy (GDP)	3.4%
Traffic (RPK)	4.7%
Cargo (RTK)	5.0%
Airplane fleet	1.7%

	New airplanes	Share by size
Large	30	3%
Twin aisle	250	22%
Single aisle	700	61%
Regional jets	160	14%
Total	**1,140**	

Market size	
Deliveries	1,140
Market value	$130B
Average value	$110M

	2011 Fleet	2031 Fleet
Large	60	50
Twin aisle	170	310
Single aisle	650	970
Regional jets	200	170
Total	**1,080**	**1,500**



World Regions
Africa

Economic development supports air travel growth

Political unrest in the north slowed African economic growth to 1 percent in 2011--well below the long-term average. Yet, as the second largest and most populous continent after Asia, Africa's long-term economic potential is strong. Over the next two decades, Africa's economy is forecast to grow faster than the world average, driven largely by demand for natural resources, including oil and metals, from both emerging and mature economies. These connections will foster demand for long-haul travel.

A growing middle class and increased urbanization also contribute to the continent's commercial aviation potential. The African Development Bank projects that Africa's middle class will grow by more than 700 million people over the next several decades. United Nations data shows that urban dwellers were about 15 percent of Africa's population in 1950 and are expected to be 50 percent by 2030--a trajectory similar to that of Asia.

Air transport expanding and increasingly competitive

North Africa's political upheaval has dampened air travel demand, particularly to and from Europe, where capacity remains below 2010 levels. Capacity to other emerging markets and North America, however, has risen 5 percent since 2010, indicating potential directions for growth. Rapid growth of traffic within Africa and with other emerging markets is overtaking Europe traffic, which constituted a 60 percent share of Africa's total traffic 20 years ago, but will fall to around 40 percent by the end of the forecast period.

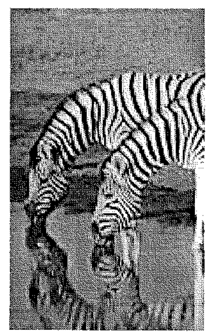
Economic links with other emerging markets also bring increased competition. Africa presents growth opportunities to airlines from other regions where demand growth is slower. Airlines in other emerging markets may take advantage of their network connections to serve African destinations. Within Africa, national airlines are expanding service to other African countries. Yet ample service opportunities remain, as relatively few airlines compete for intra-regional markets.

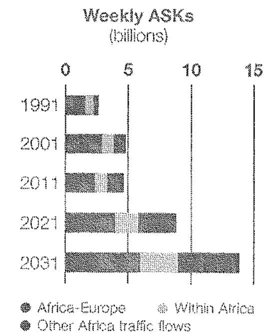
Aviation and economic development projections depend on government policy support for transport infrastructure. The flexibility of aviation networks and the relatively low cost per network kilometer make aviation infrastructure investment very attractive compared to investment in other modes.

Fleet development

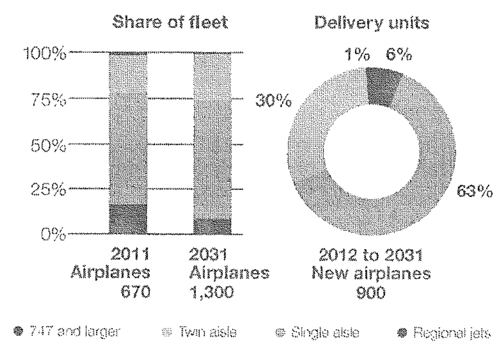
Africa is forecast to require 900 new airplanes over the next 20 years, doubling its fleet. Approximately 70 percent of forecast deliveries will support growth. Single-aisle airplanes will account for the largest share of deliveries, while twin-aisle airplanes will account for half of the value of deliveries to Africa.

Africa
Capacity to become more diverse
Source: OAG





Africa
Market value: $120 billion



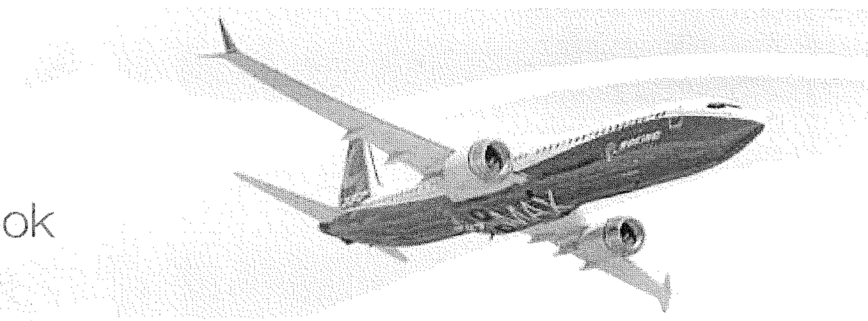
Africa
Key indicators and new airplane markets

Growth measures	
Economy (GDP)	4.4%
Traffic (RPK)	5.6%
Cargo (RTK)	5.8%
Airplane fleet	3.4%

Market size	
Deliveries	900
Market value	$120B
Average value	$130M

	New airplanes	Share by size
Large	10	1%
Twin aisle	270	30%
Single aisle	570	63%
Regional jets	50	6%
Total	**900**	

	2011 Fleet	2031 Fleet
Large	10	10
Twin aisle	140	330
Single aisle	410	850
Regional jets	110	110
Total	**670**	**1,300**



Pilot & Technician Outlook

Burgeoning demand for highly trained personnel

As global economies expand and airlines take delivery of tens of thousands of new commercial jetliners over the next 20 years, the demand for personnel to fly and maintain those airplanes will be unprecedented.

The 2012 Boeing Pilot & Technician Outlook projects a need for approximately one million new commercial airline pilots and maintenance technicians by 2031, including 460,000 new commercial airline pilots and 601,000 maintenance technicians.

Meeting this demand will require airplane manufacturers and the commercial aviation industry to rely more heavily on new digital technology, including online and mobile computing, to meet the learning requirements of a new generation. The growing diversity of aviation personnel also demands highly qualified, motivated, and knowledgeable instructors with cross-cultural and cross-generational skills. Training programs will need to focus on enabling airplane operators to gain optimum advantage of the innovative features of the latest generation of airplanes, such as the 787 Dreamliner.

Pilot outlook

A pilot shortage has already arisen in many regions of the world. Airlines across the globe are expanding their fleets and flight schedules to meet surging demand in emerging markets. Asia in particular is experiencing delays and operational interruptions due to pilot scheduling constraints.

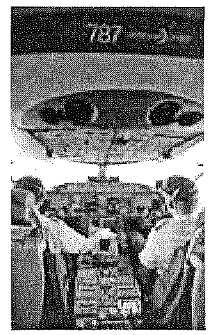
The Asia Pacific region continues to present the largest projected growth in pilot demand, with a requirement for 185,600 new pilots. China has the largest demand within the region, with a need for 71,300 pilots. Europe will require 100,900 pilots, North America 69,000, Latin America 42,000, the Middle East 36,100, Africa 14,500, and the CIS 11,900.

Technician outlook

As new-generation airplanes come to dominate the fleet over the next 20 years, airplane reliability will improve and maintenance check intervals will lengthen. Although this trend will moderate demand growth, the requirement for maintenance personnel will continue to expand with the size of the global fleet. Emerging markets that currently recruit maintenance technicians from outside the region will have to develop a foundation for training qualified technical personnel from within the local workforce.

The need for maintenance personnel is expected to grow most rapidly in the Asia Pacific region, which will require 243,500 new technical personnel. China's requirement will be the largest, with an expected need for 99,400 technicians. Airlines in Europe will require 129,700, North America 92,500, the Middle East 53,700, Latin America 47,300, the CIS 18,100, and Africa 16,200.

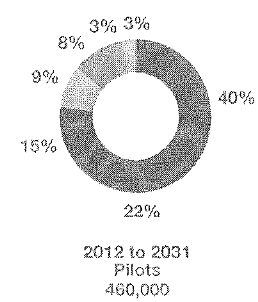
Pilot & Technician Outlook
20-year demand for aviation personnel



NEW!
Innovative training for tomorrow's workforce

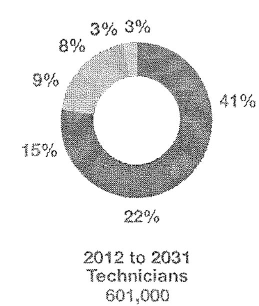
Pilot & Technician Outlook
New pilots by region 2012–2031

Region	Pilots
Asia Pacific	185,600
Europe	100,900
North America	69,000
Latin America	42,000
Middle East	36,100
CIS	11,900
Africa	14,500
Total	460,000

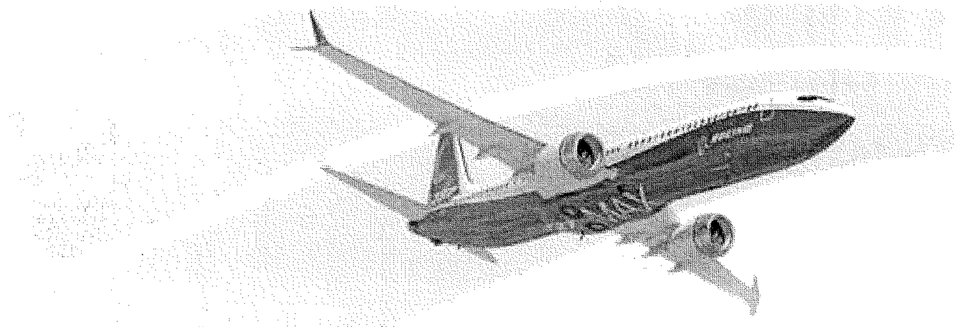


Pilot & Technician Outlook
New technicians by region 2012–2031

Region	Technicians
Asia Pacific	243,500
Europe	129,700
North America	92,500
Middle East	53,700
Latin America	47,300
CIS	18,100
Africa	16,200
Total	601,000



Passenger Traffic

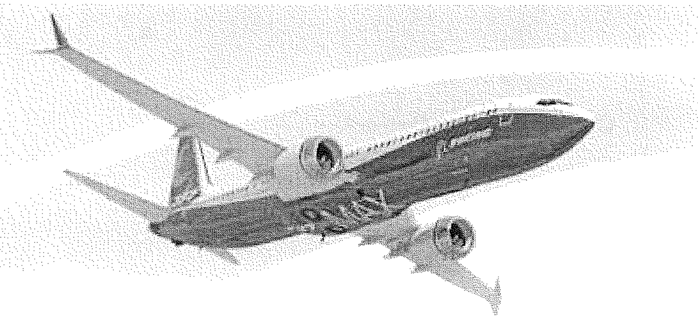


Airline passenger traffic
Growth by regional flow

Regions RPKs in billions	2003	2004	2005	2006	2007	2008	2009	2010	2011	2031	Average growth 2011 to 2031
Africa – Africa	26.67	29.48	35.97	35.56	37.31	41.58	43.88	48.66	51.06	169.58	6.2%
Africa – Europe	**96.43**	**101.73**	**106.37**	**121.95**	**125.32**	**125.60**	**128.17**	**135.45**	**134.13**	**345.53**	**4.8%**
Africa – Middle East	13.03	12.37	16.79	20.87	23.09	24.90	32.86	36.41	39.45	149.69	6.9%
Africa – N. America	**4.38**	**3.76**	**3.33**	**4.33**	**4.89**	**6.28**	**8.77**	**11.31**	**11.40**	**36.78**	**6.0%**
Africa – S.E. Asia	2.91	3.31	4.07	4.12	4.50	5.24	4.19	5.60	5.85	21.85	6.8%
C. America – C. America	**25.66**	**26.87**	**26.65**	**28.18**	**29.68**	**32.29**	**29.80**	**31.29**	**32.23**	**82.93**	**4.8%**
C. America – Europe	57.44	63.71	67.05	74.15	80.71	83.29	77.08	73.82	73.67	188.12	4.8%
C. America – N. America	**79.93**	**92.89**	**100.59**	**104.99**	**106.83**	**115.77**	**104.67**	**112.65**	**114.51**	**271.97**	**4.4%**
C. America – S. America	7.10	9.38	10.22	10.33	11.01	13.08	13.97	18.31	19.19	59.98	5.9%
China – China	**105.11**	**142.45**	**164.21**	**189.79**	**223.12**	**236.53**	**287.36**	**335.44**	**380.11**	**1,448.40**	**6.9%**
China – Europe	36.18	55.22	63.10	75.27	91.03	82.52	77.33	82.12	94.19	325.88	6.4%
China – N. America	**24.66**	**38.51**	**48.14**	**51.44**	**54.52**	**62.70**	**60.88**	**71.37**	**85.43**	**293.51**	**6.4%**
China – N.E. Asia	22.46	29.01	31.79	34.05	34.65	40.49	34.75	39.91	39.14	116.43	5.6%
China – Oceania	**10.28**	**15.36**	**17.55**	**19.26**	**19.40**	**21.37**	**22.79**	**27.43**	**31.35**	**100.10**	**6.0%**
China – S.E. Asia	36.18	49.24	55.87	52.94	57.47	58.74	53.95	66.81	76.00	332.80	7.7%
CIS – CIS	**50.23**	**54.75**	**55.95**	**57.35**	**57.72**	**61.23**	**48.98**	**53.90**	**62.52**	**160.67**	**4.8%**
CIS – International	43.62	53.86	58.07	63.66	81.24	76.17	83.72	101.56	123.75	316.83	4.8%
Europe – Europe	**474.70**	**521.22**	**561.88**	**593.32**	**634.21**	**660.55**	**624.92**	**640.17**	**659.48**	**1,305.30**	**3.5%**
Europe – Middle East	72.39	79.85	87.28	99.18	106.59	115.15	131.16	143.81	153.27	417.24	5.1%
Europe – N. America	**349.47**	**375.68**	**390.71**	**403.37**	**420.61**	**432.38**	**405.40**	**418.58**	**430.20**	**901.20**	**3.8%**
Europe – N.E. Asia	53.86	58.49	58.18	58.78	64.73	66.16	56.91	61.54	61.77	123.79	3.5%
Europe – S. America	**48.09**	**54.97**	**63.89**	**67.36**	**70.75**	**75.17**	**79.34**	**82.95**	**89.82**	**216.29**	**4.5%**
Europe – S.E. Asia	92.44	100.69	100.35	97.58	92.42	99.98	98.46	99.94	104.15	277.65	5.0%
Europe – S. Asia	**33.21**	**37.67**	**43.42**	**53.26**	**58.51**	**55.48**	**51.29**	**53.80**	**54.05**	**227.29**	**7.4%**
Middle East – Middle East	34.95	40.83	48.72	53.68	60.27	63.37	68.59	77.91	82.38	222.07	5.1%
Middle East – N. America	**12.95**	**17.23**	**16.08**	**20.65**	**23.44**	**29.54**	**41.56**	**45.70**	**50.32**	**174.30**	**6.4%**
Middle East – S.E. Asia	22.58	26.38	29.46	33.79	38.74	43.14	46.66	56.12	60.40	210.46	6.4%
Middle East – S. Asia	**32.80**	**34.34**	**36.06**	**41.97**	**46.49**	**49.46**	**64.81**	**75.11**	**83.05**	**336.95**	**7.3%**
N. America – N. America	828.27	927.73	972.26	977.36	1,022.41	974.07	898.06	926.50	952.94	1,459.61	2.2%
N. America – N.E. Asia	**104.99**	**113.90**	**122.99**	**116.55**	**126.47**	**118.81**	**100.85**	**107.69**	**115.27**	**178.80**	**2.2%**
N. America – Oceania	25.40	27.93	29.06	30.58	32.11	32.26	34.81	34.85	38.30	88.15	4.3%
N. America – S. America	**38.88**	**42.13**	**46.23**	**50.68**	**52.06**	**52.68**	**56.87**	**60.96**	**66.67**	**214.61**	**6.0%**
N. America – S.E. Asia	24.66	29.68	35.27	34.13	38.31	38.59	30.08	30.83	31.67	97.45	5.8%
N.E. Asia – N.E. Asia	**78.83**	**72.66**	**70.10**	**72.80**	**74.92**	**77.24**	**71.79**	**73.46**	**71.51**	**129.06**	**3.0%**
N.E. Asia – Oceania	17.85	20.26	19.00	19.59	20.81	19.54	12.89	16.50	15.26	28.99	3.3%
N.E. Asia – S.E. Asia	**55.99**	**66.20**	**70.95**	**77.03**	**85.71**	**84.05**	**70.21**	**75.29**	**86.75**	**246.70**	**5.4%**
Oceania – Oceania	52.09	65.23	65.25	70.84	74.35	72.01	73.29	78.37	83.82	199.82	4.4%
Oceania – S.E. Asia	**43.90**	**50.98**	**56.66**	**53.76**	**58.07**	**54.88**	**56.45**	**62.44**	**68.07**	**183.63**	**5.1%**
S. America – S. America	51.92	58.79	64.07	74.25	83.08	81.60	86.93	115.85	134.39	509.35	6.9%
S.E. Asia – S.E. Asia	**66.34**	**86.71**	**95.61**	**96.04**	**109.18**	**113.61**	**109.67**	**128.98**	**145.03**	**629.17**	**7.6%**
S.E. Asia – S. Asia	12.12	15.38	20.69	19.73	22.59	21.49	22.27	29.05	29.90	154.91	8.6%
S. Asia – S. Asia	**17.79**	**21.13**	**25.16**	**31.31**	**36.29**	**40.08**	**43.81**	**49.50**	**58.57**	**362.18**	**9.5%**
Rest of world	15.24	26.38	31.23	37.77	43.22	52.40	69.01	87.39	97.19	448.13	7.9%
World total	3,304.18	3,754.33	4,026.27	4,233.62	4,538.85	4,611.48	4,519.25	4,885.30	5,198.21	13,764.16	5.0%

RPK: Revenue passenger-kilometers. The number of fare-paying passengers multiplied by the number of kilometers they fly (i.e., airline traffic).

Airplanes Required



Passenger and freighter airplanes
Market value and demand by region

Demand and value by region

Region	$B	Airplanes
Asia Pacific	1,700	12,030
Europe	970	7,760
North America	820	7,290
Latin America	260	2,510
Middle East	470	2,370
CIS	130	1,140
Africa	120	900
World	**4,470**	**34,000**

Deliveries by airplane size and region

Region	Regional jets	Single aisle	Twin aisle	Large	Total deliveries
Asia Pacific	490	7,990	3,230	320	12,030
Europe	320	5,800	1,440	200	7,760
North America	890	5,040	1,320	40	7,290
Latin America	90	2,080	340	0	2,510
Middle East	20	1,060	1,100	190	2,370
CIS	160	700	250	30	1,140
Africa	50	570	270	10	900
World	**2,020**	**23,240**	**7,950**	**790**	**34,000**

Market value by airplane size and region*

Region	Regional jets	Single aisle	Twin aisle	Large	Total deliveries
Asia Pacific	10	720	860	110	1,700
Europe	10	520	370	70	970
North America	30	440	340	10	820
Latin America	10	170	80	–	260
Middle East	10	80	310	70	470
CIS	10	50	50	20	130
Africa	2	50	70	2	120
World	**$80**	**$2,030**	**$2,080**	**$280**	**$4,470**

*2011 $B, catalog prices. Values above 10 have been rounded to the nearest 10.

Passenger and freighter airplanes
In service and future fleet

Total airplanes in service

Size	2011	2031
747 and larger	790	1,030
Twin aisle	3,710	9,110
Single aisle	12,610	27,430
Regional jets	2,780	2,210
Total	**19,890**	**39,780**

Passenger airplanes in service

Size	2011	2031
747 and larger	470	590
Twin aisle	2,910	7,560
Single aisle	12,030	26,220
Regional jets	2,740	2,210
Total	**18,150**	**36,580**

Freighter airplanes in service

Size	2011	2031
Large*	540	1,140
Medium widebody	580	850
Standard	620	1,210
Total	**1,740**	**3,200**

Airplane demand

Size	$B	Airplanes
747 and larger	280	790
Twin aisle	2,080	7,950
Single aisle	2,030	23,240
Regional jets	80	2,020
Total	**4,470**	**34,000**

Passenger airplane demand

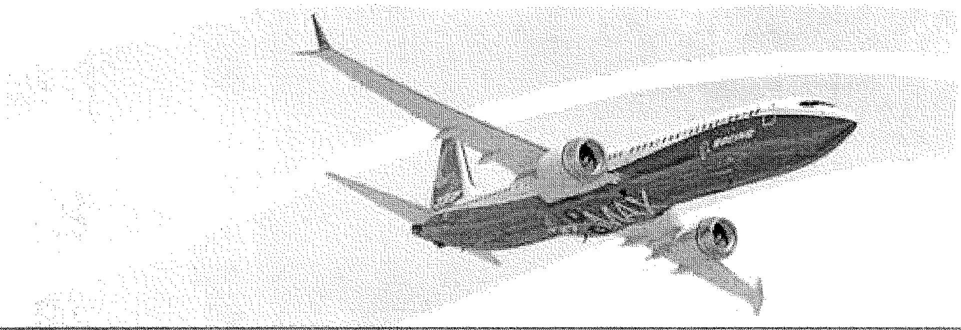
Size	$B	Airplanes
747 and larger	220	590
Twin aisle	1,890	7,210
Single aisle	2,030	23,240
Regional jets	80	2,020
Total	**4,220**	**33,060**

Freighter airplane demand

Size	$B	Airplanes
Large*	200	680
Medium widebody	50	260
Standard body	–	–
Total	**250**	**940**

*Large passenger and large freighter categories differ.

Fleet Development



Passenger and freighter airplanes
Market value and fleet development

Market by airplane size

Size	Market value 2011 $B	Market share value	New airplane deliveries	Market share units
Large*	280	6%	790	2%
Medium	1,440	32%	4,970	15%
Small	640	15%	2,980	9%
Total twin aisle	**2,360**	**53%**	**8,740**	**26%**
More than 175 seats	480	11%	4,660	14%
90 to 175 seats	1,550	34%	18,580	54%
Total single aisle	**2,030**	**45%**	**23,240**	**68%**
Total regional jets	**80**	**2%**	**2,020**	**6%**
Total fleet	**4,470**	**100%**	**34,000**	**100%**

Passenger fleet development

Size	End of year 2011	Removed from service	Converted to freighter	New deliveries 2012 to 2031	End of year 2031
Large*	470	470	–	590	590
Medium	1,630	1,450	–	4,490	4,670
Small	1,280	1,110	–	2,720	2,890
Total twin aisle	**3,380**	**3,030**	**700**	**7,800**	**8,150**
More than 175 seats	1,540	1,140	–	4,660	5,060
90 to 175 seats	10,490	7,910	–	18,580	21,160
Total single aisle	**12,030**	**9,050**	**1,120**	**23,240**	**26,220**
Total regional jets	**2,740**	**2,550**	**0**	**2,020**	**2,210**
Total passenger fleet	**18,150**	**14,630**	**1,820**	**33,060**	**36,580**

Freighter fleet development

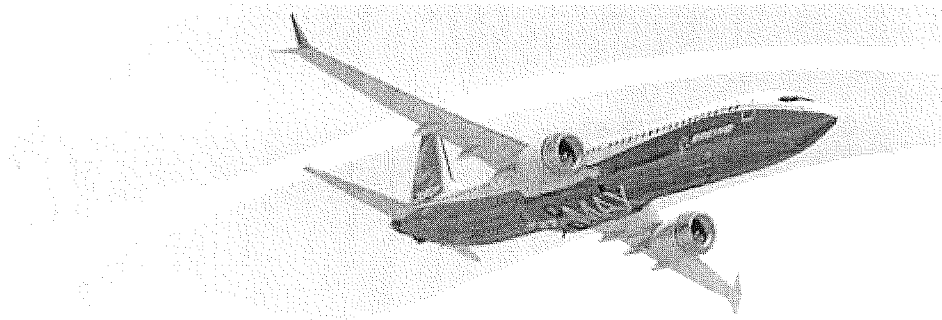
Size	End of year 2011	Removed from service	Converted to freighter	New deliveries 2012 to 2031	End of year 2031
Large*	540	330	250	690	1,140
Medium widebody	580	440	450	260	850
Standard body	620	530	1,120	0	1,210
Total freighter fleet	**1,740**	**1,300**	**1,820**	**940**	**3,200**

Total fleet

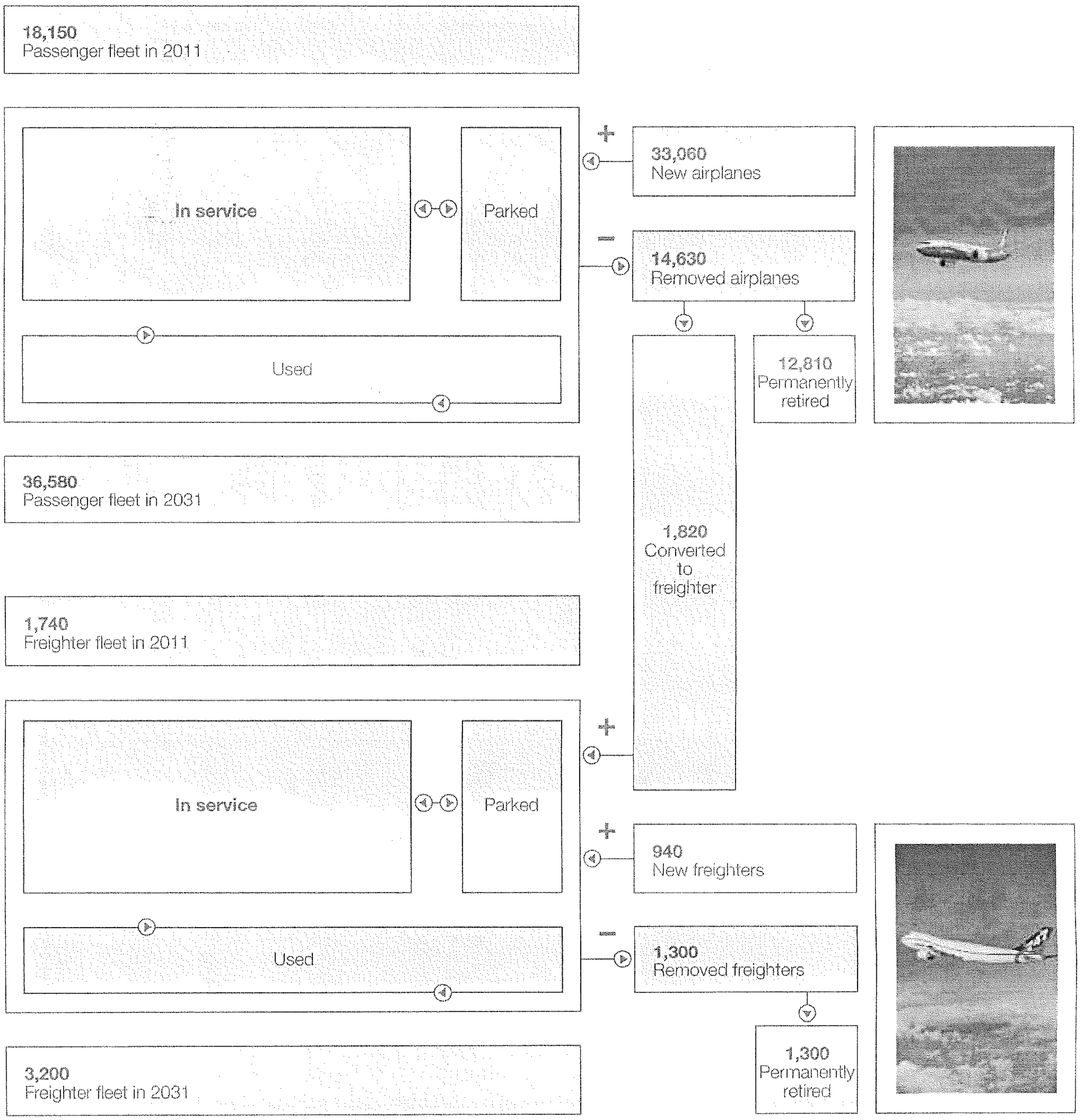
Size	End of year 2011	Removed from service	Converted to freighter	New deliveries 2012 to 2031	End of year 2031
Passenger fleet	18,150	14,630	1,820	33,060	36,580
Freighter fleet	1,740	1,300	1,820	940	3,200
Total fleet	**19,890**	**15,930**	**1,820**	**34,000**	**39,780**

*Large passenger and large freighter categories differ.

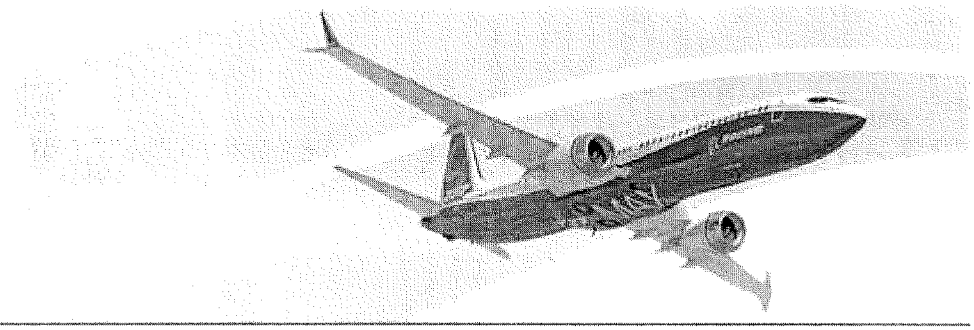
Flow of Airplanes



Airplane fleet
How the fleet develops as airplanes are added and removed



Fleet by Region



Fleet growth
By size and region

Fleet by airplane size

Size	Airplanes in service 2011	Fleet share 2011	Airplanes in service 2031	Fleet share 2031
Large*	790	4%	1,030	3%
Medium	1,850	9%	5,370	13%
Small	1,860	10%	3,740	9%
Total twin aisle	**4,500**	**23%**	**10,140**	**25%**
More than 175 seats	1,770	9%	5,550	14%
90 to 175 seats	10,840	54%	21,880	55%
Total single aisle	**12,610**	**63%**	**27,430**	**69%**
Total regional jets	**2,780**	**14%**	**2,210**	**6%**
Total fleet	**19,890**	**100%**	**39,780**	**100%**

Fleet by region in 2011

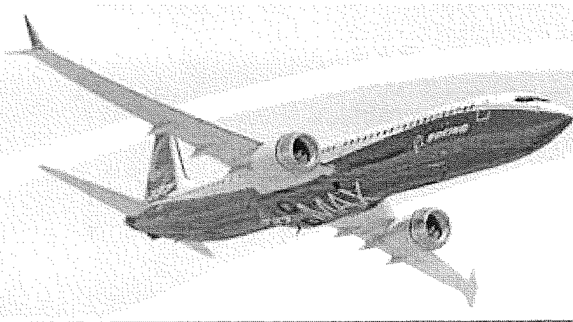
Region	Regional jets	Single aisle	Twin aisle	Large	Total fleet
Asia Pacific	120	3,170	1,080	340	4,710
North America	1,770	3,730	1,030	120	6,650
Europe	410	3,160	680	190	4,440
Latin America	110	1,020	140	0	1,270
Middle East	60	470	470	70	1,070
CIS	200	650	170	60	1,080
Africa	110	410	140	10	670
World	**2,780**	**12,610**	**3,710**	**790**	**19,890**

Fleet by region in 2031

Region	Regional jets	Single aisle	Twin aisle	Large	Total fleet
Asia Pacific	490	9,230	3,490	460	13,670
North America	890	6,090	1,740	110	8,830
Europe	340	6,120	1,630	230	8,320
Latin America	160	2,850	440	0	3,450
Middle East	50	1,320	1,170	170	2,710
CIS	170	970	310	50	1,500
Africa	110	850	330	10	1,310
World	**2,210**	**27,430**	**9,110**	**1,030**	**39,780**

*Large passenger and large freighter categories differ.

Fleet by Region – Asia Pacific



Asia Pacific fleet growth
By size and region

Fleet by airplane size

Size	Airplanes in service 2011	Fleet share 2011	Airplanes in service 2031	Fleet share 2031
Large*	340	7%	460	3%
Medium	700	15%	2,290	17%
Small	380	8%	1,200	9%
Total twin aisle	**1,420**	**30%**	**3,950**	**29%**
More than 175 seats	390	8%	2,220	16%
90 to 175 seats	2,780	59%	7,010	51%
Total single aisle	**3,170**	**67%**	**9,230**	**68%**
Total regional jets	**120**	**3%**	**490**	**4%**
Total fleet	**4,710**	**100%**	**13,670**	**100%**

Fleet by region in 2011

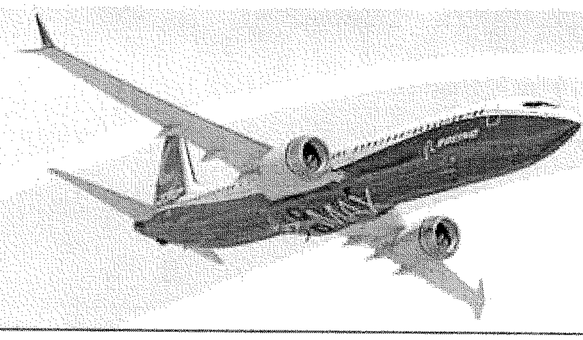
Region	Regional jets	Single aisle	Twin aisle	Large	Total fleet
China	60	1,490	280	80	1,910
Northeast Asia	30	300	300	80	710
Oceania	10	340	90	40	480
Southeast Asia	20	680	310	130	1,140
South Asia	–	360	100	10	470
Asia Pacific	**120**	**3,170**	**1,080**	**340**	**4,710**

Fleet by region in 2031

Region	Regional jets	Single aisle	Twin aisle	Large	Total fleet
China	310	4,220	1,310	140	5,980
Northeast Asia	90	580	580	120	1,370
Oceania	–	650	250	50	950
Southeast Asia	70	2,280	980	150	3,480
South Asia	20	1,500	370	–	1,890
Asia Pacific	490	**9,230**	**3,490**	**460**	**13,670**

*Large passenger and large freighter categories differ.

Major Traffic Flows



Airline traffic flows
By region

Airline passenger growth rates 2011 to 2031

RPKs	Africa	Latin America	Middle East	Europe	North America	Asia Pacific
Asia Pacific	7.4%	5.4%	7.2%	5.7%	4.8%	**6.7%**
North America	6.0%	5.1%	6.4%	3.8%	**2.2%**	
Europe	4.8%	4.6%	5.1%	**3.5%**		
Middle East	6.9%	—	**5.1%**			
Latin America	8.3%	**6.5%**				
Africa	**6.2%**					

Airline passenger traffic in 2011

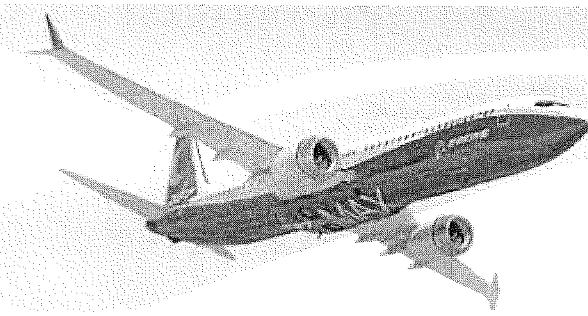
RPKs in billions	Africa	Latin America	Middle East	Europe	North America	Asia Pacific
Asia Pacific	18.8	3.4	190.9	314.2	283.8	**1,096.1**
North America	11.4	181.2	50.3	430.2	**952.9**	
Europe	134.1	163.5	153.3	**659.5**		
Middle East	39.4	—	**82.4**			
Latin America	3.2	**185.8**				
Africa	**51.1**					

Airline passenger traffic in 2031

RPKs in billions	Africa	Latin America	Middle East	Europe	North America	Asia Pacific
Asia Pacific	78.1	9.9	766.2	954.6	717.9	**3,990.0**
North America	36.8	486.6	174.3	901.2	**1,459.6**	
Europe	345.5	404.4	417.2	**1,305.3**		
Middle East	149.7	—	**222.1**			
Latin America	15.7	**652.3**				
Africa	**169.6**					

Bold: Share within region.

Traffic by Region



Airline traffic distribution
By region

Traffic in 2011

RPKs	Asia Pacific	North America	Europe	Middle East	Latin America	Africa
Asia Pacific	**58%**	15%	17%	37%	1%	7%
North America	15%	**50%**	23%	10%	34%	5%
Europe	16%	23%	**36%**	30%	30%	52%
Middle East	10%	3%	8%	**16%**	—	15%
Latin America	—	8%	9%	—	**34%**	1%
Africa	1%	1%	7%	7%	1%	**20%**
Total traffic to and from region	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Traffic in 2031

RPKs	Asia Pacific	North America	Europe	Middle East	Latin America	Africa
Asia Pacific	**61%**	19%	22%	44%	1%	10%
North America	11%	**39%**	21%	10%	31%	5%
Europe	15%	24%	**30%**	24%	26%	43%
Middle East	12%	4%	10%	**13%**	—	19%
Latin America	—	13%	9%	—	**41%**	2%
Africa	1%	1%	8%	9%	1%	**21%**
Total traffic to and from region	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

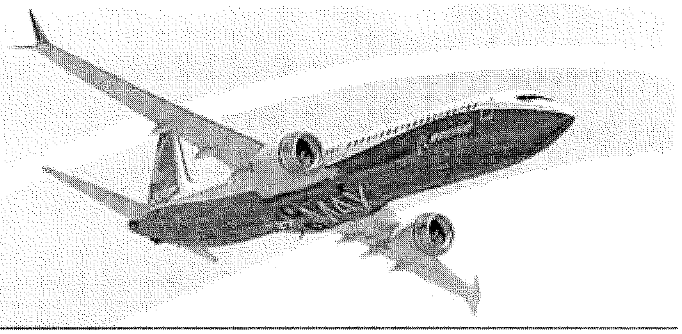
Bold: Share within region. Sum data down the table only. Excludes other small flows that are not included in the summary table (less than 1% of each region).

How to read the tables

Read down the selected column; for example:

- In 2011, traffic within North America accounted for 50% of all the total traffic to, from, within North America.
- In 2031, traffic within North America accounted for 39% of all the total traffic to, from, within North America.

Airplane Categories



Passenger and freighter
Airplane market sector definitions

Single-aisle passenger airplanes

Regional jets	90 to 175 seats	More than 175 seats
Antonov An-148	Boeing 717, 727	Boeing 707, 757
AVIC ARJ-700	Boeing 737-100 through -500	**Boeing 737-900ER**
Avro RJ70, RJ85	**Boeing 737-600, -700, -800**	**Boeing 737 MAX 9**
BAe 146-100, -200	**Boeing 737 MAX 7, MAX 8**	**Airbus A321**
Bombardier CRJ	**Airbus A318, A319, A320**	**Airbus A321neo**
Dornier 328JET	**Airbus A319neo, A320neo**	**Tupolev TU-204, TU-214**
Embraer 170, 175	Boeing-MDC DC-9, MD-80, -90	**UAC MS 21-400**
Embraer ERJ-135, -140, -145	**AVIC ARJ-900**	
Fokker 70, F28	BAe 146-300, Avro RJ100	
Mitsubishi MRJ	**Bombardier CRJ-1000**	
Sukhoi Superjet 100	**Bombardier CS100, CS300**	
Yakovlev Yak-40	**COMAC C919**	
	Embraer 190, 195	
	Fokker 100	
	Ilyushin IL-62	
	Tupolev TU-154	
	Yakovlev Yak-42	
	UAC MS 21-200 -300	

Twin-aisle passenger airplanes

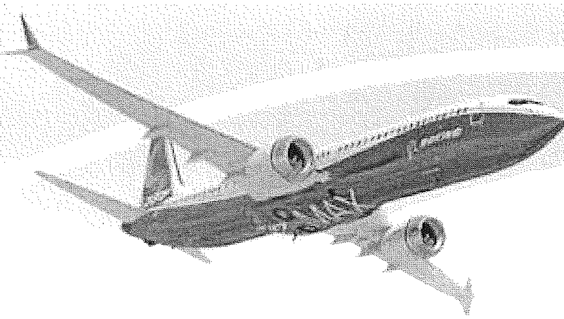
Small Two class: 230 to 340 seats Three class: 180 to 260 seats	Medium Two class: 340 to 450 seats Three class: 260 to 400 seats	Large* Three class: more than 400 seats
Boeing 767, 787	**Boeing 777**	**Boeing 747-8**
Boeing-MDC DC-10	Boeing-MDC MD-11	**Airbus A380**
Airbus A300, A310	**Airbus A330-300, A340**	Boeing 747-100 through -400
Airbus A330-200	**Airbus A350-900, -1000**	
Airbus A350-800	Ilyushin IL-86	
Lockheed L-1011		
Ilyushin IL-96		

Freighter airplanes

Standard body Less than 45 tonnes	Medium widebody 40 to 80 tonnes	Large* More than 80 tonnes
BAe 146	Boeing 767	Boeing-MDC MD-11
Boeing-MDC DC-8, -9	Lockheed L-1011SF	Boeing 747-100 through -400
Boeing 737	Boeing-MDC DC-10	Boeing 777
Boeing 727	Boeing 787	Airbus A350
Tupolev TU-204	Airbus A300, A310	Ilyushin IL-96T
Boeing 707	Airbus A330	Antonov An-124
Boeing-MDC MD-80	Ilyushin IL-76TD	
Boeing 757-200		
Airbus A318, A319, A320, A321		

Bold: Airplanes in production or launched. Production and conversion (SF) models assumed for each type unless otherwise specified. *Large passenger and large freighter categories differ.

Opinion/Feedback



We value your opinion

Please provide your name, position, company, and address below, or attach your business card.

Feedback

What do you think?

Your perspective

- What will be the main factors to affect future air transport markets?
- What will be the likely impact of these factors?

Your feedback

- What do you think of web-only access to forecast information (with a PDF for you to print locally)?
- If you have used the interactive forecast database on our website, tell us what you think of it.
- What areas would you like to see covered in more detail in the *Current Market Outlook?*
- What additional data would you like us to make available?
- What did you find most valuable?
- Was there anything you disliked?

Send your comments to us

Our contact details are below.

Your comments

Any other questions or comments?

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Forecast database
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EXHIBIT B

L.A. CEQA THRESHOLDS GUIDE

Your Resource for Preparing
CEQA Analyses in Los Angeles

City of Los Angeles
2006

I. NOISE

I.1. CONSTRUCTION NOISE

1. INITIAL STUDY SCREENING PROCESS

A. Initial Study Checklist Questions

XI.a): Would the project result in exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?

XI.b): Would the project result in exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?

XI.d): Would the project result in a substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?

XI.e): For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?

XI.f): For a project within the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?

B. Introduction

Construction of facilities and structures requires the use of equipment, which may generate high noise levels and adversely affect noise sensitive uses.[1] In assessing the impact of construction noise upon the environment, the nature and level of activities that generate the noise, the pathway through which the noise travels, the sensitivity of the receptor, and the period of exposure are all considered.

Environmental noise is measured in decibels (dB). To better approximate the range of sensitivity of the human ear to sounds of different frequencies, the A-weighted decibel scale (dBA) was devised. Because the human ear is less sensitive to low frequency sounds, the A-scale de-emphasizes these frequencies by incorporating frequency weighting of the sound signal. When the A-scale is used, the decibel levels are represented by dBA. On this scale, the range of human

[1] *For impacts during operation, see I.2 OPERATIONAL NOISE, I.3. RAILROAD NOISE, and I.4. AIRPORT NOISE, as appropriate.*

hearing extends from about 3 dBA to about 140 dBA. A 10-dBA increase is judged by most people as a doubling of the sound level.

To account for the fluctuation in noise levels over time, noise impacts are commonly evaluated using time-averaged noise levels. The Community Noise Equivalent Level (CNEL) represents an energy average of the A-weighted noise levels over a 24-hour period with 5 dBA and 10 dBA increases added for nighttime noise between the hours of 7:00 p.m. and 10:00 p.m. and 10:00 p.m. to 7:00 a.m., respectively. The increases were selected to account for reduced ambient noise levels during these time periods and increased human sensitivity to noise during the quieter periods of the day.

Typical construction equipment types are presented in Exhibit I.1-1. Noise levels from these equipment types ranges from 76 to 91 dBA for equipment powered by internal combustion engines, saws, and vibrators and from the mid-80s to more than 100 dBA for impact equipment. Exhibit I.1-2 provides typical noise levels for each construction phase. The excavation and finishing phases include the noisiest construction activities.

The Environmental Protection Agency (EPA), establishes emission standards for construction equipment according to the provisions of the Noise Control Act of 1972, set forth in 40 CFR, Part 204. In addition, the City of Los Angeles Noise Ordinance addresses noise generated at construction sites, including permissible hours of construction, increases in ambient noise levels, and the technical feasibility of reducing noise from certain construction equipment. The Los Angeles Police Department (LAPD) enforces the provisions of the Noise Ordinance.[2]

C. Screening Criteria

- Would construction activities occur within 500 feet of a noise sensitive use?

- For projects located within the City of Los Angeles, would construction occur between the hours of 9:00 p.m. and 7:00 a.m. Monday through Friday, before 8:00 a.m. or after 6:00 p.m. on Saturday, or at anytime on Sunday?

A “yes” response to any of the preceding questions indicates further study in an expanded Initial Study, Negative Declaration, Mitigated Negative Declaration, or EIR may be required. Refer

2 *Refer to Sections 41.40, 112.02, and 112.05 of the Los Angeles Municipal Code (LAMC). Technical infeasibility means that specified noise limitations cannot be achieved despite the use of mufflers, shields, sound barriers and/or any other noise reduction devices or techniques during operation of the equipment.*

to the Significance Threshold for Construction Noise and review the associated Methodology to Determine Significance, as appropriate.

A "no" response to all of the preceding questions indicates that there would normally be no significant impact from the proposed project.

D. Evaluation of Screening Criteria

Review the description of the proposed project, including information on construction activities. Consult a map showing the location of noise sensitive uses within 500 feet of the project site. Noise sensitive uses include residences, transient lodgings, schools, libraries, churches, hospitals, nursing homes, auditoriums, concert halls, amphitheaters, playgrounds, and parks. Determine whether construction activities would occur within 500 feet of a noise sensitive use or during the hours specified in the Screening Criteria.

2. DETERMINATION OF SIGNIFICANCE

A. Significance Threshold

A project would normally have a significant impact on noise levels from construction if:

- Construction activities lasting more than one day would exceed existing ambient exterior noise levels by 10 dBA or more at a noise sensitive use;

- Construction activities lasting more than 10 days in a three month period would exceed existing ambient exterior noise levels by 5 dBA or more at a noise sensitive use; or

- Construction activities would exceed the ambient noise level by 5 dBA at a noise sensitive use between the hours of 9:00 p.m. and 7:00 a.m. Monday through Friday, before 8:00 a.m. or after 6:00 p.m. on Saturday, or at anytime on Sunday.

B. Methodology to Determine Significance

<u>Environmental Setting</u>

In a description of the environmental setting, include the following information:

- Identification of noise sensitive land uses within 500 feet of the project site, including description, location, and distance from the project; and

- Quantification of ambient noise levels (existing and projected at the time of construction) measured in CNEL.

One of the following methodologies can be used to determine ambient noise levels:

- Field measurements involving the use of a noise meter at and surrounding the project site;

- "Presumed Ambient Noise Levels," as set forth in the LAMC, Section 111.03 (see Exhibit I.1-3); or

- A noise monitoring program performed according to the procedures set forth in the LAMC, Sections 111.02 and 112.05. This involves taking measurements at selected locations to establish ambient background noise levels.

Project Impacts

Review the description of the proposed project, including the duration of construction activities. Identify the type, amount, and scheduling of construction equipment to be used during each construction phase, and the distance from construction activities to noise sensitive uses.

Calculate the noise emissions from individual equipment by using the noise levels shown in Exhibits I.1-1 and I.1-2, or other applicable references, the distance to the noise sensitive uses, and noise attenuation standards. Noise models may be used, as appropriate. Noise levels 50 feet from a source decrease by approximately 3 dBA over a hard, unobstructed surface, such as asphalt, and by approximately 4.5 dBA over a soft surface, such as vegetation. For every doubling of distance thereafter, noise levels drop another 3 dBA over a hard surface and 4.5 dBA over a soft surface. Machinery equipped with noise control devices or other noise-reducing design features does not generate the same level of emissions as that shown in Exhibit I.1-1.

Determine the combined noise levels from equipment that will be operated simultaneously. Noise levels measured in decibels increase logarithmically and cannot be added arithmetically. When transmission path topography between the construction noise source and the receptor location is complex, consult an experienced noise specialist, as necessary.

Establish the change in noise level from construction activities at the location of sensitive receptors. Subtract the projected noise level without construction equipment from the projected noise level during construction activities. Considering the number of days various noise levels are projected, determine whether construction activities would exceed both the number of days, times of day, and dBA increases in the Significance Threshold.

Cumulative Impacts

As feasible, identify construction activities for related projects that would coincide with the project's construction operations. Calculate noise levels using the methodology in Project Impacts and logarithmically add the noise from these construction activities to the project-related construction noise to determine the cumulative effect of the construction activities. Consult a noise specialist, or use a noise model, as needed.

Sample Mitigation Measures

Potential mitigation measures include the following:

- Use noise control devices, such as equipment mufflers, enclosures, and barriers. Natural and artificial barriers such as ground elevation changes and existing buildings can shield construction noise. Stage construction operations as far from noise sensitive uses as possible;

- Avoid residential areas when planning haul truck routes;

- Maintain all sound-reducing devices and restrictions throughout the construction period;

- Replace noisy equipment with quieter equipment (for example, a vibratory pile driver instead of a conventional pile driver and rubber-tired equipment rather than track equipment); and

- Change the timing and/or sequence of the noisiest construction operations to avoid sensitive times of the day.

3. DATA, RESOURCES, AND REFERENCES

Noise Ordinance No. 161,574, LAMC Section 112.05 and No. 166,170, LAMC Section 41.40 provide construction hours and construction equipment noise thresholds.

Noise Ordinance No. 156,363, LAMC Section 111.02 provides sound level measurement procedures.

Noise Ordinance No. 156,363, LAMC Section 111.03 provides ambient noise levels.

Los Angeles Association of Environmental Professionals (AEP), Thresholds of Significance, Construction noise threshold used by Port of Long Beach, 1992.

EPA, Noise from Construction Equipment and Operations, Building Equipment and Home Appliances, Prepared by Bolt, Beranek and Newman, 1971.

Categories of Construction Equipment

1. Impact equipment and tools: This group includes pile drivers, pavement breakers, tampers, rock drills, and small; hand-held pneumatically, hydraulically, or electrically powered tools. In the case of conventional pile drivers, whether steam-powered or diesel-powered, the impact of the hammer dropping onto the pile is the dominant noise-generating component. However, sonic or vibratory pile drivers do not produce impact noise as it vibrates the pile at resonance, rather than using a drop hammer.

2. Equipment powered by internal combustion engines: The internal combustion engine, usually of the diesel type, is used to provide motive and/or operating power. Engine powered equipment can be divided into categories according to its mobility and operating characteristics as earthmoving equipment (highly mobile), materials handling equipment (semi-mobile), and stationary equipment.

3. Other equipment: Certain types of construction equipment, such as power saws or concrete vibrators do not fall under either of the two categories above.

Selected Legislation

Federal

Federal Noise Control Act of 1972 (40 CFR Sec. 204)

Public Law 92-574. Regulates noise emissions from operation of all construction equipment and facilities; establishes noise emission standards for construction equipment and other categories of equipment; and provides standards for the testing, inspection, and monitoring of such equipment. Gives states and municipalities primary responsibility for noise control.

State

California Noise Control Act of 1973 (Health and Safety Code, Division 28)

Declares that excessive noise is a serious hazard to the public health and welfare; establishes the Office of Noise Control with the responsibility to set standards for noise exposure in cooperation with local governments or the state legislature.

Exhibit I.1-1
NOISE LEVEL RANGES OF TYPICAL CONSTRUCTION EQUIPMENT

Equipment	Levels in dBA at 50 feet[a]
Front Loader	73-86
Trucks	82-95
Cranes (moveable)	75-88
Cranes (derrick)	86-89
Vibrator	68-82
Saws	72-82
Pneumatic Impact Equipment	83-88
Jackhammers	81-98
Pumps	68-72
Generators	71-83
Compressors	75-87
Concrete Mixers	75-88
Concrete Pumps	81-85
Back Hoe	73-95
Pile Driving (peaks)	95-107
Tractor	77-98
Scraper/Grader	80-93
Paver	85-88

[a] Machinery equipped with noise control devices or other noise-reducing design features does not generate the same level of emissions as that shown in this table.

Source: EPA, Noise from Construction Equipment and Operations, Building Equipment and Home Appliances, PB 206717, 1971.

Exhibit I.1-2
OUTDOOR CONSTRUCTION NOISE LEVELS

Construction Phase	Noise Level (dBA Leq)	
	50 feet	Noise Levels at 50 feet with Mufflers (dBA)
Ground Clearing	84	82
Excavation, Grading	89	86
Foundations	78	77
Structural	85	83
Finishing	89	86

Source: EPA, Noise from Construction Equipment and Operations, Building Equipment and Home Appliances, PB 206717, 1971.

Exhibit I.1-3
PRESUMED AMBIENT NOISE LEVELS (dBA)

Zone		Day	Night
Residential:	A1, A2, RA, RE, RS, RD, RW1, RW2, R1, R2, R3, R4, R5	50	40
Commercial:	P, PB, CR, C1, C1.5, C2, C4, C5, CM	60	55
Manufacturing:	M1, MR1, MR2	60	55
Heavy Manufacturing:	M2, M3	65	65

Source: LAMC, Section 111.03.

I.2. OPERATIONAL NOISE

1. INITIAL STUDY SCREENING PROCESS

A. Initial Study Checklist Questions

XI.a): Would the project result in exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?

XI.b): Would the project result in exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?

XI.c): Would the project result in a substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?

XI.d): A substantial temporary or periodic increase in ambient noise levels in the project vicinity above the existing without the project?

XI.e): For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?

XI.f): For a project within the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?

B. Introduction

Stationary and mobile vehicular noise sources associated with the operation of a project may increase existing noise levels and/or adversely expose people to severe noise levels.[1]

Environmental noise is measured in decibels (dB). To better approximate the range of sensitivity of the human ear to sounds of different frequencies, the A-weighted decibel scale (dBA) was devised. Because the human ear is less sensitive to low frequency sounds, the A-scale de-emphasizes these frequencies by incorporating frequency weighting of the sound signal. When the A-scale is used, the decibel levels are represented by dBA. On this scale, the range of human hearing extends from about 3 dBA to about 140 dBA. A 10-dBA increase is judged by most people as a doubling of the sound level.

---

1 *For other noise impacts, see I.1. CONSTRUCTION NOISE, I.3. RAILROAD NOISE, and I.4. AIRPORT NOISE, as appropriate.*

To account for the fluctuation in noise levels over time, noise impacts are commonly evaluated using time-averaged noise levels. The Community Noise Equivalent Level (CNEL) represents an energy average of the A-weighted noise levels over a 24-hour period with 5 dBA and 10 dBA increases added for nighttime noise between the hours of 7:00 p.m. and 10:00 p.m. and 10:00 p.m. to 7:00 a.m., respectively. The increases were selected to account for reduced ambient noise levels during these time periods and increased human sensitivity to noise during the quieter periods of the day.

Because stationary noise sources include a wide range of noise-generating equipment and processes, which come from an equally wide range of uses, noise levels generated by stationary sources can vary substantially (for examples and descriptions, see 3. Data, Resources, and References). The effects of stationary noise depend on factors such as characteristics of the equipment and operations, distance and pathway between the generator and receptor, and weather. Stationary noise sources may be regulated at the point of manufacture (e.g., equipment or engines) or as a part of local codes and requirements (e.g., noise ordinance or zoning).

The predominant noise source within the City of Los Angeles is transportation, including railroad, airport and motor vehicle sources. Traffic volume, average speed, vehicular fleet mix (i.e., combination of automobiles, motorcycles, buses, and trucks), roadway steepness, distance and characteristics of the pathway between generator and receptor, and weather all influence the level of noise near roadways. For example, as the roadway traffic volume, speed, proportion of fleet mix represented by trucks, and roadway grade increase, so do the composite noise levels at the locations affected by the traffic noise. However, as the roadway volume increases beyond a certain point, congestion increases, in turn causing reduced traffic speeds, which would to some extent offset noise from the traffic volume increase. Dense urban areas within the City of Los Angeles may experience noise levels ranging from the low- to high-70 decibel range. The California Department of Motor Vehicles (DMV) has jurisdiction over noise emissions from individual vehicles (Motor Vehicle Code Section 23130).

C. Screening Criteria

- Would the proposed project introduce a stationary noise source[2] likely to be audible beyond the property line of the project site?

- Would the project include 75 or more dwelling units, 100,000 square feet (sf) or greater of

2 *Stationary noise sources may include, but are not limited to, machinery, engines, energy production, and other mechanical or powered equipment and activities such as loading and unloading or public assembly that may occur at commercial, industrial, manufacturing, or institutional facilities. Stationary noise sources do not include vehicles entering or exiting the property.*

nonresidential development or have the potential to generate 1,000 or more average daily vehicle trips?

A "yes" response to any of the preceding questions indicates further study in an expanded Initial Study, Negative Declaration, Mitigated Negative Declaration, or EIR may be required. Refer to the Significance Threshold for Operational Noise, and review the associated Methodology to Determine Significance, as appropriate.

A "no" response to all of the preceding questions indicates that there would normally be no significant impact from Operational Noise from the proposed project.

D. Evaluation of Screening Criteria

Review the description of the proposed project and the project traffic study to determine the size of each land use involved, information on stationary noise sources such as machinery or motorized equipment, and the vehicle trips that would be generated by the project. L.1. INTERSECTION CAPACITY explains how to calculate the number of average daily vehicle trips.

Determine the noise level from stationary sources at the property line by evaluating the decibel output of each source, the distance to the property line and the path over which the sound travels. Use an applicable noise model, as needed. In general, at a distance of 50 feet from the source over a hard surface, the decibel level decreases by 3 dBA, and over a soft surface (such as grass) the decibel level decreases by 4.5 dBA. For every doubling of distance thereafter, noise levels drop another 3 dBA over a hard surface and 4.5 dBA over a soft surface.[3]

Compare this information to the Screening Criteria.

2. DETERMINATION OF SIGNIFICANCE

A. Significance Threshold

A project would normally have a significant impact on noise levels from project operations if the project causes the ambient noise level measured at the property line of affected uses to increase by 3 dBA in CNEL to or within the "normally unacceptable" or "clearly unacceptable" category, or any 5 dBA or greater noise increase (see the chart below).

[3] *Federal Highway Administration (FHWA), Highway Traffic Noise Prediction Model (FHWA R77-108), 1978.*

Land Use	Community Noise Exposure CNEL, db Normally Acceptable	Conditionally Acceptable	Normally Unacceptable	Clearly Unacceptable
Single Family, Duplex, Mobile Homes	50 - 60	55 - 70	70 - 75	above 70
Multi-Family Homes	50 - 65	60 - 70	70 - 75	above 70
Schools, Libraries, Churches, Hospitals, Nursing Homes	50 - 70	60 - 70	70 - 80	above 80
Transient Lodging - Motels, Hotels	50 - 65	60 - 70	70 - 80	above 80
Auditoriums, Concert Halls, Amphitheaters	-	50 - 70	-	above 65
Sports Arena, Outdoor Spectator Sports	-	50 - 75	-	above 70
Playgrounds, Neighborhood Parks	50 - 70	-	67 - 75	above 72
Golf Courses, Riding Stables, Water Recreation, Cemeteries	50 - 75	-	70 - 80	above 80
Office Buildings, Business and Professional Commercial	50 - 70	67 - 77	above 75	-
Industrial, Manufacturing, Utilities, Agriculture	50 - 75	70 - 80	above 75	-

Normally Acceptable: Specified land use is satisfactory, based upon the assumption that any buildings involved are of normal conventional construction without any special noise insulation requirements.
Conditionally Acceptable: New construction or development should be undertaken only after a detailed analysis of the noise reduction requirements is made and needed noise insulation features included in the design. Conventional construction, but with closed windows and fresh air supply systems or air conditioning will normally suffice.
Normally Unacceptable: New construction or development should generally be discouraged. If new construction or development does proceed, a detailed analysis of the noise reduction requirements must be made and needed noise insulation features included in the design.
Clearly Unacceptable: New construction or development should generally not be undertaken.

Source: California Department of Health Services (DHS).

B. Methodology to Determine Significance

Environmental Setting

In a description of the environmental setting, include the following information:

- Identification of surrounding land uses, including description, location and distance from the project; and

- Quantification of ambient noise levels (existing and projected at the time of project occupancy) measured in CNEL.

One of the following methodologies can be used to determine ambient noise levels:

- Field measurements involving the use of a noise meter at and surrounding the project site;

- "Presumed Ambient Noise Levels," as set forth in the Los Angeles Municipal Code (LAMC), Section 111.03 (see Exhibit I.1-1[4]); or

- A noise-monitoring program performed according to the procedures set forth in LAMC, Section 111.02 and 112.05. This involves taking measurements at selected locations to establish ambient background noise levels.

Project Impacts

The change in ambient noise levels is measured by adding project-generated operational noise to the projected future ambient noise level at the time of project occupancy. The incremental increase in noise generated by the project is the project impact. Calculate the future exterior ambient noise level according to the procedure outlined above, under Environmental Setting.

Stationary Sources

Review the project description and identify the type, amount, noise impact, and operating characteristics of proposed equipment on the project site (e.g., 24-hour function, sporadic use expected). Identify the distance and the characteristics of the pathway between the noise source and the nearby land uses that would receive the noise. Noise models may be used, as appropriate.

Noise levels 50 feet from a source decrease by approximately 3 dBA over a hard, unobstructed surface, such as asphalt, and by approximately 4.5 dBA over a soft surface, such as a vegetated area. For every doubling of distance thereafter, noise levels drop another 3 dBA over a hard surface and 4.5 dBA over a soft surface. These reduction rates can be used to adjust noise levels at the noise receptor locations, based on their relative distances from the project equipment.

4 *See I.1. CONSTRUCTION NOISE.*

Once noise levels from individual pieces of equipment on the project site have been calculated, logarithmically add together the noise levels from all equipment operating simultaneously. (Noise levels measured in decibels increase logarithmically and cannot be added arithmetically.) Where the noise transmission path between the source and the receptor is complex, consult a noise specialist as necessary.

To determine the change in noise level, subtract the projected ambient noise level without the project's stationary noise from the projected noise level during project operation. Use the chart in the Significance Threshold to determine the significance of the difference.

Mobile Vehicular Sources

Review the project description, determine the number of vehicle trips to be generated by the project, and distribute the trips on the street system (use the traffic study or methodology described in L.1. INTERSECTION CAPACITY). Determine the characteristics of the noise transmission pathway. Using a mobile noise prediction model, project the future exterior ambient noise levels for these streets with and without the proposed project. Base the selected noise model on the Federal Highway Administration (FHWA) highway noise prediction procedures described in FHWA-77-108 or the most recent revision. The City of Los Angeles recommends the use of either LEQV2 or SOUND32 prediction models as developed by California Department of Transportation (Caltrans). LEQV2 requires the following information: (a) traffic volumes, (b) roadway, barrier and receiver geometry, (c) vehicle speed, (d) number of lanes, (e) fleet mix, and (f) drop-off rates. It uses angles, distances and elevations to define source-receptor spatial relationships. SOUND32 requires the following information: (a) traffic volumes, (b) roadway, barrier and receiver geometry, and (c) drop-off rates. This model uses a three dimensional coordinate system to define source-receptor spatial relationships.

If monitoring was used to quantify existing noise levels, use existing traffic conditions (volumes, roadway geometry, etc.) to model the existing noise levels. A comparison of monitored existing noise levels and modeled existing noise levels can be used to calibrate the modeling resulting.

To determine the change in noise level, subtract the projected noise level on the selected roadways without the project's traffic-generated noise from the projected noise level, including the project's traffic-generated noise. Use the chart in the Significance Threshold to determine the significance of the difference.

Noise levels increase approximately 3 dBA for each doubling of roadway traffic volume, assuming that the speed and fleet mix remain constant. A change in vehicle speed can also change noise levels. If vehicle speed and fleet mix can be assumed to remain constant after project implementation, and the project would result in traffic that is less than double the existing traffic, then the project's mobile noise impacts can be assumed to be less than significant.

For a program-level analysis where project details are unknown, assume the full build out of allowable land use and density. Use the methodology above to determine program-generated noise increases.

Cumulative Impacts

For impacts from stationary sources, as feasible, identify the type and amount of equipment to be used by the related projects. Determine whether noise from these sources would impact the same land uses impacted by the proposed project. For those, calculate and logarithmetically add the related project noise to project-generated noise to determine the cumulative effect of the activities.

The analysis for project impacts from mobile vehicular sources uses future traffic levels to establish future ambient noise levels. As these traffic levels include trips from the related projects, additional evaluation is not required.

Sample Mitigation Measures

Potential mitigation measures include the following:

Stationary Sources

- Redesign the source to radiate less noise (e.g., substitute a quieter equipment type process or enclose the source with sound absorbent material);

- Use insulation or construct solid barriers between noise sources and noise receivers;

- Separate noise sources from noise receivers by distances sufficient to attenuate the noise to acceptable levels;

- Insulate structures;

- Limit the hours of use for the equipment;

- Prepare an acoustical analysis and adopt the resulting insulation and attenuation measures; and

- Conduct inspections of the equipment prior to issuance of the occupancy permit to verify on-site containment of noise emissions.

Mobile Vehicular Sources

- Attenuate the sound by using barriers, or redirect sound transmission paths;

- Reduce vehicle trip generation, or reduce speed limits on roadways; and

- Locate any delivery, truck loading, or trash pickup areas as far from noise sensitive land uses as possible. Limit designated hours for deliveries.

3. DATA, RESOURCES, AND REFERENCES

Noise Element, 1999. Available from the City Planning Department's Central Publications Unit at 200 N. Spring St., 5th Floor, Los Angeles, California 90012; Telephone: (213) 978-1255.

Noise Ordinance No. 156,363, LAMC Section 111.02 provides sound level measurement procedures.

Noise Ordinance No. 156,363, LAMC Section 111.03 provides ambient noise levels.

Noise Control Act of 1972.

Association of Environmental Professionals (AEP), Thresholds of Significance, Noise Thresholds, 1992.

FHWA Highway Traffic Noise Prediction Model (FHWA-RD-77-108), 1978.

LEQV2 and SOUND32 sound prediction models, developed by Caltrans.

California Noise Insulation Standards, CAC, Title 25, Housing and Community Development.

California Motor Vehicle Code, Section 23130.

Stationary Source Categories

Agricultural operations: Agricultural noise is generated by a host of soil preparation and crop harvesting equipment, pesticide applicators, and conveying and elevating equipment.

Commercial/Institutional: Building service equipment is generally considered a stationary noise source. Building service equipment includes heating, ventilating, and air conditioning facilities, water and waste water systems elevators, and escalators. The most common urban noise source in the air conditioning category is the modern high efficiency-cooling tower, which contains two noise sources - fans and water spray. The increasing use of window or through the wall packaged air conditioning units leads to the generation of noise outside. In addition to their inherent noise characteristics, as these units age, loose metal parts and window frames may rattle.

Home workshops and gardening tools: Noise from these sources includes various motors that operate power mowers, power trimmers, edgers and leaf blowers, and power operated saws and drills.

Industrial: Much of the equipment used in industry and many industrial processes and operations generate noise. The intakes and discharges from fans, compressors, and engines often penetrate the walls of industrial buildings. Even a wholly enclosed industrial plant can generate noise because ducts and piping outside buildings radiate the noises generated from the inside. Inadequately insulated walls and roofs transmit noise. Sheet metal walls, for example, vibrate in response to inside noise and become effective noise radiators. Outdoor industrial operations also constitute sources of noise, including storage operations, steel and scrap yards, and truck and rail freight handling yards.

Lumbering operations: These operations involve the use of diesel powered equipment, chain saws, and hoisting and conveying equipment. Sawmill noise is produced by saws and planers and other lumber shaping equipment, the operation of hoisting and conveying equipment, and the operation of yard and loading equipment.

Mineral production: Mineral production includes both surface and underground mining; sand and gravel pit operations, and crushed rock operations. Noises generated from these sources include sounds emanating from rock crushers, screens, conveyor belts, diesel engines, electric motors, dump trucks, power shovels, rock drills, and blasting.

Petroleum production and refining: Principal sources of noise from petroleum production operations include pressure-reducing valves in pipes, steam turbines, derricks, gear boxes, compressors, electric motors, diesel engines, and maintenance equipment.

Port Operations: Primary noise sources from port activities include bulk-loading facilities, shipping container-handling equipment, truck traffic, and train movements. The sound of ship engines and trains running contribute to the low steady-state noise emanating from a port, which is punctuated by ship whistles and train horns.

Public and private utilities: Public and private utilities engage in construction activities producing the same kind of noises discussed in I.1 CONSTRUCTION NOISE. They also operate hydroelectric, steam and diesel electric generation plants, compressors, pumps and pipelines, all of which generate noises similar to those discussed above as industrial noise sources.

Public services: Sources of noise from public services include sirens on emergency vehicles, truck and loading noise from rubbish collection and disposal, and equipment noise generated through the maintenance of streets, sewers and water systems.

Mobile Source Categories

Automobiles: The passenger automobile usually makes much less noise than other types of motor vehicles. They produce little exhaust noise except at low frequencies. The combination of wind, gearing, and tire noises produces an identifiable spectrum of noise at speeds over 40 mph and at distances over 100 feet. At higher speeds, this combination of sounds is identifiable at distances up to one mile under quiet ambient conditions. The loudest element of automobile noise at a long distance is the sound of tires.

Buses: Buses tend to radiate less noise than other heavy vehicles because their engine compartments are sealed. Bus noise, however, usually increases with use because of damage to these seals.

Motorcycles: Motorcycle noise is distinctive because, in addition to noise from intake, exhaust, and gearing systems, motorcycles radiate considerable noise directly through the engine walls.

Trucks: Trucks make more noise than other motor vehicles. Diesel trucks are generally the most significant motor vehicle noise source. A single, large diesel truck may produce noise levels equal to noise generated by 30 passenger cars. Under most conditions of operation, exhaust noise predominates. At low speeds, under heavy acceleration, engine and transmission noise may be louder. At high speeds on level roadways, tire noise predominates. Other sources of noise from trucks include the chassis, brakes, sheet metal parts, loose pins, and cargo.

I.3. RAILROAD NOISE

1. INITIAL STUDY SCREENING PROCESS

A. Initial Study Checklist Questions

XI.a): Would the project result in exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?

XI.b): Would the project result in exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?

XI.c): A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?

XI.d): A substantial temporary or periodic increase in ambient noise levels in the project vicinity above the existing without the project?

B. Introduction

Railroad operations may increase existing noise levels and/or adversely affect noise-sensitive land uses. The effects of railroad noise depend on factors such as characteristics of the equipment and operations; distance and characteristics of the pathway between the generator and receptor; and weather. Section 17 of the Federal Noise Control Act, rather than state or local regulations, establishes controls and limits on railroad operations, through the United States Environmental Protection Agency (EPA) and United States Department of Transportation (U.S. DOT).

Environmental noise is measured in decibels (dB). To better approximate the range of sensitivity of the human ear to sounds of different frequencies, the A-weighted decibel scale (dBA) was devised. Because the human ear is less sensitive to low frequency sounds, the A-scale de-emphasizes these frequencies by incorporating frequency weighting of the sound signal. When the A-scale is used, the decibel levels are represented by dBA. On this scale, the range of human hearing extends from about 3 dBA to about 140 dBA. A 10-dBA increase is judged by most people as a doubling of the sound level.

To account for the fluctuation in noise levels over time, noise impacts are commonly evaluated using time-averaged noise levels. The Community Noise Equivalent Level (CNEL) represents an energy average of the A-weighted noise levels over a 24-hour period with 5 dBA and 10 dBA penalties added for nighttime noise between the hours of 7:00 p.m. and 10:00 p.m. and 10:00 p.m. to

7:00 a.m., respectively. The penalties were selected to account for reduced ambient noise levels during these time periods and increased human sensitivity to noise during the quieter periods of the day. The Day-Night Sound Level (Ldn), like CNEL, measures noise exposure over a 24-hour period and adds a penalty based on the time of day, although only for late night/early morning hours (10 dBA penalty from 10:00 p.m. to 7:00 a.m.). Thus, the Ldn measurement is slightly less sensitive than CNEL, but it results in very similar noise ratings for most community settings, usually differing by less than 1 dBA.

Railroad operations are generally classified into either line operations or yard operations. Line operations consist of the movements of trains of various types over the main line and local tracks; yard operations are the various activities concentrated in a railway terminal. Yard operations generate noise through the disassembling and recoupling of cars to form new trains, and the maintenance and repair of cars and locomotives. For analytical purposes these may be considered as complex sources of stationary noise. Railroad operations are a much more common source of railroad noise than yard operations. The noise generated by train pass-bys is based on the type of vehicle in use, how it is operated, and the configuration of the track-bed relative to the surrounding terrain. The Federal Transit Authority (FTA) regulates noise generated by moving trains (e.g. whistles, warning signals, wheels on rails), rail maintenance yards, and activity associated with rail facilities.

The Department of Housing and Urban Development (HUD) prepared a Noise Guidebook, which addresses railroad noise, provides guidance on calculating noise levels from railroad operations, and includes a threshold of 3,000 feet between a railroad line and a noise-sensitive land use.

C. Screening Criteria

- Would project development result in a noise-sensitive land use being located within 3,000 feet of a railroad line?

- Would the project result in an increase in the number or length of non-commuter trains operating on existing tracks within 3,000 feet of a noise-sensitive land use?

A "yes" response to any of the preceding questions indicates further study in an expanded Initial Study, Negative Declaration, Mitigated Negative Declaration, or EIR may be required. Refer to the Significance Threshold for Railroad Noise and review the associated Methodology to Determine Significance, as appropriate.

A "no" response to all of the preceding questions indicates that there would normally be no significant impact from Railroad Noise from the proposed project.

D. Evaluation of Screening Criteria

Review the description of the proposed project, including information on railroad activities. Consult a map showing the location of noise-sensitive land uses within 3,000 feet of the project site. Noise-sensitive land uses include residences, schools, libraries, hospitals, day-care facilities, convalescent/retirement homes, and parks. Determine whether the project would result in railroad noise being generated within 3,000 feet of a noise-sensitive land use.

2. DETERMINATION OF SIGNIFICANCE

A. Significance Threshold

A project would normally have a significant impact with regard to exterior noise levels resulting from railroad operations if the project causes noise measured at the property line of a noise sensitive receptor to increase by 3 dBA in CNEL, to or within the "normally unacceptable" or "clearly unacceptable" category, or any 5 dBA or greater noise increase (see the chart below).

Land Use	Community Noise Exposure CNEL, db			
	Normally Acceptable	Conditionally Acceptable	Normally Unacceptable	Clearly Unacceptable
Single Family, Duplex, Mobile Homes	50 - 60	55 - 70	70 - 75	above 70
Multi-Family Homes	50 - 65	60 - 70	70 - 75	above 70
Schools, Libraries, Churches, Hospitals, Nursing Homes	50 - 70	60 - 70	70 - 80	above 80
Playgrounds, Neighborhood Parks	50 - 70	---	67 - 75	above 72

Normally Acceptable: Specified land use is satisfactory, based upon the assumption that any buildings involved are of normal conventional construction without any special noise insulation requirements.

Conditionally Acceptable: New construction or development should be undertaken only after a detailed analysis of the noise reduction requirements is made and needed noise insulation features included in the design. Conventional construction, but with closed windows and fresh air supply systems or air conditioning will normally suffice.

Normally Unacceptable: New construction or development should generally be discouraged. If new construction or development does proceed, a detailed analysis of the noise reduction requirements must be made and needed noise insulation features included in the design.

Clearly Unacceptable: New construction or development should generally not be undertaken.

Source: California Department of Health Services (DHS).

B. Methodology to Determine Significance

Environmental Setting

In a description of the environmental setting, include the following information:

- Identification of noise-sensitive land uses within 3,000 feet of the project site, including description, location and distance from the site; and

- Ambient noise levels (existing and future) measured in CNEL.

One of the following methodologies can be used to determine ambient noise levels:

- Field measurements involving the use of a noise meter at and surrounding the project site;

- "Presumed Ambient Noise Levels", as set forth in the Los Angeles Municipal Code (LAMC), Section 111.03 (see Exhibit I.1-1[1]); and

- A noise measurement program performed according to the procedures in the LAMC, Section 111.02 and 112.05. This involves taking measurements at selected locations to establish ambient background noise levels.

Project Impacts

Review the project description and identify the proposed number and type of rail operations per day. Use a map showing existing land uses to determine the location of, and distance between, sensitive receptors and railroad noise sources.

Guidance in the HUD Noise Guidebook can be used to calculate the resulting Ldn and, thus, CNEL levels. Using Exhibits I.3-1 and I.3-2, and based on the receptor distance from the railroad track, locate the appropriate distance on the horizontal axis (Effective Distance) and vertical axis (Average Daily Number of Operations). At the point of intersection of these two measurements, the diagonal axis will show the Ldn level.

HUD Methodology Assumptions:

- A clear line of sight exists between the railway track and the sensitive receptor;

1 *See I.1. CONSTRUCTION NOISE.*

- There are 50 cars per train;

- The average train speed is 30 miles per hour; and

- Nighttime operations represent 15 percent of the 24-hour total.

With diesel locomotives:

- There are two locomotives per train; and

- The site is not near a grade crossing requiring prolonged use of the train's horn or whistle.

With rapid transit and passenger trains:

- Rails are welded together.

If the project characteristics vary substantially from the HUD methodology assumptions, consult a qualified noise specialist for a more detailed analysis, as necessary. For diesel locomotives, the model described in *Assessment of Noise Environment Around Railroad Operations* may be utilized.[2] It includes variables not included in the HUD model, such as attenuation due to barrier shielding, duration in time of a train pass-by, correction for the presence of additional helper locomotives on an upgrade, and accounting for welded rails, bridges, and grade crossings. In addition, this model has several graphs for use in conjunction with the formula. These graphs include the decibel volume for the duration of a train pass-by depending on distance from the source, the noise level of rail cars based on the speed they are traveling, and the attenuation of sound levels due to a shielding barrier.

Establish the change in noise level from the project. Subtract the projected noise level without the project's railroad operations from the projected noise level with the project's railroad operations. Compare this information to the Significance Threshold.

<u>Cumulative Impacts</u>

As feasible, identify the type and amount of railroad activity expected as a result of related projects. Consider noise-sensitive land uses within 3,000 feet of the proposed and related projects(s). Add the increase in noise at the sensitive receptors from the related projects to that from the proposed project to determine the cumulative impact.

2 *Wyle Laboratories, Assessment of Noise Environments Around Railroad Operations, pages 3-24 - 3-37, 1973.*

Sample Mitigation Measures

Potential mitigation measures include the following:

Railroad Lines and Vehicles

- Use continuous welded rail instead of jointed rail on the steel wheel/rail interface;
- Utilize lightweight trucks to minimize unsprung weight;
- Use special grinding (truing) equipment to ensure smooth wheel/rail interaction;
- Use resilient rail fasteners instead of fixed rail fasteners for track fixation;
- Utilize resiliently supported ties where resilient rail fasteners are inadequate; and
- Provide sound barrier walls or insulation.

Rail Yards

- Enclose rail yards with solid fencing or walls;
- Insulate buildings; and
- Include sound attenuators on fans and ducts.

3. DATA, RESOURCES, AND REFERENCES

American Public Transit Association, Guidelines and Principles for Design of Rapid Transit Facilities, 1983.

T.J. Schultz, W.J. Galloway, Office of Policy Development and Research, HUD, Noise Assessment Guidelines - Technical Background, 1980.

U.S. DOT, Los Angeles Rail Rapid Transit Project Final Environmental Impact Statement (EIS), 1983.

EPA, Background Document for Railroad Noise Emission Standards, 1975.

HUD, Noise Guidebook.

Wilson, Ihrig and Associates, Inc., Noise and Vibration Study for the Metro Rail Project, Final Report, 1982.

Wyle Laboratories, Assessment of Noise Environments Around Railroad Operations, 1973 (prepared for Southern Pacific Transportation Co., Union Pacific Railroad, the Atchison, Topeka and Santa Fe Railway Company, the Association of American Railroads.)

See also I.2. OERATIONAL NOISE.

Railroad Operations and Characteristics

There are three major railroad companies with regular freight traffic operating in the City of Los Angeles: Southern Pacific, Santa Fe, and Union Pacific. The Southern Pacific has an active rail yard in the Boyle Heights area within the City of Los Angeles. The Santa Fe and Union Pacific rail yards are located outside the City of Los Angeles, in the cities of Vernon and Commerce, respectively. In addition, such rapid transit systems as Amtrak, light rail trains (Blue Line), and commuter trains (MetroLink) serve the City of Los Angeles.

There are three general types of railroad vehicles: locomotives, rail cars, and rapid transit vehicles. These vehicles, either in combination with one of the other types or by themselves, form three general train categories. These are freight trains, conventional passenger trains, and rapid transit trains. A freight train consists of one or more locomotives, usually diesel, pulling a combination of various types of freight cars. A conventional passenger train is similar to a freight train in that it consists of one or more locomotives pulling several coaches, but one important difference is that the locomotive may either be diesel-electric or all electric (there are also gas turbine locomotives, but these are few in numbers). The third type, rapid transit trains, differs from the others in that there is not a centralized source of propulsion pulling a series of cars, but rather electric motors on the axles of each car.

A diesel locomotive utilizes a diesel engine driving an electrical alternator or generator, which in turn drives electric traction motors on the wheels. An all-electric locomotive, on the other hand, obtains its electrical power from an external source; normally an overhead line or third rail, to drive its traction motors. Having no propulsion system, freight cars and passenger coaches generate noise mainly by the rolling of the wheels on the rails. The magnitude of the noise depends heavily on the condition of the wheels and track, and on the type of vehicle suspension. In regards to rail cars, modern passenger coaches with auxiliary hydraulic suspension systems in addition to normal springs can be about 10 dBA quieter than older passenger coaches or freight cars which have only springs. The noise of rapid transit trains, even though there are electric motors on each axle that are sources of noise, is also predominantly generated by the interaction of the wheels upon the rails. In fact, because rapid transit vehicles are usually newer and have better suspension systems, they are generally quieter than freight cars or passenger coaches. Exhibit I.3-4 shows average noise levels for locomotives, locomotives with mufflers and railcars.

Evidence indicates that jointed tracks exceed noise levels produced by welded tracks by up to 8 dBA. Railway traffic noise can be affected by several other sources, including jointed tracks, as indicated in Exhibit I.3-5. Rail yard noise is usually not an issue due to the size of rail yards and their location in less noise sensitive industrial areas. However, Exhibit I.3-6 includes some average noise levels for different sources of rail yard noise.

Selected Legislation

Federal

Section 17 of the Federal Noise Control Act requires that the EPA set noise emission standards for the equipment and facilities of interstate railroad carriers and establishes that the Secretary of Transportation will enforce them. In order to ensure safety considerations and technological availability, any standard or revision to a standard may be issued only after consulting with the Secretary of Transportation. These standards apply to the equipment's use and maintenance. On December 31, 1975, the EPA issued its first railroad noise regulation. This regulation set noise emission standards for locomotives and rail cars operated by interstate rail carriers. The regulation, which became effective December 31, 1976, set the following noise emission standards for locomotives measured from a distance of 100 feet:

73 dBA at idle;
93 dBA stationary at all other throttle settings; and
96 dBA moving at any speed.

The standards established for rail cars were:

88 dBA up to 46 miles per hour; and
93 dBA greater than 45 miles per hour.

For new locomotives in service after December 31, 1979, the standards set were:

70 dBA at idle;
87 dBA stationary at all other throttle settings; and
90 dBA moving.

In January 1980, the EPA published final noise emission regulations for four railroad noise sources. The regulations, which took effect in January 1984, set additional noise emission standards for rail yard operations and equipment, such as switcher locomotives, retarders, and car coupling.

Local

The Noise Element includes the following guidelines:

- Ensure that any steel track rapid transit system serving the City considers the use of welded rails in preference to jointed rails in order to reduce track vibration noise; and
- Develop a program to encourage railroads to provide noise-attenuating buffers along railroad rights-of-way (ROW) in residential areas.

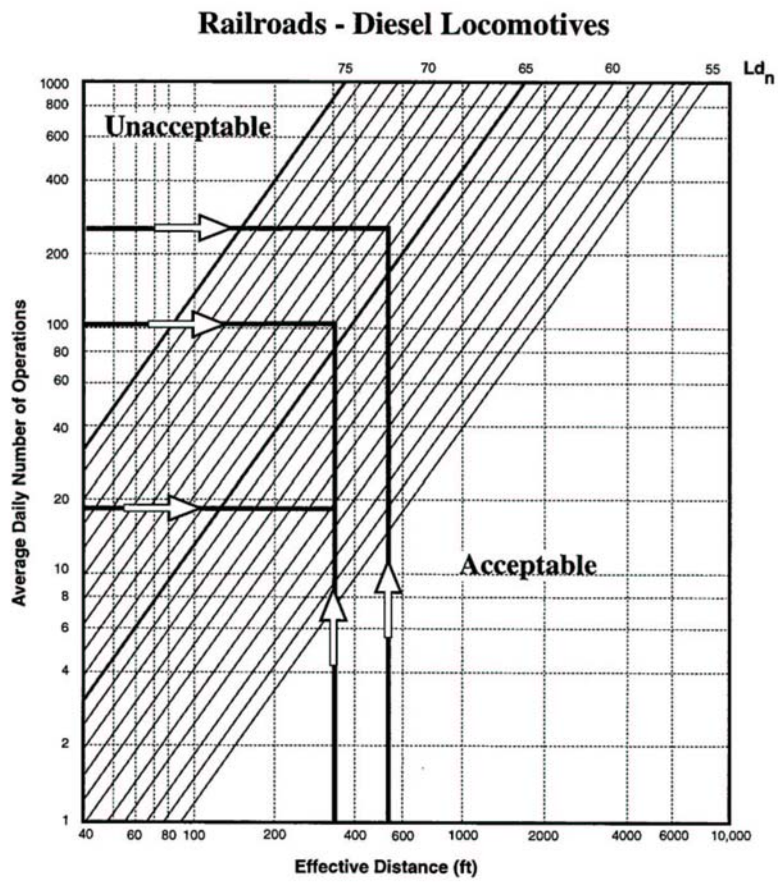

Exhibit I.3-1

Planning
Consultants
Research

FIGURE 1
DIESEL LOCOMOTIVES NOISE

Source: U.S. Department of Housing and Urban Development

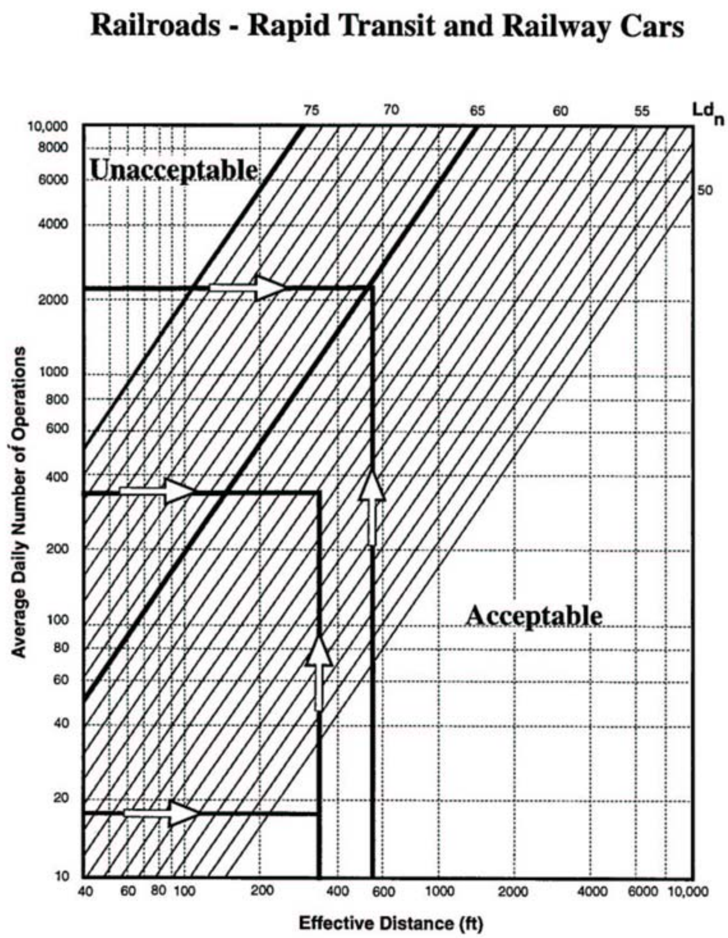

Exhibit I.3-2

Planning Consultants Research

FIGURE 2
ELECTRIC RAPID TRANSIT NOISE

Source: U.S. Department of Housing and Urban Development

Exhibit I.3-3
AVERAGE LOCOMOTIVE, RAILCAR, AND RAPID TRANSIT NOISE LEVELS

Type	Overall Maximum[a] (dBA)
Locomotive	93
Locomotive with Exhaust Muffler	87
Railcar -less than 45 miles per hour (mph)	88
Railcar - over 45 mph	93
Rapid Transit	85

[a] At a distance of 100 feet

Source: EPA, Background Document for Railroad Noise Emission Standards, pages 2-2 to 2-4.

Exhibit I.3-4
VARIABLES AFFECTING RAILCAR WHEEL/RAIL NOISE EMISSION

Variable	Noise Emission[a]
Jointed Rails (vs. Welded)	4 to 8 dBA
Grade Crossings	6 to 8 dBA
Wheel Irregularities – Flat Spots or Built-up Tread	Up to 15 dBA
Bridges	
a. Light Steel Structure	Up to 30 dBA
b. Heavy Steel Structure	Up to 15 dBA
c. Concrete Structure	0 to 12 dBA
Short Radius Curves	
a. Less than 600 foot radius	15 to 25 dBA
b. 600 to 900 foot radius	5 to 15 dBA

[a] These factors are assumed to act individually. When in combinations of two or more, the net increase will not be equal to the sum of each component, but most likely the largest individual factor.

Source: Wyle Laboratories, Assessment of Noise Environments Around Railroad Operations, page 2-3.

Exhibit I.3-5
AVERAGE RAIL YARD NOISE LEVELS

Noise Source	Level (dBA)[a]
Switcher Movement	76 - 80
Car Impact	91
Retarder	94 - 109
Public Address Systems	90 - 95
Engine Load Tests	92
Locomotive Service Racks	79.5
Mechanical Refrigerator Car - Engine Side	71
Mechanical Refrigerator Car - Condenser Side	64
Idling Locomotive	73
Idling Locomotive with Exhaust Muffler	70

[a] At a distance of 100 feet

Source: Wyle Laboratories, Assessment of Noise Environments Around Railroad Operations, pages 4-1 to 4-29.

I.4. AIRPORT NOISE

1. INITIAL STUDY SCREENING PROCESS

A. Initial Study Checklist Questions

XI.a): Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?

XI.b): Exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?

XI.c): A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?

XI.d): A substantial temporary or periodic increase in ambient noise levels in the project vicinity above the existing without the project?

XI.e): For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?

XI.f): For a project within the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?

B. Introduction

New or modified airport and heliport operations and associated aircraft activities may increase existing noise levels and may adversely affect noise-sensitive land uses. The California Department of Transportation's (Caltrans) Division of Aeronautics has developed a set of noise regulations, based on the Federal Aviation Administration's (FAA) Federal Aviation Regulations (FAR), which set noise limits for specific aircraft and provide guidance for land-use compatibility around airports. The effects of airport noise depends on factors such as characteristics of the equipment and operations; distance and pathway between the generator and receptor; and weather. Noise generated due to aircraft flyovers depends upon such variables as type and size of the aircraft (e.g. 2- or 3-engine turbofan versus 4-engine widebody turbofan) and its operating characteristics (primarily its thrust level).

The four airports operated by the City of Los Angeles include Los Angeles International (LAX), Van Nuys, Palmdale, and Ontario. The Burbank-Pasadena-Glendale Airport, due to its proximity to the City, influences the noise environment in some areas of Los Angeles. Noise levels generated by the operation of two other airports within or near the City of Los Angeles, Santa

Monica Municipal Airport and Whiteman Airport, generally do not exceed 65 decibels within the Community Noise Equivalency Level (CNEL) contours, and as such do not strongly influence the City's noise environment.

Environmental noise is measured in decibels (dB). To better approximate the range of sensitivity of the human ear to sounds of different frequencies, the A-weighted decibel scale (dBA) was devised. Because the human ear is less sensitive to low frequency sounds, the A-scale de-emphasizes these frequencies by incorporating frequency weighting of the sound signal. When the A-scale is used, the decibel levels are represented by dBA. On this scale, the range of human hearing extends from about 3 dBA to about 140 dBA. A 10-dBA increase is judged by most people as a doubling of the sound level.

To account for the fluctuation in noise levels over time, noise impacts are commonly evaluated using time-averaged noise levels. CNEL represents an energy average of the A-weighted noise levels over a 24-hour period with 5dBA and 10 dBA penalties added for nighttime noise between the hours of 7:00 p.m. and 10:00 p.m. and 10:00 p.m. to 7:00 a.m., respectively. The penalties were selected to account for reduced ambient noise levels during these time periods and increased human sensitivity to noise during the quieter periods of the day. The Day-Night Sound Level (Ldn), like CNEL, measures noise exposure over a 24-hour period and adds a penalty based on the time or day, although only for late night/early morning hours (10 dBA penalty). Thus, the Ldn measurement is slightly less sensitive than CNEL, but it results in very similar noise ratings for most community settings, usually differing by less than 1 dBA.

For the purpose of airport noise impact analyses, CNEL levels are described as contours. A contour is an interpolation of noise levels drawn to connect all points of a similar level. These contours are displayed on maps and appear similar to topographical contours, forming "footprints" surrounding a noise source.

The FAA regulates noise levels for aircraft at all United States airports. In 1969, FAR Part 36 certified noise levels for specific aircraft. FAR Part 150, Airport Noise Compatibility Planning, which became effective in 1981, provides guidance for land-use compatibility around airports. This FAR established a voluntary program, which provides that airport noise impacts are quantified and made public and that noise compatibility plans and mitigation measures are subject to public review and FAA approval. Part 150 states that in general, residential uses are not compatible within the 65 or above dBA Ldn contour and that all types of land uses are compatible in areas below 65 dBA Ldn. In addition, the FAA's Airport Environmental Handbook indicates that its threshold of significance is a 1.5 dBA Ldn increase in noise in any sensitive area located within the 65 dBA Ldn contour.

The Division of Aeronautics is responsible for granting variances from compliance with state noise laws for airports in California. The Division of Aeronautics has also developed noise regulations, adopted in 1970, which are based in part on the FAR Part 150 guidelines. These regulations state that the aircraft noise level in a residential setting should be no greater than 65 dB CNEL. One of the objectives of the Division of Aeronautics is to create an urban development pattern in which all land included within the 65 dB CNEL contour is devoted to either airport or non-sensitive land uses.

C. Screening Criteria

- If the proposed project includes the construction or expansion of an airport or heliport and has the potential to expose noise-sensitive land uses to high noise levels (through proximity of such land uses to the flight path, etc.), would the project result in an incompatible land use existing within the 65 dB CNEL contour of an airport or heliport?

A "yes" response to the preceding question indicates further study in an expanded Initial Study, Negative Declaration, Mitigated Negative Declaration, or EIR may be required. Refer to the Significance Threshold for Airport Noise and review the associated Methodology to Determine Significance, as appropriate.

A "no" response to the preceding question indicates that there would normally be no significant impact from Airport Noise from the proposed project.

D. Evaluation of Screening Criteria

Review the description of the proposed project, including information on airport activities. Consult a map showing the 65 dB CNEL contour and surrounding land uses. Consider whether potential incompatible land uses have acoustical insulation, an avigation agreement with the airport operator, etc. Operations at commercial airports involving turboprop or piston engine aircraft under 70,000 lbs. have reduced potential to expose sensitive land uses to high noise levels because of the quieter noise levels generated by these aircraft. Compare this information with the screening criteria to determine whether incompatible uses would be located within the 65 dB CNEL contour.

Incompatible land uses include the following[1]:

- Residences, including but not limited to, detached single-family dwellings, multi-family dwellings, high-rise apartments, condominiums and mobile homes, unless:

1 *Division of Aeronautics, Noise Standards (Title 21, Subchapter 6, Article 1) 1990, pages 225-226.*

- An avigation easement[2] for aircraft noise, has been acquired by the airport proprietor;

- A dwelling unit which was in existence at the same location prior to January 1, 1989, and has adequate acoustic insulation to ensure an interior CNEL of 45 dB or less due to aircraft noise in all habitable rooms;

- A residence is a high rise apartment or condominium having an interior CNEL of 45 dB or less in all habitable rooms due to aircraft noise, and an air circulation or air conditioning system, as appropriate;

- A residence exposed to an exterior CNEL less than 80 dB (75 dB if the residence has an exterior normally occupiable private habitable area) where the airport proprietor has made a genuine effort to acoustically treat the residence or acquire avigation easements for the residence involved, or both, but the property owner has refused to take part in the program; or

- A residence which is owned by the airport proprietor;

• Public and private schools of standard construction for which an avigation easement for noise has not been acquired by the airport proprietor, or that do not have adequate acoustic performance to ensure an interior CNEL of 45 dB or less in all classrooms due to aircraft noise;

• Hospitals and convalescent homes for which an avigation easement for noise has not been acquired by the airport proprietor, or that do not have adequate acoustic performance to provide an interior CNEL of 45 dB or less due to aircraft noise in all rooms used for patient care; and

• Churches and other places of worship for which an avigation easement for noise has not been acquired by the airport proprietor or that do not have adequate acoustic performance to ensure an interior CNEL of 45 dB or less due to aircraft noise.

2 *An avigation easement is a legal agreement to purchase the right to fly over a property owner's land without penalty.*

2 DETERMINATION OF SIGNIFICANCE

A. Significance Threshold

A significant impact on ambient noise levels would normally occur if noise levels at a noise sensitive use attributable to airport operations exceed 65 dB CNEL and the project increases ambient noise levels by 1.5 dB CNEL or greater.

B. Methodology to Determine Significance

Environmental Setting

In a description of the environmental setting, include the following:

- Identification of ambient noise levels (existing and future) measured in CNEL. Use the 65 dB CNEL contour map or mathematical models to assess existing (at the expected time of project implementation) noise conditions. Model future noise levels by establishing parameters and assumptions, including aircraft fleet compositions at the airport for which a project is being analyzed, fleet forecasts, appropriate aircraft substitutions, departure profiles, tracks, thrusts settings, operational time of day (day, evening, or night), airport configurations (runway length and location, departure and landing thresholds, etc), and the algorithms used to calculate individual aircraft noise profiles. Use a recognized aircraft noise model, such as one of the following:

  - The Integrated Noise Model (INM), developed by the FAA and used extensively for commercial airports, produces noise contours to geographically demonstrate the location and level of average, weighted noise impacts;

  - The Area Equivalent Method (AEM), developed by the FAA, produces the aggregate area of noise impact without demonstrating the location of specific noise levels; it can be used as a screening tool to determine whether the more sophisticated and time consuming INM is warranted;

  - The Helicopter Noise Model (HNM), developed by the FAA, is used for projects which primarily involve helicopter operations; and

  - The Noise Map, developed by the United States Air Force (USAF), is primarily used to analyze military operations.

- Characterization of noise-sensitive land uses within the 65-dBA contour of airport operations, including the description and location within the contour. Identify noise attenuation devices, avigation easements, and other relevant features of the land uses; and

Project Impacts

Use the information from the Evaluation of Screening Criteria and Environmental Setting and one of the aircraft noise models described above to develop future noise contours. Results from the INM are preferred for commercial airports because of the level of sophistication and detail provided. Identify noise sensitive uses at which noise levels exceed 65 dB CNEL as a result of airport operations. Calculate the increase in ambient noise levels due to project operations at these locations. Compare this information to the Significance Threshold.

Cumulative Impacts

The projection of future baseline ambient noise levels incorporates background increases in noise and airport-related noise from the related projects. Therefore, no new analysis is required.

Sample Mitigation Measures

Possible mitigation measures include the following:

- Redirect air traffic over the ocean (for coastal airports) or over less populated areas;*

- Acquire noise-impacted land. The FAA's Uniform Relocation Assistance and Real Property Acquisition rules and provisions govern land acquisition and relocation assistance;

- Purchase avigation easements;

- Reduce the number of flights during evening and nighttime hours;*

- Increase takeoff angles within safety parameters or reducing thrust settings, depending on proximity and configuration of surrounding land uses;*

- Plan runway utilization schedules to take into account adjacent residential areas, noise characteristics of aircraft, and noise-sensitive time periods;*

- Employ shielding to obstruct the noise path to incompatible uses, using natural terrain, buildings, and other obstructions to noise; and

- Develop compatible land uses within the noise boundary through rezoning, or application of acoustical insulation.

* ***Strategies marked with * require FAA approval***

3. DATA, RESOURCES, AND REFERENCES

Los Angeles World Airports, Van Nuys Airport Noise Control Regulation EIR, 1992.

Los Angeles World Airports, Draft Van Nuys Airport Master Plan, 1995.

Division of Aeronautics, Noise Standards, 1990.

FAA, Airport Environmental Handbook, 1985.

See also I.2. OPERATIONAL NOISE.

Selected Legislation

<u>Federal</u>

FAR, Part 36

Establishes noise standards and provisions for issuing certificates for various types of aircraft. Also, the aircraft must meet the airworthiness regulations constituting the type certification basis of the aircraft under the conditions in which compliance with this part is shown.

FAR, Part 150

Describes the procedures, standards, and methodology governing the development, submission, and review of airport noise exposure maps and airport noise compatibility programs, including the process for evaluating and approving or disapproving those programs. Makes matching funds available for abatement programs.

State

California Airport Noise Standards Act, 1970 (CAC, Title 4)

Implements the FAA airport standards, administered by the State Division of Aeronautics. Requires civilian airports to meet FAA noise standard of 65 dB CNEL at airport boundaries.

CCR, Title 21 (Business Regulations)

Requires airports to monitor noise impacts and report to the County Airport Land Use Commission and State Division of Aeronautics on a quarterly basis.

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EXHIBIT C

Emission Factors for Greenhouse Gas Inventories

Last Modified: 7 November 2011

Typically, greenhouse gas emissions are reported in units of carbon dioxide equivalent (CO_2e). Gases are converted to CO_2e by multiplying by the gas' global warming potential (GWP). The emission factors listed in this sheet have not been converted to CO_2e. In order to do so, multiply the emissions by the corresponding GWP listed in the table below.

Gas	GWP
CH_4	21
N_2O	310

Source:
Intergovernmental Panel on Climate Change (IPCC) (1995); Second Assessment Report.

Table 1 Stationary Combustion Emission Factors

Fuel Type	Heating Value	CO_2 Factor	CH_4 Factor	N_2O Factor	CO_2 Factor	CH_4 Factor	N_2O Factor	Unit
	mmBtu per short ton	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per short ton	g CH_4 per short ton	g N_2O per short ton	
Coal and Coke								
Anthracite Coal	25.09	103.54	11	1.6	2,598	276	40	short tons
Bituminous Coal	24.93	93.40	11	1.6	2,328	274	40	short tons
Sub-bituminous Coal	17.25	97.02	11	1.6	1,674	190	28	short tons
Lignite Coal	14.21	96.36	11	1.6	1,369	156	23	short tons
Mixed (Commercial Sector)	21.39	95.26	11	1.6	2,038	235	34	short tons
Mixed (Electric Power Sector)	19.73	94.38	11	1.6	1,862	217	32	short tons
Mixed (Industrial Coking)	26.28	93.65	11	1.6	2,461	289	42	short tons
Mixed (Industrial Sector)	22.35	93.91	11	1.6	2,099	246	36	short tons
Coke	24.80	102.04	11	1.6	2,531	273	40	short tons
Fossil Fuel-derived Fuels (Solid)								
Municipal Solid Waste	9.95	90.70	32	4.2	902	318	42	short tons
Petroleum Coke (Solid)	30.00	102.41	32	4.2	3,072	960	126	short tons
Plastics	38.00	75.00	32	4.2	2,850	1,216	160	short tons
Tires	26.87	85.97	32	4.2	2,310	860	113	short tons
Biomass Fuels (Solid)								
Agricultural Byproducts	8.25	118.17	32	4.2	975	264	35	short tons
Peat	8.00	111.84	32	4.2	895	256	34	short tons
Solid Byproducts	25.83	105.51	32	4.2	2,725	827	108	short tons
Wood and Wood Residuals	15.38	93.80	32	4.2	1,443	492	65	short tons
	mmBtu per scf	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per scf	g CH_4 per scf	g N_2O per scf	
Natural Gas								
Natural Gas (per scf)	0.001028	53.02	1.0	0.10	0.05450	0.001028	0.000103	scf
Fossil-derived Fuels (Gaseous)								
Blast Furnace Gas	0.000092	274.32	0.022	0.10	0.02524	0.000002	0.000009	scf
Coke Oven Gas	0.000599	46.85	0.480	0.10	0.02806	0.000288	0.000060	scf
Fuel Gas	0.001388	59.00	0.022	0.10	0.08189	0.000031	0.000139	scf
Propane Gas	0.002516	61.46	0.022	0.10	0.15463	0.000055	0.000252	scf
Biomass Fuels (Gaseous)								
Biogas (Captured Methane)	0.000841	52.07	3.200	0.630	0.04379	0.002691	0.000530	scf
	mmBtu per gallon	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per gallon	g CH_4 per gallon	g N_2O per gallon	
Petroleum Products								
Asphalt and Road Oil	0.158	75.36	3.0	0.60	11.91	0.47	0.09	gallon
Aviation Gasoline	0.120	69.25	3.0	0.60	8.31	0.36	0.07	gallon
Butane	0.101	65.15	3.0	0.60	6.58	0.30	0.06	gallon
Butylene	0.103	67.73	3.0	0.60	6.98	0.31	0.06	gallon
Crude Oil	0.138	74.49	3.0	0.60	10.28	0.41	0.08	gallon
Distillate Fuel Oil No. 1	0.139	73.25	3.0	0.60	10.18	0.42	0.08	gallon
Distillate Fuel Oil No. 2	0.138	73.96	3.0	0.60	10.21	0.41	0.08	gallon
Distillate Fuel Oil No. 4	0.146	75.04	3.0	0.60	10.96	0.44	0.09	gallon
Ethane	0.069	62.64	3.0	0.60	4.32	0.21	0.04	gallon
Ethylene	0.100	67.43	3.0	0.60	6.74	0.30	0.06	gallon
Heavy Gas Oils	0.148	74.92	3.0	0.60	11.09	0.44	0.09	gallon
Isobutane	0.097	64.91	3.0	0.60	6.30	0.29	0.06	gallon
Isobutylene	0.103	67.74	3.0	0.60	6.98	0.31	0.06	gallon
Kerosene	0.135	75.20	3.0	0.60	10.15	0.41	0.08	gallon
Kerosene-type Jet Fuel	0.135	72.22	3.0	0.60	9.75	0.41	0.08	gallon
Liquefied Petroleum Gases (LPG)	0.092	62.98	3.0	0.60	5.79	0.28	0.06	gallon
Lubricants	0.144	74.27	3.0	0.60	10.69	0.43	0.09	gallon
Motor Gasoline	0.125	70.22	3.0	0.60	8.78	0.38	0.08	gallon
Naphtha (<401 deg F)	0.125	68.02	3.0	0.60	8.50	0.38	0.08	gallon
Natural Gasoline	0.110	66.83	3.0	0.60	7.35	0.33	0.07	gallon
Other Oil (>401 deg F)	0.139	76.22	3.0	0.60	10.59	0.42	0.08	gallon
Pentanes Plus	0.110	70.02	3.0	0.60	7.70	0.33	0.07	gallon
Petrochemical Feedstocks	0.129	70.97	3.0	0.60	9.16	0.39	0.08	gallon
Petroleum Coke	0.143	102.41	3.0	0.60	14.64	0.43	0.09	gallon
Propane	0.091	61.46	3.0	0.60	5.59	0.27	0.05	gallon
Propylene	0.091	65.95	3.0	0.60	6.00	0.27	0.05	gallon
Residual Fuel Oil No. 5	0.140	72.93	3.0	0.60	10.21	0.42	0.08	gallon
Residual Fuel Oil No. 6	0.150	75.10	3.0	0.60	11.27	0.45	0.09	gallon
Special Naphtha	0.125	72.34	3.0	0.60	9.04	0.38	0.08	gallon
Still Gas	0.143	66.72	3.0	0.60	9.54	0.43	0.09	gallon
Unfinished Oils	0.139	74.49	3.0	0.60	10.35	0.42	0.08	gallon
Used Oil	0.135	74.00	3.0	0.60	9.99	0.41	0.08	gallon
Biomass Fuels								
Biodiesel (100%)	0.128	73.84	1.1	0.11	9.45	0.14	0.01	gallon
Ethanol (100%)	0.084	68.44	1.1	0.11	5.75	0.09	0.01	gallon
Rendered Animal Fat	0.125	71.06	1.1	0.11	8.88	0.14	0.01	gallon
Vegetable Oil	0.120	81.55	1.1	0.11	9.79	0.13	0.01	gallon
	mmBtu per gallon	kg CO2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu				
Steam and Hot Water								
Steam and Hot Water		88.18	8.169	0.603				mmBtu

Sources:

Solid, gaseous, liquid and biomass fuels: Federal Register (2009) EPA*; 40 CFR Parts 86, 87, 89 et al; Mandatory Reporting of Greenhouse Gases; Final Rule*, 30Oct09, 261 pp. Tables C-1 and C-2 at FR pp. 56409-56410. Revised emission factors for selected fuels: Federal Register (2010) EPA; 40 CFR Part 98; Mandatory Reporting of Greenhouse Gases; Final Rule, 17Dec10, 81 pp.

Steam and Hot Water: United States. Energy Information Administration (2010); *Voluntary Reporting of Greenhouse Gases, 1605(b) Program*, Appendix N: Emissions Factors for Steam and Chilled Water.

Table 2 — CO_2 Emissions for Transportation Fuels for Road Vehicles, Locomotives, and Aircraft

Fuel Type	kg CO_2 per unit	Unit
Aviation Gasoline	8.31	gallon
Biodiesel	9.45	gallon
Compressed Natural Gas (CNG)	0.0545	scf
Diesel Fuel	10.21	gallon
Ethane	4.32	gallon
Ethanol	5.75	gallon
Jet Fuel (kerosene type)	9.75	gallon
Liquefied Natural Gas (LNG)	4.46	gallon
LPG	5.79	gallon
Methanol	4.10	gallon
Motor Gasoline	8.78	gallon
Propane	5.59	gallon
Residual Fuel Oil (Resid #5; Bunker C)	11.27	gallon

Sources:

Federal Register (2009) *EPA; 40 CFR Parts 86, 87, 89 et al; Mandatory Reporting of Greenhouse Gases; Final Rule*, 30Oct09, 261 pp. Tables C-1 and C-2 at FR pp. 56409-56410.
LNG sourced from: US EPA (2008); *Greenhouse Gas Inventory Protocol Core Module Guidance - Direct Emissions from Mobile Combustion Sources,* EPA Climate Leaders, Table B-5, p. 33.

Methanol sourced from: The Climate Registry (2011); *General Reporting Protocol for the Voluntary Reporting Program*, Default Emission Factors, Table 13.1 US Default CO2 Emission Factors for Transport Fuels.

Table 3 — CH_4 and N_2O Emissions for Highway Vehicles

Vehicle Type	Year	CH_4 Factor (g / mile)	N_2O Factor (g / mile)
Gasoline Passenger Cars	1984-1993	0.0704	0.0647
	1994	0.0531	0.0560
	1995	0.0358	0.0473
	1996	0.0272	0.0426
	1997	0.0268	0.0422
	1998	0.0249	0.0393
	1999	0.0216	0.0337
	2000	0.0178	0.0273
	2001	0.0110	0.0158
	2002	0.0107	0.0153
	2003	0.0114	0.0135
	2004	0.0145	0.0083
	2005	0.0147	0.0079
	2006	0.0161	0.0057
	2007	0.0170	0.0041
	2008	0.0172	0.0038
	2009-present	0.0173	0.0036
Gasoline Light-duty Trucks (Vans, Pickup Trucks, SUVs)	1987-1993	0.0813	0.1035
	1994	0.0646	0.0982
	1995	0.0517	0.0908
	1996	0.0452	0.0871
	1997	0.0452	0.0871
	1998	0.0391	0.0728
	1999	0.0321	0.0564
	2000	0.0346	0.0621
	2001	0.0151	0.0164
	2002	0.0178	0.0228
	2003	0.0155	0.0114
	2004	0.0152	0.0132
	2005	0.0157	0.0101
	2006	0.0159	0.0089
	2007	0.0161	0.0079
	2008	0.0163	0.0066
	2009-present	0.0163	0.0066
Gasoline Heavy-duty Vehicles	1985-1986	0.4090	0.0515
	1987	0.3675	0.0849
	1988-1989	0.3492	0.0933
	1990-1995	0.3246	0.1142
	1996	0.1278	0.1680
	1997	0.0924	0.1726
	1998	0.0641	0.1693
	1999	0.0578	0.1435
	2000	0.0493	0.1092
	2001	0.0528	0.1235
	2002	0.0546	0.1307
	2003	0.0533	0.1240
	2004	0.0341	0.0285
	2005	0.0326	0.0177
	2006	0.0326	0.0175
	2007	0.0327	0.0173
	2008	0.0327	0.0171
	2009-present	0.0327	0.0169

Sources:

1984-2005 factors from: US EPA (2008); *Greenhouse Gas Inventory Protocol Core Module Guidance - Direct Emissions from Mobile Combustion Sources*, EPA Climate Leaders, Table 3.
2006-2009 factors from: US EPA (2011) *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009, EPA 430-R-11-005*. All Values are calculated from Tables A-97 through A-100.

Table 4 — CH_4 and N_2O Emissions for Highway Vehicles: Diesel and Alternative Fuels

Vehicle Type	Vehicle Year	CH_4 Factor (g / mile)	N_2O Factor (g / mile)
Diesel Passenger Cars	1960-1982	0.0006	0.0012
	1983-present	0.0005	0.0010
Diesel Light-duty Trucks	1960-1982	0.0011	0.0017
	1983-1995	0.0009	0.0014
	1996-present	0.0010	0.0015
Diesel Heavy-duty Vehicles	1960-present	0.0051	0.0048
Gasoline Motorcycles (Non-Catalyst)	Non-catalyst Control	0.0672	0.0069
Gasoline Motorcycles (Uncontrolled)	Uncontrolled	0.0899	0.0087
CNG Light-duty Vehicles		0.737	0.050
CNG Heavy-duty Vehicles		1.966	0.175
CNG Buses		1.966	0.175
LPG Light-duty Vehicles		0.037	0.067
LPG Heavy-duty Vehicles		0.066	0.175
LNG Heavy-duty Vehicles		1.966	0.175
Ethanol Light-duty Vehicles		0.055	0.067
Ethanol Heavy-duty Vehicles		0.197	0.175
Ethanol Buses		0.197	0.175

Source:
US EPA (2008); *Greenhouse Gas Inventory Protocol Core Module Guidance - Direct Emissions from Mobile Combustion Sources*, EPA Climate Leaders, Table 3.

Table 5 — CH_4 and N_2O Emissions for Non-highway Vehicles

Vehicle Type	CH_4 Factor (g / gallon)	N_2O Factor (g / gallon)
LPG Non-Highway Vehicles	0.50	0.22
Residual Oil Ships and Boats	0.86	0.30
Diesel Ships and Boats	0.74	0.26
Gasoline Ships and Boats	0.64	0.22
Diesel Locomotives	0.80	0.26
Gasoline Agricultural Equip.	1.26	0.22
Diesel Agricultural Equip.	1.44	0.26
Gasoline Construction Equip.	0.50	0.22
Diesel Construction Equip.	0.58	0.26
Jet Fuel Aircraft	0.27	0.31
Aviation Gasoline Aircraft	7.04	0.11
Biodiesel Vehicles	0.58	0.26
Other Diesel Sources	0.58	0.26
Other Gasoline Sources	0.50	0.22

Note:
LPG non-highway vehicles assumed equal to other gasoline sources. Biodiesel vehicles assumed equal to other diesel sources.

Source:
US EPA (2008); *Greenhouse Gas Inventory Protocol Core Module Guidance - Direct Emissions from Mobile Combustion Sources*, EPA Climate Leaders, Tables A-6 and A-7.

Table 6 — Refrigerants and Global Warming Potentials (GWPs)

Gas	GWP
CO_2	1
CH_4	21
N_2O	310
SF_6	23,900
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
CF_4	6,500
C_2F_6	9,200
C_3F_8	7,000
$c\text{-}C_4F_8$	8,700
C_4F_{10}	7,000
C_5F_{12}	7,500
C_6F_{14}	7,400

Source:
Intergovernmental Panel on Climate Change (IPCC) (1995); *Second Assessment Report*. Use of the Second Assessment Report on Global Warming Potential v alues is consistent with current international agreements.

Table 6b	Blended Refrigerants (ASHRAE #)

ASHRAE #	Blend GWP HFC/PFC	Blend Make-up
R - 401A	18.2	53% HCFC-22 , 34% HCFC-124 , 13% HFC-152a
R - 401B	15.4	61% HCFC-22 , 28% HCFC-124 , 11% HFC-152a
R - 401C	21	33% HCFC-22 , 52% HCFC-124 , 15% HFC-152a
R - 402A	1,680	38% HCFC-22 , 6% HFC-125 , 2% propane
R - 402B	1,064	6% HCFC-22 , 38% HFC-125 , 2% propane
R - 403B	2,730	56% HCFC-22 , 39% PFC-218 , 5% propane
R - 404A	3,260	44% HFC-125 , 4% HFC-134a , 52% HFC 143a
R - 406A	-	55% HCFC-22 , 41% HCFC-142b , 4% isobutane
R - 407A	1,770	20% HFC-32 , 40% HFC-125 , 40% HFC-134a
R - 407B	2,285	10% HFC-32 , 70% HFC-125 , 20% HFC-134a
R - 407C	1,525.5	23% HFC-32 , 25% HFC-125 , 52% HFC-134a
R - 407D	1,427.5	15% HFC-32 , 15% HFC-125 , 70% HFC-134a
R - 407E	1,362.5	25% HFC-32 , 15% HFC-125 , 60% HFC-134a
R - 408A	1,944	47% HCFC-22 , 7% HFC-125 , 46% HFC 143a
R - 409A	-	60% HCFC-22 , 25% HCFC-124 , 15% HCFC-142b
R - 410A	1,725	50% HFC-32 , 50% HFC-125
R - 410B	1,832.5	45% HFC-32 , 55% HFC-125
R - 411A	15.4	87.5% HCFC-22 , 11 HFC-152a , 1.5% propylene
R - 411B	4.2	94% HCFC-22 , 3% HFC-152a , 3% propylene
R - 413A	1,774	88% HFC-134a , 9% PFC-218 , 3% isobutane
R - 414A	-	51% HCFC-22 , 28.5% HCFC-124 , 16.5% HCFC-142
R - 414B	-	5% HCFC-22 , 39% HCFC-124 , 9.5% HCFC-142b
R - 417A	1,954.8	46.6% HFC-125 , 5% HFC-134a , 3.4% butane
R - 422A	2,532.3	85.1% HFC-125 , 11.5% HFC-134a , 3.4% isobutane
R - 422D	2,232.3	65.1% HFC-125 , 31.5% HFC-134a , 3.4% isobutane
R - 423A	2,060	47.5% HFC-227ea , 52.5% HFC-134a ,
R - 424A	2,011	Mixture of: HFC-125 , HFC-134a , butane, pentane.
R - 426A	1,349	Mixture of: HFC-125 , HFC-134a , butane, pentane.
R - 428A	2,930	77.5% HFC-125 , 2% HFC-143a , 1.9% isobutane
R - 434A	2,652	Mixture of: HFC-125 , HFC-134a , HFC-143a. GWP
R - 500	36.7	73.8% CFC-12 , 26.2% HFC-152a , 48.8% HCFC-22
R - 502	-	48.8% HCFC-22 , 51.2% CFC-115
R - 504	313.3	48.2% HFC-32 , 51.8% CFC-115
R - 507	3,300	5% HFC-125 , 5% HFC143a
R - 508A	10,175	39% HFC-23 , 61% PFC-116
R - 508B	10,350	46% HFC-23 , 54% PFC-116

Source:
Intergovernmental Panel on Climate Change (IPCC) (1995); *Second Assessment Report*. Use of the Second Assessment Report on Global Warming Potential v alues is consistent with current international agreements.

The blended refrigerants are based on internet research to determine the constituents, and the GWP is based on the blend of HFC and PFC gases.

Table 7	Electricity Emission Factors (System Average)

Subregion	CO_2 Factor ($lb\ CO_2$ /MWh)	CH_4 Factor ($lb\ CH_4$ /MWh)	N_2O Factor ($lb\ N_2O$ /MWh)
AKGD (ASCC Alaska Grid)	1,284.72	0.02711	0.00744
AKMS (ASCC Miscellaneous)	535.73	0.02265	0.00448
AZNM (WECC Southwest)	1,252.61	0.01880	0.01657
CAMX (WECC California)	681.01	0.02829	0.00623
ERCT (ERCOT All)	1,252.57	0.01776	0.01399
FRCC (FRCC All)	1,220.11	0.04119	0.01525
HIMS (HICC Miscellaneous)	1,343.82	0.13515	0.02171
HIOA (HICC Oahu)	1,620.76	0.09105	0.02089
MROE (MRO East)	1,692.32	0.02879	0.02905
MROW (MRO West)	1,722.67	0.02897	0.02919
NEWE (NPCC New England)	827.95	0.07698	0.01520
NWPP (WECC Northwest)	858.79	0.01634	0.01364
NYCW (NPCC NYC/Westchester)	704.80	0.02622	0.00335
NYLI (NPCC Long Island)	1,418.74	0.09050	0.01310
NYUP (NPCC Upstate NY)	683.27	0.01741	0.00990
RFCE (RFC East)	1,059.32	0.02740	0.01703
RFCM (RFC Michigan)	1,651.11	0.03255	0.02779
RFCW (RFC West)	1,551.52	0.01837	0.02593
RMPA (WECC Rockies)	1,906.06	0.02363	0.02889
SPNO (SPP North)	1,798.71	0.02122	0.02920
SPSO (SPP South)	1,624.03	0.02452	0.02242
SRMV (SERC Mississippi Valley)	1,004.10	0.02180	0.01115
SRMW (SERC Midwest)	1,779.27	0.02057	0.02960
SRSO (SERC South)	1,495.47	0.02364	0.02457
SRTV (SERC Tennessee Valley)	1,540.85	0.01987	0.02548
SRVC (SERC Virginia/Carolina)	1,118.41	0.02226	0.01908

Source:
US EPA (2011); eGRID2010 Version 1.1 Year 2007 Data.

This is a representational map; many of the boundaries shown on this map are approximate because they are based on companies; not on strictly geographical boundaries.
Source:
USEPA eGRID2010 Version 1.0 December 2010.

Table 7b Electricity Emission Factors (Non-baseload); Used for Green Power / REC Calculations

Subregion	CO_2 Factor (lb CO_2/MWh)	CH_4 Factor (lb CH_4/MWh)	N_2O Factor (lb N_2O/MWh)
AKGD (ASCC Alaska Grid)	1,363.19	0.03499	0.00695
AKMS (ASCC Miscellaneous)	1,462.30	0.06168	0.01218
AZNM (WECC Southwest)	1,211.84	0.02056	0.00931
CAMX (WECC California)	1,045.30	0.03942	0.00474
ERCT (ERCOT All)	1,096.19	0.01969	0.00563
FRCC (FRCC All)	1,286.41	0.04340	0.01150
HIMS (HICC Miscellaneous)	1,645.57	0.12294	0.02133
HIOA (HICC Oahu)	1,630.89	0.10618	0.01852
MROE (MRO East)	1,905.18	0.03525	0.02998
MROW (MRO West)	1,988.69	0.05359	0.03298
NEWE (NPCC New England)	1,204.91	0.06069	0.01341
NWPP (WECC Northwest)	1,279.58	0.04331	0.01575
NYCW (NPCC NYC/Westchester)	1,234.06	0.03765	0.00488
NYLI (NPCC Long Island)	1,397.80	0.04408	0.00699
NYUP (NPCC Upstate NY)	1,384.20	0.03155	0.01619
RFCE (RFC East)	1,671.96	0.03329	0.02219
RFCM (RFC Michigan)	1,803.64	0.03209	0.02733
RFCW (RFC West)	1,982.05	0.02430	0.03148
RMPA (WECC Rockies)	1,554.38	0.02317	0.01645
SPNO (SPP North)	1,958.22	0.02540	0.02775
SPSO (SPP South)	1,435.24	0.02503	0.01314
SRMV (SERC Mississippi Valley)	1,171.05	0.02825	0.00691
SRMW (SERC Midwest)	1,945.66	0.02402	0.02969
SRSO (SERC South)	1,551.05	0.02850	0.02169
SRTV (SERC Tennessee Valley)	1,917.25	0.02598	0.03005
SRVC (SERC Virginia/Carolina)	1,661.11	0.03801	0.02451
US Average	1,520.21	0.03223	0.01841

Source:
US EPA (2011); eGRID2010 Version 1.1 Year 2007 Data.

Table 8 Business Travel Emission Factors

Vehicle Type	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Passenger Car	0.364	0.031	0.032	vehicle-mile
Light-duty Truck	0.519	0.036	0.047	vehicle-mile
Motorcycle	0.167	0.070	0.007	vehicle-mile
Intercity Rail (i.e. Amtrak)	0.185	0.002	0.001	passenger-mile
Commuter Rail	0.172	0.002	0.001	passenger-mile
Transit Rail (i.e. Subway, Tram)	0.163	0.004	0.002	passenger-mile
Bus	0.107	0.0006	0.0005	passenger-mile
Air Travel - Short Haul (< 300 miles)	0.286	0.0084	0.0091	passenger-mile
Air Travel - Medium Haul (>= 300 miles, < 2300 miles)	0.168	0.0009	0.0053	passenger-mile
Air Travel - Long Haul (>= 2300 miles)	0.194	0.0009	0.0061	passenger-mile

Sources:
US EPA (2008); *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Optional Emissions from Employee Commuting, Business Travel and Product Transport.*

Air travel sourced from: Department for Environment Food and Rural Affairs (2011); *2011 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. Status Final;* Version 1.0; updated July 7, 2011.

Table 9 Product Transport Emission Factors

Vehicle Type	CO_2 Factor	CH_4 Factor	N_2O Factor	Units
Medium- and Heavy-duty Truck	1.726	0.021	0.017	vehicle-mile
Passenger Car	0.364	0.031	0.032	vehicle-mile
Light-duty Truck	0.519	0.036	0.047	vehicle-mile
Truck	0.297	0.0035	0.0027	ton-mile
Rail	0.0252	0.002	0.0006	ton-mile
Waterborne Craft	0.048	0.0041	0.0014	ton-mile
Aircraft	1.527	0.0417	0.0479	ton-mile

Source:
Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Optional Emissions from Employee Commuting, Business Travel and Product Transport (May 2008).

EXHIBIT D

IEA STATISTICS

2012 EDITION

CO_2 EMISSIONS FROM FUEL COMBUSTION

HIGHLIGHTS

International Energy Agency

2012

EDITION

CO_2 EMISSIONS FROM FUEL COMBUSTION

HIGHLIGHTS

In the lead-up to the UN climate negotiations in Doha, the latest information on the level and growth of CO_2 emissions, their source and geographic distribution will be essential to lay the foundation for a global agreement. To provide input to and support for the UN process the IEA is making available for free download the "Highlights" version of *CO_2 Emissions from Fuel Combustion.*

This annual publication contains:

- estimates of CO_2 emissions by country from 1971 to 2010;
- selected indicators such as CO_2/GDP, CO_2/capita, CO_2/TPES and CO_2/kWh; and
- CO_2 emissions from international marine and aviation bunkers, and other relevant information.

The eighteenth session of the Conference of the Parties to the Climate Change Convention (COP 18), in conjunction with the eighth meeting of the Parties to the Kyoto Protocol (CMP 8), will be meeting in Doha, Qatar from 26 November to 7 December 2012. This volume of "Highlights", drawn from the full-scale study, was specially designed for delegations and observers of the meeting in Doha.

2012 EDITION

CO_2 EMISSIONS FROM FUEL COMBUSTION

HIGHLIGHTS

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea (Republic of)
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA.

International Energy Agency

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www.iea.org

FOREWORD

In the lead-up to the UN climate negotiations in Doha, Qatar, the latest information on the level and growth of CO_2 emissions, their source and geographic distribution will be essential to lay the foundation for a global agreement. To provide input to and support for the UN process, the IEA is making available for free download – the "Highlights" version of *CO_2 Emissions from Fuel Combustion*. The PDF publication and an EXCEL file with the tables can be downloaded for free at *www.iea.org/co2highlights*.

Recent years have witnessed a fundamental change in the way governments approach energy-related environmental issues. Promoting sustainable development and combating climate change have become integral aspects of energy planning, analysis and policy making in many countries, including all IEA member states.

The purpose of this volume is to put our best and most current information in the hands of those who need it, including in particular the participants in the UNFCCC process. The IEA Secretariat is a contributor to the official Intergovernmental Panel on Climate Change (IPCC) methodologies for estimating greenhouse-gas emissions. The IEA's energy data are the figures most often cited in the field. For these reasons, we felt it appropriate to publish this information in a comprehensive form.

These data are only for energy-related CO_2, not for any other greenhouse gases. Thus they may differ from countries' official submissions of emissions inventories to the UNFCCC Secretariat. However, the full-scale study contains data for CO_2 from non-energy-related sources and gas flaring, and emissions of CH_4, N_2O, HFC, PFC and SF_6. In addition, the full-scale study also includes information on "Key Sources" from fuel combustion, as developed in the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*.

This report is published under my responsibility as Executive Director of the IEA and does not necessarily reflect the views of IEA member countries.

Maria Van der Hoeven
Executive Director

What's New?

Electricity-only emission factors

In previous editions of this publication, the IEA has published an indicator for CO_2 emissions per kWh for the electricity and heat generating industries. This indicator was useful as an overall carbon intensity measure of a country's electricity and heat generating sectors, and it was easy to calculate. However, this indicator had a number of drawbacks and the IEA received many requests for electricity-only emission factors.

We are pleased to announce that starting with this edition, we have replaced the former indicator with an electricity-only factor expressed in grammes of CO_2 per kWh. For a complete description of the methodology used to estimate this indicator, please see Chapter 4.

Country/territory coverage

Starting with this edition, Kosovo and Montenegro are now available separately. Data for Kosovo are available starting in 2000. Between 1990 and 1999, data for Kosovo are included in Serbia. Prior to 1990, they are included in Former Yugoslavia. Data for Montenegro are available starting in 2005. Between 1990 and 2004, data for Montenegro are included in Serbia. Prior to 1990, they are included in Former Yugoslavia.

The IEA has also made some small changes in the terminology of countries and regions. The region Latin America and the region Other Latin America have been renamed Non-OECD Americas and Other Non-OECD Americas.

Subsequent to the release of the 2012 edition of the *CO_2 emissions from fuel combustion* publication an error was detected in the calculation used to produce the indicator on CO_2 emissions per kWh from electricity generation. This meant that for certain countries/regions an incorrect CO_2 emission amount was used in the calculation. These indicators were recalculated in March 2013 and a corrigendum was released.

TABLE OF CONTENTS

Important cautionary notes

The estimates of CO_2 emissions from fuel combustion presented in this publication are calculated using the IEA energy balances and the default methods and emission factors from the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.* There are many reasons why **the IEA Secretariat estimates may not be the same as the numbers that a country submits to the UNFCCC**, even if a country has accounted for all of its energy use and correctly applied the *IPCC Guidelines*.

In this publication, the IEA Secretariat presents CO_2 emissions calculated using both the IPCC Reference Approach and the IPCC Tier 1 Sectoral Approach. In some of the OECD non-member countries, there can be **large differences between the two sets of calculations** due to various problems in some energy data. As a consequence, this can lead to different emission trends between 1990 and 2009 for certain countries. Please see Chapter 3 for further details.

Energy data on OECD member and non-member countries[1] are collected by the Energy Data Centre (EDC) of the IEA Secretariat, headed by Jean-Yves Garnier. The IEA would like to thank and acknowledge the dedication and professionalism of the statisticians working on energy data in the countries. Karen Tréanton, with the assistance of Aidan Kennedy, is responsible for the estimates of CO_2 emissions from fuel combustion. Alex Blackburn developed the new indicator for CO_2 emissions per kWh. Desktop publishing support was provided by Sharon Burghgraeve.

CO_2 emission estimates from 1960 to 2010 for the Annex II countries and from 1971 to 2010 for all other countries are available on CD-ROM suitable for use on Windows-based systems. To order, please see the information provided at the end of this publication.

In addition, a data service is available on the Internet. It includes unlimited access through an annual subscription as well as the possibility to obtain data on a pay-per-view basis. Details are available at *www.iea.org*.

Enquiries about data or methodology should be addressed to:

Karen Tréanton:
Telephone: (+33-1) 40-57-66-33,
E-mail: emissions@iea.org.

1. This document is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area. In this publication, “country” refers to a country or a territory, as the case may be.

1. SNAPSHOT OF CO_2 EMISSIONS

Latest developments in 2010[2] (and beyond)

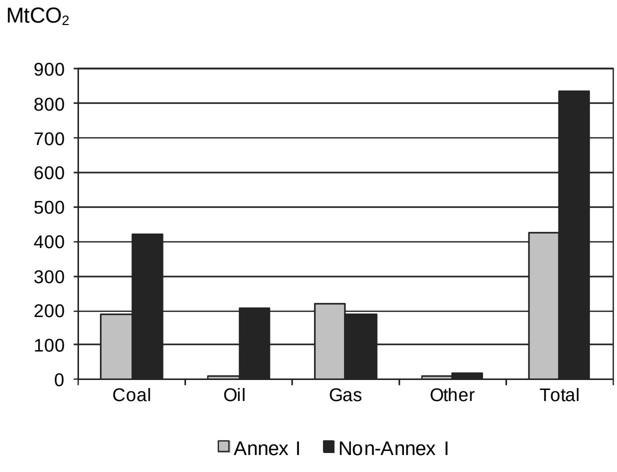
Global CO_2 emissions rose by 4.6% in 2010, after having declined in 2009 due to the impact of the financial crisis, in particular on Western economies. Emissions in Annex I[3] countries increased by 3.3% in 2010 after falling sharply in 2009, while emissions in non-Annex I countries continued to increase rapidly (5.6%). A more positive long-term assessment shows that, collectively, emissions in Annex I countries were 3.7% below their 1990 level, while emission levels for the group of countries participating in the Kyoto Protocol were 12.4% below their 1990 level.

In absolute terms, global CO_2 emissions increased by 1.3 $GtCO_2$ between 2009 and 2010. However, growth rates by region varied greatly: emissions in Latin America[4], Asia and China grew strongly (6.0% to 6.5%), while as mentioned above, emissions in Annex I countries grew at a more modest rate (3.3%). Africa was the only region where emissions did not increase in 2010 (-0.1%). Due to these differing growth rates, the share of total emissions (excluding bunkers) for non-Annex I countries increased slightly to just over 54% (their share surpassed that of Annex I countries for the first time in 2008).

The changes were not equal across fuels, regions and sectors. The 0.4-$GtCO_2$ increase in emissions for Annex I countries was primarily due to similar increases in gas and coal demand (demand for oil was almost static). By contrast, the 0.8-$GtCO_2$ increase in emissions for non-Annex I countries was more spread out: 50% from coal, 25% from oil and 23% from natural gas (Figure 1).

Early indications suggest that CO_2 emissions in developing countries in 2011 continued to increase at a faster rate than in the Annex I countries, mainly as a result of growing fossil fuel consumption in some of the larger countries.

Figure 1. Global change in CO_2 emissions (2009-10)



Key point: CO_2 emissions increased in both Annex I and non-Annex I countries in 2010; however, the source of the emissions growth varied.

2. Energy consumption in 2009 was affected by the global financial crisis and some of the CO_2 emission trends seen may be deceptive.

3. The Annex I Parties to the 1992 UN Framework Convention on Climate Change (UNFCCC) are: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, the Czech Republic, Denmark, Estonia, European Economic Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lichtenstein, Lithuania, Luxembourg, Malta, Monaco, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom and United States. See *www.unfccc.int*. For country coverage of Annex I EIT and Annex II, see Geographical Coverage.

4. For the purposes of this discussion, Latin America includes non-OECD Americas and Chile.

In the medium term, in its New Policies Scenario, the *World Energy Outlook (WEO 2012)*[5] projects that global CO_2 emissions from fuel combustion will continue to grow unabated, albeit at a lower rate, reaching 37.0 $GtCO_2$ by 2035, compared to 30.3 $GtCO_2$ in 2010. This is an improvement over the WEO Current Policies Scenario and in line with the worst-case scenario presented by the Intergovernmental Panel on Climate Change (IPCC)[6] in the *Fourth Assessment Report* (2007), which projects that emissions will stimulate a world average temperature increase of between 2.4°C and 6.4°C by 2100.

CO_2 emissions by fuel

In 2010, 43% of CO_2 emissions from fuel combustion were produced from coal, 36% from oil and 20% from gas. Growth of these fuels in 2010 was quite different, reflecting varying trends that are expected to continue (Figure 2).

Between 2009 and 2010, CO_2 emissions from the combustion of coal increased by 4.9% and represented 13.1 $GtCO_2$. Currently, coal fills much of the growing energy demand of those developing countries (such as China and India) where energy-intensive industrial production is growing rapidly and large coal reserves exist with limited reserves of other energy sources. Without additional abatement measures, the *WEO 2012* projects that emissions from coal will grow to 15.3 $GtCO_2$ in 2035. However, adopting a pathway towards limiting the long-term temperature increase to 2°C as in the *WEO 2012* 450 Scenario – through use of more efficient plants and end-use technologies as well as increased use of renewables, nuclear and carbon capture and storage (CCS) technologies – could see coal consumption drop and CO_2 emissions from coal reduced to 5.6 Gt by 2035. *Energy Technology Perspectives 2012 (ETP 2012)* also shows that intensified use of coal would substantially increase CO_2 emissions unless there was a very widespread deployment of CCS.

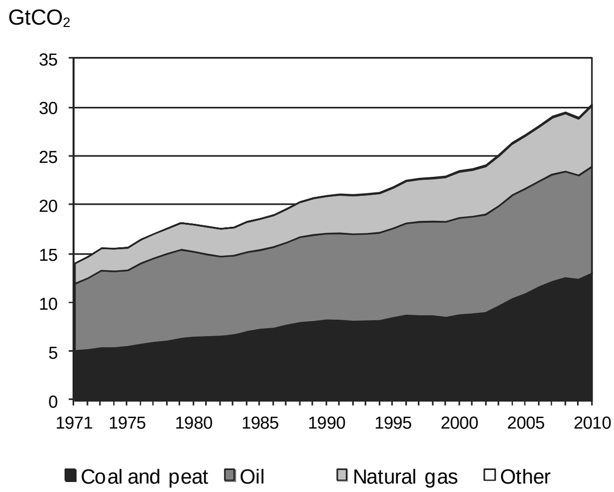
5. Unless otherwise specified, projections from the *World Energy Outlook* refer to the New Policies Scenario from the 2012 edition. This scenario takes account of the broad policy commitments and plans that have been announced by countries around the world, including national pledges to reduce GHG emissions and plans to phase out fossil-energy subsidies – even where the measures to implement these commitments have yet to be identified or announced. These commitments are assumed to be implemented in a relatively cautious manner, reflecting their non-binding character and, in many cases, the uncertainty shrouding how they are to be put into effect.

6. The IPCC was created in 1988 by the World Meteorological Organisation and the United Nations Environment Programme to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts, and options for adaptation and mitigation.

CO_2 emissions from oil represented 10.9 $GtCO_2$ in 2010, an increase of 2.7%. The decreasing share of oil in total primary energy supply (TPES), as a result of the growth of coal and the penetration of gas, limited the increase of CO_2 emissions from oil. *WEO 2012* projects, however, that emissions from oil will grow to 12.6 $GtCO_2$ in 2035, principally due to increased transport demand.

Emissions of CO_2 from gas in 2010 represented 6.2 $GtCO_2$, 7.1% higher than in the previous year. Again, the *WEO 2012* projects emissions from gas will continue to grow, rising to 9.2 $GtCO_2$ in 2035.

Figure 2. CO_2 emissions by fuel



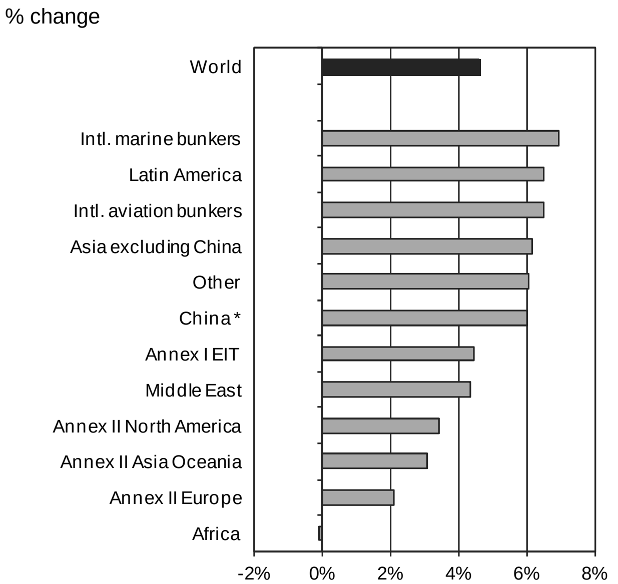
Key point: Combustion of coal has driven the growth in global emissions in recent years. Although there was a decline in 2009 due to the financial crisis, this anomaly was short term and the trend has returned to its previous trajectory.

CO_2 emissions by region

Between 2009 and 2010, CO_2 emissions increased in all regions except Africa, however, growth rates varied among regions. As mentioned earlier, CO_2 emissions from non-Annex I countries grew by 5.6%, while those of Annex I countries rose by a more modest 3.3%, having decreased in 2009. As a result, the gap between the aggregate emissions of non-Annex I countries and Annex I countries continued to grow.

At the regional level (Figure 3), between 2009 and 2010, CO_2 emissions increased significantly in Latin America (6.5%), Asia excluding China (6.1%) and China (6.0%). CO_2 emissions increased at a lower rate in Annex II regions, ranging from 2.1% in Annex II Europe to 3.4% in Annex II North America. Emissions in Africa remained stable.

Figure 3. Change in CO_2 emissions by region (2009-10)

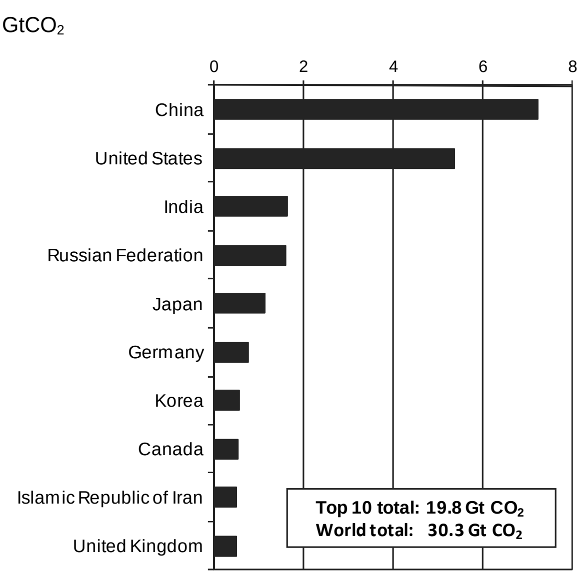


* China includes Hong Kong.

Key point: Between 2009 and 2010, CO_2 emissions grew in all regions with the exception of Africa.

Regional differences in contributions to global emissions conceal even larger differences among individual countries.

Figure 4. Top 10 emitting countries in 2010



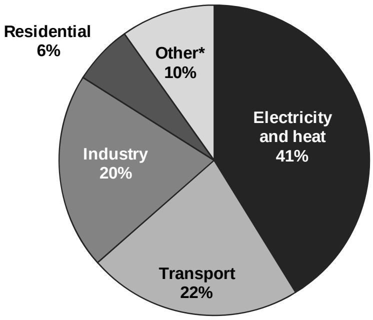
Key point: The top 10 emitting countries account for nearly two-thirds of the world CO_2 emissions.

Nearly two-thirds of global emissions for 2010 originated from just ten countries, with the shares of China (23.8%) and the United States (17.7%) far surpassing those of all others. Combined, these two countries alone produced 12.6 $GtCO_2$, 41.5% of world CO_2 emissions (Figure 4).

CO_2 emissions by sector

Two sectors produced nearly two-thirds of global CO_2 emissions in 2010: electricity and heat generation accounted for 41% while transport produced 22% (Figure 5).

Figure 5. World CO_2 emissions by sector in 2010



* Other includes commercial/public services, agriculture/forestry, fishing, energy industries other than electricity and heat generation, and other emissions not specified elsewhere.

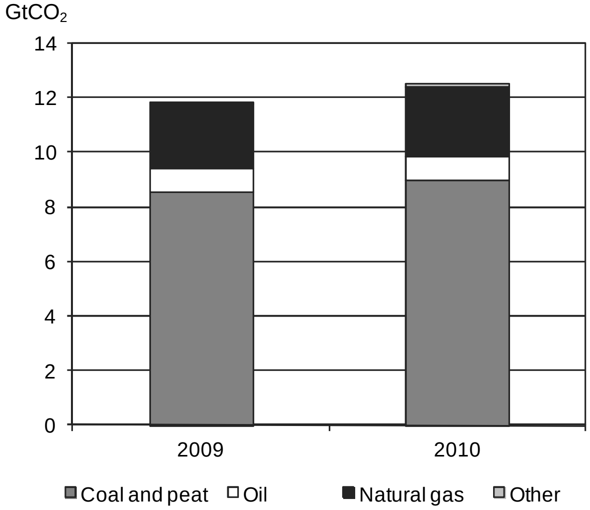
Key point: The combined share of electricity and heat generation and transport represented nearly two-thirds of global emissions in 2010.

Generation of electricity and heat was by far the largest producer of CO_2 emissions and was responsible for 41% of world CO_2 emissions in 2010. Worldwide, this sector relies heavily on coal, the most carbon-intensive of fossil fuels, amplifying its share in global emissions. Countries such as Australia, China, India, Poland and South Africa produce between 68% and 94% of their electricity and heat through the combustion of coal.

Between 2009 and 2010, total CO_2 emissions from the generation of electricity and heat increased by 5.6% (Figure 6), while the fuel mix remained unchanged. CO_2 emissions from oil increased the least, by 0.3%, while more substantial increases were seen for coal (4.7%) and gas (9.5%). Future development of the emissions intensity of this sector depends strongly on the fuels used to generate electricity and on the share of non-emitting sources, such as renewables and nuclear as well as fossil-fuel plants equipped with CCS.

By 2035, the *WEO 2012* projects that demand for electricity will be more than 70% higher than current demand. This demand will be driven by rapid growth in population and income in developing countries, by the continuing increase in the number of electrical devices used in homes and commercial buildings, and by the growth in electrically driven industrial processes. Meanwhile, renewables-based electricity generation is expected to continue growing over the next 25 years, benefiting from government support, declining investment costs and rising fossil-fuel prices. Under the three scenarios, the share of renewables in total electricity generation rises from 20% in 2010 to 24% (Current Policies), 31% (New Policies) and 48% (450 Scenario).

Figure 6. CO_2 emissions from electricity and heat generation* in 2009 and 2010



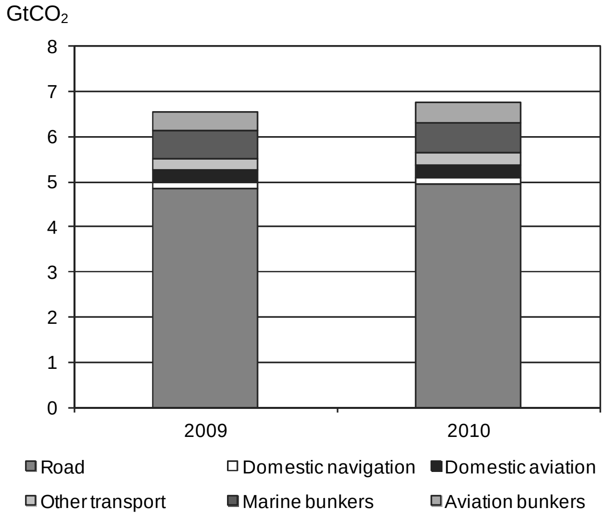
* Refers to main activity producers and autoproducers of electricity and heat.

Key point: CO_2 emissions from electricity and heat generation increased between 2009 and 2010, after having decreased slightly the previous year.

As mentioned above, transport, the second-largest sector in terms of emissions, represented 22% of global CO_2 emissions in 2010, reflecting an increase of 3.0% between 2009 and 2010 (Figure 7). Almost three-quarters of the emissions from transport were due to road.

The United States has the highest level of passenger travel per capita in the world (more than 25 000 km per person per year). Until recently, lower fuel prices in the United States contributed to the use of larger vehicles, while in Europe higher fuel prices encouraged improved fuel economy. As a result, there is more than a 50% variation in the average fuel consumption of new light-duty vehicles across OECD member countries. This is rapidly evolving as most OECD countries now have adopted fleet average fuel economy standards, leading to fast improvements of the average fuel economy (Table 13.1, p. 439, *ETP 2012*).

Figure 7. CO_2 emissions from transport in 2009 and 2010



Key point: CO_2 emissions from road make up the vast majority of emissions from transport.

Global demand for transport appears unlikely to decrease in the foreseeable future; the *WEO 2012* projects that transport fuel demand will grow by nearly 40% by 2035. To limit emissions from this sector, policy makers should implement measures to encourage or require improved vehicle efficiency, as the United States has recently done and the European Union is currently doing as a follow-up to the voluntary agreements. Policies that encourage a shift from cars to public transportation and to lower-emission modes of transportation can also help. Finally, policies can encourage a shift to new, preferably low-carbon fuels. These include electricity (*e.g.* electric and plug-in hybrid vehicles), hydrogen (*e.g.* through the introduction of fuel cell vehicles) and greater use of biofuels (*e.g.* as a blend in gasoline and diesel fuel). To avoid a rebound in transport fuel demand, these moves must also be backed up by emissions pricing or fuel excise policies.

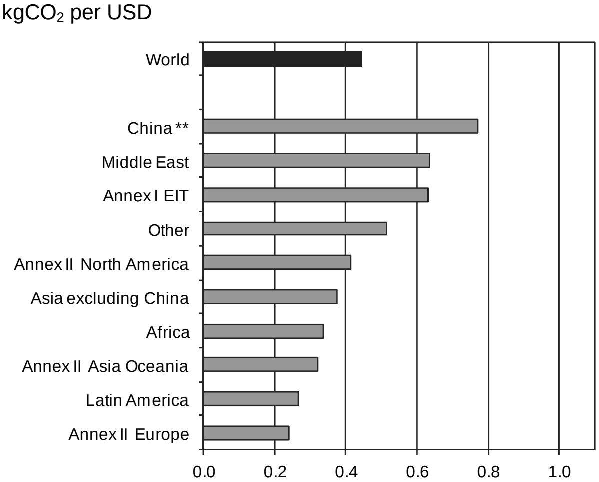
These policies would both reduce the environmental impact of transport and help to secure domestic fuel supplies, which are sometimes unsettled (e.g. by the threat of supply disruptions, whether from natural disasters, accidents or the geopolitics of oil trade). As these policies will ease demand growth, they are also likely to help keep oil prices below the increases projected in a business-as-usual scenario.

Although most of transport emissions are due to road travel, it is interesting to note that despite efforts of the international community to limit emissions from marine bunkers and aviation bunkers for international transport, these emissions grew significantly in 2010. CO_2 emissions from international marine bunkers were 7.0% above 2009 levels and those of aviation bunkers were 6.7% higher.

Coupling emissions with socio-economic indicators[7]

Indicators such as those briefly discussed in this section strongly reflect energy constraints and choices made to support the economic activities of each country. They also reflect sectors that predominate in different countries' economies.

Figure 8. CO_2 emissions per GDP* by major world regions in 2010



* GDP in 2005 USD, using purchasing power parities.

** China includes Hong Kong.

Key point: Emission intensities in economic terms vary greatly around the world.

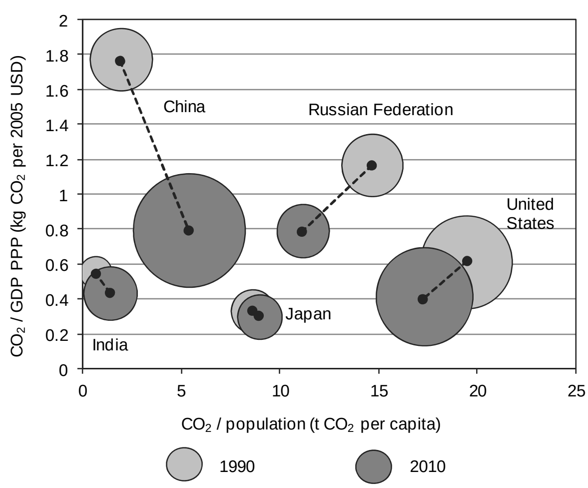
In 2010, the five largest emitters (China, the United States, India, the Russian Federation and Japan) comprised 45% of the total population and together produced 46% of the world gross domestic product[8] (GDP) and 56% of the global CO_2 emissions and. However, the relative shares of these five countries for all three variables were very diverse.

In the United States, the large share of global emissions is associated with a commensurate share of economic output (as measured by GDP), the largest in the world. Japan, with a GDP almost double that of the Russian Federation, emits 28% less than the Russian Federation.

Although climate and other variables also affect energy use, relatively high values of emissions per GDP indicate a potential for decoupling CO_2 emissions from economic growth. Possible improvements can derive from fuel switching away from carbon-intensive sources or from energy efficiency at all stages of the energy value chain (from raw material extraction to energy end-use).[9]

Among the five largest emitters of CO_2 in 2010, China, the Russian Federation and the United States have significantly reduced their CO_2 emissions per unit of GDP between 1990 and 2010 (Figure 9).

Figure 9. Trends in CO_2 emission intensities for the top five emitting countries*



* Size of circle represents total CO_2 emissions from the country in that year.

Key point: China, the Russian Federation and the United States have all made significant improvements in reducing the amount of CO_2 emitted per unit of GDP.

A note of caution is necessary concerning this indicator. CO_2 emissions per GDP can be very useful to measure efforts over time for one country – it is less useful when comparing countries. The ratio is very dependant on the base year used for the GDP purchasing

7. No single indicator can provide a complete picture of a country's CO_2 emissions performance or its relative capacity to reduce emissions. The indicators discussed here are certainly incomplete and should only be used to provide a rough indication of the situation in a country.

8. Throughout this analysis, GDP refers to GDP in 2005 USD, using purchasing power parities.

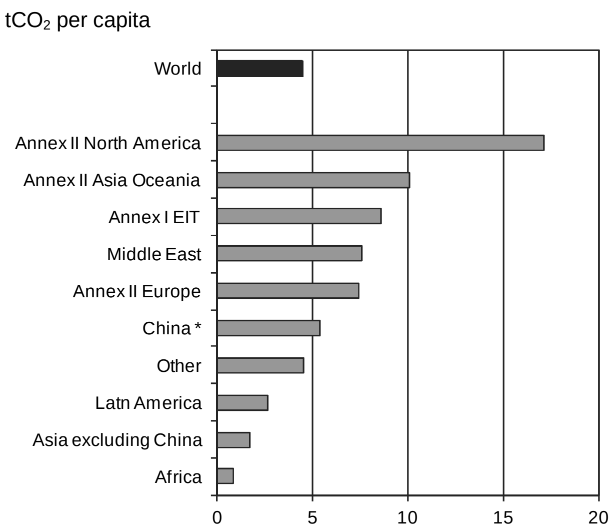
9. The IEA's Policies and Measures Databases offer access to information on energy-related policies and measures taken or planned to reduce GHG emissions, improve energy efficiency and support renewable energy development and deployment. The online databases can be consulted at: *www.iea.org/textbase/pm/index.html*.

power parity (PPP). In this edition, the GDP and GDP PPP series, and all associated ratios, have been rebased from 2000 USD to 2005 USD. As a result, the CO_2/GDP PPP ratio of China expressed in 2005 USD is twice as high as that of the United States; when the ratios were expressed in 2000 USD, China was only about 20% higher than the United States.

As compared to emissions per unit of GDP, the range of per-capita emission levels across the world is even larger, highlighting wide divergences in the way different countries and regions use energy.

In 2010, the United States alone generated almost 18% of world CO_2 emissions, despite having a population of less than 5% of the global total. Conversely, China contributed a comparable share of world emissions (24%) while accounting for 20% of the world population. India, with 17% of population, contributed more than 5% of CO_2 emissions. Among the five largest emitters, the levels of per-capita emissions were very diverse, ranging from 1 tCO_2 per capita for India and 5 tCO_2 for China to 17 tCO_2 for the United States.

Figure 10. CO_2 emissions per capita by major world regions in 2010



* China includes Hong Kong.

Key point: Emissions per capita vary even more widely across world regions than GDP per capita.

Industrialised countries emit far larger amounts of CO2 per capita than the world average (Figure 10). However, some rapidly expanding economies are significantly increasing their emissions per capita. For example, between 1990 and 2010, among the top five emitting countries, China increased its per-capita emissions by over 2.5 times and India doubled them. Clearly, these two countries contributed much to the 11% increase of global per-capita emissions over the period. Conversely, per-capita emissions were decreased significantly in both the Russian Federation (24%) and the United States (11%) over the same period.

Developing a low-carbon world

Traditionally, industrialised countries have emitted the large majority of anthropogenic greenhouse gases (GHGs). More recently, however, shares of developing country emissions have been rising very rapidly and are projected to continue to do so. To shift towards a low-carbon world, mitigation measures now taking shape within industrialised countries will need to be accelerated, and complemented by comprehensive efforts worldwide.

A breakthrough in this effort was the agreement at the United Nations Framework Convention on Climate Change (UNFCCC) 17th Conference of the Parties (COP17) talks in Durban (December 2011) to "launch a process to develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties". The goal is to negotiate the new agreement by 2015, and for it to come into force from 2020. If agreement can be reached, this will be the first international climate agreement to extend mitigation obligations to all countries, both developed and developing.

This builds on decisions at the two previous UNFCCC meetings (in Copenhagen and Cancún), which invited developing countries to put forward voluntary mitigation pledges, which in turn built on the earlier Bali Roadmap (from 2005) that encouraged voluntary mitigation actions in developing countries. Developed and developing countries that have submitted pledges under the Copenhagen Accord collectively account for over 80% of global emissions. Although the ambition of these pledges is currently insufficient to limit temperature rise to 2°C above pre-industrial levels, the breadth of participation in mitigation commitments marks a significant improvement on the previous climate agreement, the Kyoto Protocol of the UNFCCC.

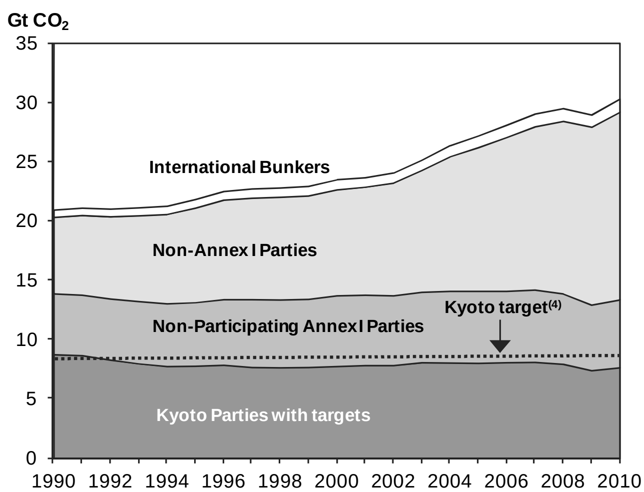
The Kyoto Protocol commits industrialised countries (as a group) to curb domestic emissions by about 5% relative to 1990 by the 2008-12 first commitment period. Alongside the agreement to negotiate a new climate agreement by 2015, certain countries have agreed to take commitments under a second commitment period of the Kyoto Protocol to begin in 2013. Details of these commitments will be finalised at COP 18 in Doha (December 2012).

Table 1. World CO_2 emissions from fuel combustion and Kyoto Protocol targets[1]

$MtCO_2$

	1990	2010	% change 90-10	Kyoto Target
KYOTO PARTIES WITH TARGETS	**8 784.3**	**7 695.8**	**-12.4%**	**-4.7% e**
North America	*432.9*	*536.6*	*24.0%*	
Canada	432.9	536.6	24.0%	-6%
Europe	*3 152.8*	*3 056.6*	*-3.1%*	
Austria	56.4	69.3	22.9%	-13%
Belgium	107.9	106.4	-1.4%	-7.5%
Denmark	50.4	47.0	-6.8%	-21%
Finland	54.4	62.9	15.7%	0%
France [2]	352.3	357.8	1.6%	0%
Germany	949.7	761.6	-19.8%	-21%
Greece	70.1	84.3	20.2%	+25%
Iceland	1.9	1.9	2.3%	+10%
Ireland	29.8	38.7	29.7%	+13%
Italy	397.4	398.5	0.3%	-6.5%
Luxembourg	10.4	10.6	1.6%	-28%
Netherlands	155.8	187.0	20.0%	-6%
Norway	28.3	39.2	38.5%	+1%
Portugal	39.3	48.2	22.6%	+27%
Spain	205.2	268.3	30.7%	+15%
Sweden	52.8	47.6	-9.8%	+4%
Switzerland	41.4	43.8	5.9%	-8%
United Kingdom	549.3	483.5	-12.0%	-12.5%
Asia Oceania	*1 347.8*	*1 557.4*	*15.6%*	
Australia	260.0	383.5	47.5%	+8%
Japan	1 064.4	1 143.1	7.4%	-6%
New Zealand	23.4	30.9	31.8%	0%
Economies in Transition	*3 850.8*	*2 545.1*	*-33.9%*	
Bulgaria	74.8	43.8	-41.4%	-8%
Croatia	21.6	19.0	-11.9%	-5%
Czech Republic	155.1	114.5	-26.2%	-8%
Estonia	36.1	18.5	-48.9%	-8%
Hungary	66.4	48.9	-26.3%	-6%
Latvia	18.7	8.1	-56.8%	-8%
Lithuania	33.1	13.4	-59.6%	-8%
Poland	342.1	305.1	-10.8%	-6%
Romania	167.0	75.6	-54.8%	-8%
Russian Federation	2 178.8	1 581.4	-27.4%	0%
Slovak Republic	56.7	35.0	-38.3%	-8%
Slovenia	12.5	15.3	22.5%	-8%
Ukraine	687.9	266.6	-61.2%	0%

	1990	2010	% change 90-10	Kyoto Target
OTHER COUNTRIES	**11 571.8**	**21 481.3**	**85.6%**	
Non-participating Annex I Parties	*5 122.4*	*5 702.3*	*11.3%*	
Belarus	124.5	65.3	-47.5%	none
Malta	2.3	2.5	8.3%	none
Turkey	126.9	265.9	109.5%	none
United States	4 868.7	5 368.6	10.3%	-7%
Other Regions	*6 338.5*	*15 609.9*	*146.3%*	none
Africa	544.4	929.7	70.8%	none
Middle East	557.1	1 546.3	177.6%	none
N-OECD Eur. & Eurasia [3]	641.8	499.4	-22.2%	none
Latin America [3]	843.0	1 482.3	75.8%	none
Asia (excl. China) [3]	1 508.1	3 893.7	158.2%	none
China	2 244.1	7 258.5	223.5%	none
INTL. MARINE BUNKERS	**362.5**	**643.7**	**77.6%**	
INTL. AVIATION BUNKERS	**255.3**	**455.3**	**78.3%**	
WORLD	**20 973.9**	**30 276.1**	**44.4%**	



(1) The targets apply to a basket of six greenhouse gases and allow sinks and international credits to be used for compliance with the target. The overall EU-15 target under the Protocol is 8%, but the member countries have agreed on a burden-sharing arrangement as listed. Because of lack of data and information on base years and gases, an overall "Kyoto target" cannot be precisely calculated for total Kyoto Parties: estimates applying the targets to IEA energy data suggest the target is equivalent to about 4.7% on an aggregate basis for CO_2 emissions from fuel combustion.

(2) Emissions from Monaco are included with France.

(3) Composition of regions differs from elsewhere in this publication to take into account countries that are not Kyoto Parties.

(4) The Kyoto target is calculated as percentage of the 1990 CO_2 emissions from fuel combustion only, therefore it does not represent the total target for the six-gas basket. This assumes that the reduction targets are spread equally across all gases.

Key point: The existing climate targets under the Kyoto Protocol are not sufficiently comprehensive to lead to reductions in global CO_2 emissions from fuel combustion.

The Kyoto Protocol also creates “flexible mechanisms” by which industrialised countries can transfer emission allowances among themselves and earn emission credits from emissions reduction projects in participating developing countries and economies in transition (EITs). Despite its extensive coverage (192 countries), the Protocol is limited in its potential to address global emissions since not all major emitters are included in reduction commitments. The United States remains outside of the Protocol’s jurisdiction and though most developing countries (*i.e.* non-Annex I countries) have signed, they do not face emissions targets. The Kyoto Protocol implies action on only one-quarter of global CO_2 emissions, as measured in 2010.

Through its flexibility mechanisms and provisions for international trading, the Kyoto Protocol has made CO_2 a tradable commodity, and has been a key driver for the development of emissions trading schemes as detailed below. In 2011 the total value of the global carbon market was USD 176 billion, with 10.3 billion allowances traded (World Bank, 2012).

Emissions trading systems

Emissions trading systems (ETS) are developing or being proposed in several regions and countries around the world. Some are operational or being launched (EU ETS, Australia, New Zealand, Norway, Tokyo, Switzerland, in California and through the Regional Greenhouse Gas Initiative in the United States, and in the Canadian provinces of Alberta and Quebec) while others are under development (Korea, China, Kazakhstan, Ukraine and Chile). The year 2012 saw significant developments in emissions trading, with final details being put in place to enable the start of the Australian scheme in July 2012, and the Quebec and California ETS schemes in January 2013.

The Australian ETS started in July 2012 with a fixed-price transitional phase, and will move to full trading in 2015. The Australian government and European Union have announced intentions to link their systems, starting with one-way trading of European allowances into the Australian market from 2015, followed by full two-way linking from 2018.

Rules for the California and Quebec schemes were developed co-operatively under the umbrella of the Western Climate Initiative, an agreement among US states and Canadian provinces to promote a common platform for emissions trading. The California and Quebec systems will both start trading in January 2013, and intend to formally link and hold joint auctions of allowances. The California system will play a critical role in reducing California’s emissions to 1990 levels by 2020, as required under the Global Warming Solutions Act of 2006 (AB 32). The California ETS covers large stationary energy and industrial sources from 2013, and expands to cover natural gas and transport fuel suppliers from 2015.

The largest scheme in operation is the EU ETS, which began in 2005 and covers emitters in the energy, industry and aviation sectors, representing about 45% of the energy-related CO_2 emissions of the region. Norway’s ETS is fully linked to the EU system. The lessons from its first two phases have helped to shape the scheme’s post-2012 design (Ellerman *et al.*, 2010).

In December 2008, the European Council and the European Parliament endorsed an agreement on a climate change and energy package which implements a political commitment by the European Union to reduce its GHG emissions by 20% by 2020 compared to 1990 levels.[10] The package also includes a target for renewables in the European Union, set at 20% of final energy demand by 2020.

The EU ETS will play a key role in achieving this target. The 2020 emissions cap for ETS installations is 21% below the actual level of 2005 emissions,[11] with the option to lower the cap to 34% below 2005 levels if there is ambitious climate action internationally. These targets were set in 2008, before the scale of the global financial crisis was apparent. Due to the economic slow-down, European GHG emissions have decreased to the point where the 21% target is expected to be achieved without any abatement effort from industry. As a result, allowance prices in the EU ETS have dropped substantially. European governments are now considering whether and how to reform the EU ETS to improve its effectiveness.

In New Zealand, a comprehensive economy-wide emission trading scheme (NZ ETS) is being progressively introduced. It began with the forestry sector in January 2008; the energy, transport and industrial sectors have been included since July 2010. Waste and agricultural emissions will enter by 2015. A transition phase, from 2010 to 2015, is based on a capped price and partial obligations. The scheme is fully linked to the international Kyoto market, and allows unlimited

10. A 30% reduction target is proposed if other Parties were to take equally ambitious mitigation objectives.

11. Annual cap: 1 974 Mt in 2013, falling in linear fashion to 1 720 Mt by 2020; average annual cap over 2013-20: 1 846 Mt (compared to an annual cap of 2 083 Mt for the period 2008-12).

use of Kyoto Protocol project and forestry credits. No emissions cap is specified: linking to the international market is intended rather to ensure that an appropriate carbon price is set in the New Zealand economy.

Several other ETS schemes are operating, including in countries that are not Parties to the Kyoto Protocol. In the United States, the first regional scheme (the Regional Greenhouse Gas Initiative covering the electricity sector in the northeastern states) began on 1 January 2009. Small schemes are also in place in Tokyo (covering commercial sites) and Alberta (covering large emitters). Switzerland's ETS allows companies to manage their emissions through trading instead of facing the country's carbon tax. Switzerland is in negotiations to link its scheme to the EU ETS.

A number of other domestic trading schemes are also under development, in both Annex I and non-Annex I countries. The Korean government has passed legislation to establish an emissions trading scheme from 2015, to assist in delivering Korea's target of a 30% improvement on business-as-usual (BAU) emissions by 2020. As part of its 12^{th} Five-Year Plan (2011-15), the Chinese government is introducing ETS pilots in seven provinces and cities. These pilots are to be developed by 2013, to inform the potential implementation of a nation-wide policy after 2015. Kazakhstan also intends to launch a trading scheme in 2013.

An important development in extending emissions trading to developing economies has been the World Bank's Partnership for Market Readiness, which provides funding and technical assistance to developing countries for capacity building toward the development and piloting of market-based instruments for GHG reduction. Chile, China, Columbia, Costa Rica, Indonesia, Mexico, Thailand and Turkey received grants in the first round of funding.

Steps for future action

After the unprecedented move at COP15 and COP/MOP5 in Copenhagen, where heads of states and high-level representatives failed to negotiate a comprehensive accord and settled for the Copenhagen Accord, COP16 and COP/MOP6 in Cancún were widely seen as having revitalized the international negotiating process. In Cancún, the key elements of the Copenhagen Accord were formally adopted into the UN process, including: the goal of limiting global temperature increase to less than 2°C above pre-industrial levels; commitments for the provision of financial resources; and sketching a framework for monitoring and reviewing mitigation actions and commitments. Annex I Parties submitted quantified economy-wide GHG targets to 2020 as part of the accord, and several non-Annex I countries also listed mitigation actions, or sectoral or economy-wide GHG targets. With the agreement at COP17 in Durban to launch negotiations on a new global agreement, the focus of the UNFCCC negotiations is now very much on the roadmap to 2015, coupled with decisions on extending the Kyoto Protocol to a second commitment period.

A key challenge in defining this new agreement is that while obligations are to start from 2020, global emissions need to peak before 2020 if temperature rise is to be limited to below 2°C. This points to the need for an ambitious start point in 2020, but also the importance of complementary initiatives outside the UNFCCC that can constrain emissions in the period up to 2020. In addition to defining a framework for mitigation actions across developed and developing countries, the Durban Platform will cover enhanced actions on adaptation, technology development and on the provision of financial resources. The concept of both mitigation actions and financial flows being "measurable, reportable and verifiable" is now central to the establishment of a post-2015 framework for climate action. The next step in the UNFCCC process is COP18 in Doha, where decisions on the Kyoto Protocol need to be finalised ahead of expiration of the First Commitment Period in December 2012, in addition to making progress toward the new 2015 agreement.

Alongside the UNFCCC process, progress toward a low-carbon future is being made in numerous other fora. The challenge of post-2012 discussions is the need to engage developing countries with approaches, possibly including the carbon market, that suit their capacity and their legitimate aspiration for economic and social development. The Asia Pacific Partnership for Clean Development and Climate (APP or AP7), the G8 2005 Gleneagles Plan of Action, and the Major Economies Forum on Energy and Climate (MEF) and Clean Energy Ministerial (CEM) processes have sought to involve developed and developing nations in common measures to address climate change. Other international fora gathering both developed and developing countries have emerged that can further mitigate efforts in specific areas, such as the International Renewable Energy Agency (IRENA), and the International Partnership for Energy Efficiency Co-operation (IPEEC).

The AP7, which groups Australia, Canada, China, India, Japan, Korea and the United States, focuses on the emissions of specific sectors (iron and steel, cement, aluminium, mining, buildings and appliances) and methods of clean fossil energy use, renewable energy generation and more efficient power generation and transmission.

Canada, France, Germany, Italy, Japan, the Russian Federation, the United Kingdom and the United States launched the July 2005 G8 Gleneagles Plan of Action to, in part, promote clean energy and sustainable development while mitigating climate change. The IEA was tasked under the Plan of Action to develop concrete recommendations to help the G8 achieve its clean energy objectives. Additionally, the G8 sought to engage South Africa, India, Brazil, China and Mexico in an official dialogue to address climate change, clean energy and sustainable development worldwide. This commitment by the G8 was reiterated at all subsequent summits.

The G20 summits have also served as a forum to advance climate change and clean energy discussions, including a commitment to rationalising and phasing out inefficient fossil fuel subsidies over the medium term. In 2011, the G20 formed a new Clean Energy and Energy Efficiency (C3E) Working Group to advance its work in this area. The Clean Energy Ministerial process, launched in 2009, is a high-level global forum to accelerate deployment of clean energy, through sharing experience in policies and programmes. It is based on a series of concrete initiatives to advance key technologies. The IEA is involved in some of these initiatives and also prepares an annual tracking report on global clean energy deployment for the CEM meeting.

In all these efforts, timely and accurate CO_2 and other GHG statistics will prove central to ascertaining compliance with international agreements and to informing policy makers and carbon market participants. The ability of countries to monitor and review emissions from their sources is essential in their engagement towards national and global GHG mitigation.

References

Ellerman, D.A., F.J. Convery, C. de Perthuis, E. Alberola, R. Baron, B.K. Buchner, A. Delbosc, C. Hight, F. Matthes and J. Keppler (2010), *Pricing Carbon, The European Emissions Trading Scheme*, Cambridge University Press, Cambridge.

IEA (2012), *World Energy Outlook 2012* (WEO 2012), OECD/IEA, Paris.

IEA (2012), *Energy Technology Perspectives 2012 (ETP 2012*), OECD/IEA, Paris.

IPCC (2007), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (1996 IPCC Guidelines)*, IPCC, Bracknell, UK.

World Bank (2012), *State and Trends of the Carbon Market 2012*, World Bank, Washington.

2. REGIONAL ASPECTS OF THE ENERGY-CLIMATE CHALLENGE

A growing body of evidence has established links between climate change and the carbon dioxide (CO_2) emissions that arise from energy production and consumption. This chapter provides background on the link between energy use and climate change, and then examines how growing demand in some rapidly expanding economies – all of which are in non-OECD regions – will dramatically change future emissions trends. It closes with a call for all countries (not just the industrialised countries) to address this increasingly urgent global issue.

Understanding energy and climate change

In its *Fourth Assessment Report*,[12] the IPCC concluded: "Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse-gas concentrations." The language "very likely" has been upgraded from "likely," which was used six years earlier in the *Third Assessment Report*, thus confirming the broad acceptance by scientists of the link between greenhouse-gas (GHG) emissions and global climate change. Energy production and use have various environmental implications: since energy accounts for about 65% of global anthropogenic GHG emissions, reducing emissions must necessarily start with actions geared to reduce emissions from fuel combustion.

12. *IPCC Fourth Assessment Report – Climate Change 2007*, available at *www.ipcc.ch*. In the summary for policy makers, the following terms have been used to indicate the assessed likelihood, using expert judgement, of an outcome or a result: *virtually certain* > 99% probability of occurrence; *extremely likely* > 95%; *very likely* > 90%; *likely* > 66%; *more likely than not* > 50%; *unlikely* < 33%; *very unlikely* < 10%; and *extremely unlikely* < 5%.

Greenhouse gases and global warming

The increased concentrations of key greenhouse gases are a direct consequence of human activities. Since anthropogenic greenhouse gases accumulate in the atmosphere, they produce net warming by strengthening the natural "greenhouse effect".

Carbon dioxide (CO_2) concentrations in the atmosphere have been increasing over the past century compared to the rather steady level evident during the pre-industrial era (about 280 parts per million in volume, or ppmv). The 2005 concentration of CO_2 (379 ppmv) was about 35% higher than in the mid-1800s, with the fastest growth occurring in the last ten years (1.9 ppmv/year in the period 1995-2005). Significant increases have also occurred in levels of methane (CH_4) and nitrous oxide (N_2O).

Some impacts of the increased GHG concentrations may be slow to become apparent since stability is an inherent characteristic of the interacting climate, ecological and socio-economic systems. Even after stabilisation of the atmospheric concentration of CO_2, anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks. Some changes in the climate system would be irreversible in the course of a human lifespan.

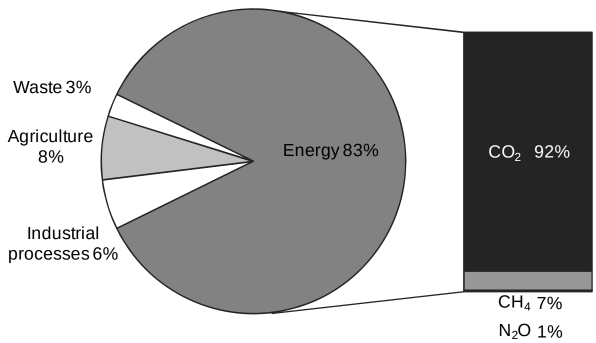
Given the long lifetime of CO_2 in the atmosphere, stabilising concentrations of greenhouse gases at any level would require large reductions of global CO_2 emissions from current levels. The lower the chosen level for stabilisation, the sooner the decline in global CO_2 emissions would need to begin, or the deeper the emission reduction would need to be over time.

The UNFCCC creates a structure for inter-governmental efforts to tackle the challenge posed by climate change. The Convention's ultimate objective is to stabilise GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. This would require significant reductions in global GHG emissions.

Energy use and greenhouse gases

Among the many human activities that produce greenhouse gases, the use of energy represents by far the largest source of emissions. Smaller shares correspond to agriculture, producing mainly CH_4 and N_2O from domestic livestock and rice cultivation, and to industrial processes not related to energy, producing mainly fluorinated gases and N_2O (Figure 11).

Figure 11. Shares of anthropogenic GHG emissions in Annex I countries, 2010*



* Based on Annex I data for 2010; without Land Use, Land-Use Change and Forestry, and with Solvent Use included in Industrial Processes and "other" included with waste.

Source: UNFCCC.

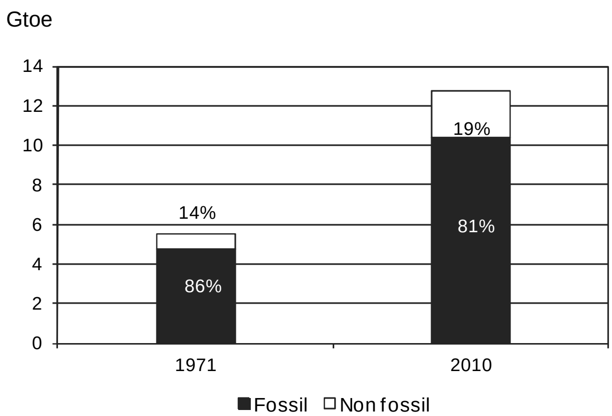
Key point: Accounting for the largest share of global GHG emissions, energy emissions are predominantly CO_2.

Direct combustion of fuels dominates the GHG emissions from the energy sector.[13] A by-product of fuel combustion, CO_2 results from the oxidation of carbon in fuels.

CO_2 from energy represents 83% of the anthropogenic GHG emissions for Annex I countries but only about 65% of global emissions. This percentage varies greatly by country, due to diverse national energy structures.

Worldwide economic growth and development require energy. Global total primary energy supply (TPES) more than doubled between 1971 and 2010, mainly relying on fossil fuels (Figure 12).

Figure 12. World primary energy supply*



* World primary energy supply includes international bunkers.

Key point: Fossil fuels still account for most – over 80% – of the world energy supply.

Despite the growth of non-fossil energy (such as nuclear and hydropower) considered as non-emitting,[14] the share of fossil fuels within the world energy supply is relatively unchanged over the past 39 years. In 2010, fossil sources accounted for 81% of the global TPES.

Though coal represented only 28% of the world TPES in 2010, it accounted for 43% of the global CO_2 emissions due to its heavy carbon content per unit of energy released (Figure 13). As compared to gas, coal is nearly twice as emission intensive on average.[15]

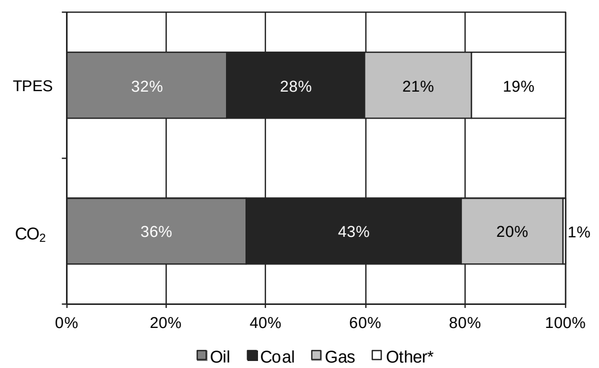
13. Energy includes emissions from "fuel combustion" (the large majority) and "fugitive emissions", which are intentional or unintentional releases of gases resulting from production, processes, transmission, storage and use of fuels (*e.g.* CH_4 emissions from coal mining or oil and gas systems).

14. Excluding the life cycle of all non-emitting sources and excluding combustion of biofuels (considered as non-emitting CO_2, based on the assumption that the released carbon will be reabsorbed by biomass regrowth, under balanced conditions).

15. IPCC default carbon emission factors from the *1996 IPCC Guidelines*: 15.3 tC/TJ for gas, 16.8 to 27.5 tC/TJ for oil products, 25.8 to 29.1 tC/TJ for primary coal products.

Figure 13. World primary energy supply and CO_2 emissions: shares by fuel in 2010

Percent share



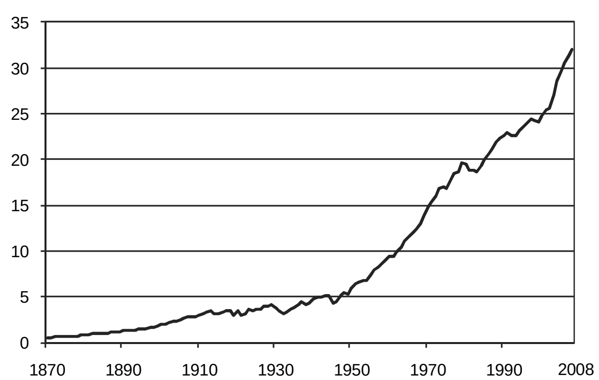
* Other includes nuclear, hydro, geothermal, solar, tide, wind, biofuels and waste.

Key point: Coal combustion generates about twice the CO_2 emissions of gas use, while having a comparable share in the world energy supply.

Growing world energy demand from fossil fuels plays a key role in the upward trend in CO_2 emissions (Figure 14). Since the Industrial Revolution, annual CO_2 emissions from fuel combustion dramatically increased from near zero to over 30 $GtCO_2$ in 2010.

Figure 14. Trend in CO_2 emissions from fossil fuel combustion

$GtCO_2$



Source: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, Tenn., United States.

Key point: Since 1870, CO_2 emissions from fuel combustion have risen exponentially.

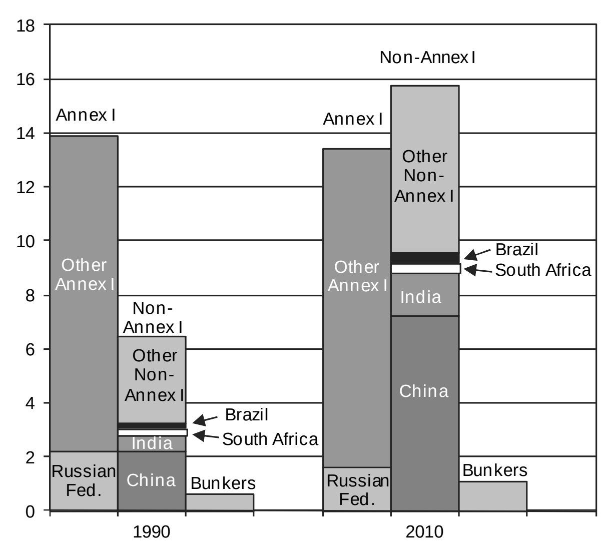
The link between climate change and energy is a part of the larger challenge of sustainable development. The socio-economic and technological characteristics of development paths will strongly affect emissions, the rate and magnitude of climate change, climate change impacts, the capability to adapt and the capacity to mitigate the emissions themselves.

BRICS countries altering the regional balance

One of the most important recent developments in the world economy is the increasing economic integration of large non-OECD countries, in particular Brazil, the Russian Federation, India, China and South Africa, the so-called BRICS countries. In 2010, the BRICS represented about one-quarter of world GDP,[16] up from 16% in 1990. Also in 2010, these five countries represented 33% of global energy use and 37% of CO_2 emissions from fuel combustion (Figure 15). These shares are likely to rise further in coming years if the strong economic performance currently occurring in most of these countries continues, as many commentators expect. In fact, China, the Russian Federation and India are already three of the four countries that emit the most CO_2 emissions in absolute terms.

Figure 15. The growing importance of GHG emissions in the BRICS countries

$GtCO_2$



Key point: With the exception of the Russian Federation, the BRICS countries represent a growing share of CO_2 emissions in the world.

This brief discussion focuses on the BRICS countries, of which only the Russian Federation is a member of Annex I Parties to the UNFCCC. Each of these countries has very different endemic resources, energy

16. Throughout this analysis, GDP refers to GDP in 2005 USD, using purchasing power parities.

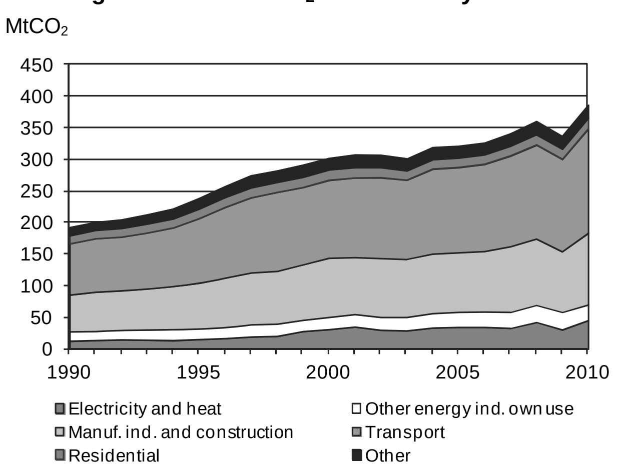
supply constraints and sectoral consumption patterns. Consequently, the issues relating to CO_2 emissions facing these five countries are quite different.

Brazil

Brazil is the third-largest emitter of total greenhouse gases in the world, with the particularity that the country's energy system has a relatively minor impact on GHG emissions (about 27%). The bulk of Brazilian GHG emissions comes from agriculture, land-use and forestry activities, mainly through the expansion of agricultural frontiers in the Amazon region.

Compared to the Russian Federation, China and India, CO_2 emissions from fuel combustion in Brazil are small, representing only 1.3% of global CO_2 emissions from fuel combustion. Brazil's energy matrix is one of the cleanest in the world with renewables accounting for 44% of TPES. Within the energy sector, the sub-sectors that contribute the most to total GHG emissions – transport (43% in 2010) and industry (29%) – are those likely to grow the most over the next years (Figure 16).

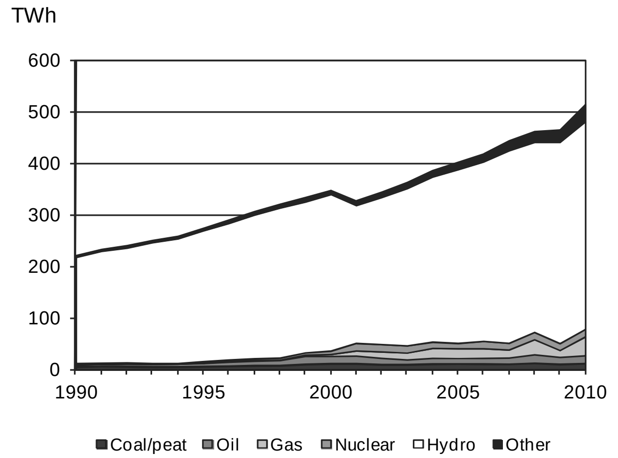
Figure 16. Brazil: CO_2 emissions by sector



Key point: The transport sector produces the largest share of CO_2 emissions from fuel combustion in Brazil.

Electricity generation in Brazil relies heavily on hydropower (Figure 17). Over the last three decades, the number of major dams has grown steadily and hydropower accounted for 78% of total electricity generation in 2010. Many of Brazil's hydropower generating facilities are located far away from the main demand centres, resulting in high transmission and distribution losses. Droughts in recent years have led to a wider diversification in the electricity production mix, increasing the use of natural gas. Electricity generation from natural gas rose to 7% in 2010, having fallen from 6% in 2008 to 3% in 2009 due to the global economic crisis.

Figure 17. Brazil: Electricity generation by fuel



Key point: Brazilian electricity generation draws heavily on hydropower.

In 2009, the Brazilian government announced plans to build two new large hydroelectric plants. As a result, there are currently 22 GW of hydropower capacity already contracted and under construction (including the 11.2 GW of the Belo Monte) plus 3.9 GW of small hydro plants. However, large hydro projects are frequently faced with opposition by environmental groups and indigenous communities, leading to protracted legal disputes, project delays and higher project costs.

In 2007, amid concerns about the risk of power-supply shortages beyond 2012 unless Brazil builds new capacity, the Brazilian government announced the development of five new nuclear power plants. The government's 2030 National Energy Plan anticipates 5.3 GW of additional installed generation capacity from new nuclear plants (Angra 3 and four other plants) by 2030. After the Fukushima accident, however, the Brazilian government decided not to include the latter four plants in its 10-year power expansion plan 2011-20. Moreover, electricity produced from co-generation plants (mainly from sugarcane bagasse) is planned to constitute 11.4% of the country's electricity supply by 2030.

Biofuels supply a comparatively significant share of the energy consumed for road transport in Brazil (Figure 18). As such, Brazilian transport has a relatively low CO_2 emissions intensity.[17] CO_2 emissions per unit of fuel consumed in road traffic are 20% lower than the world average (2.3 versus 2.8 tCO_2 per toe).

17. See box on "Using biofuels to reduce emissions" for a more complete discussion on the advantages and limitations of using biofuels to replace oil. Note: CO_2 emissions intensity considers the tank-to-wheel emissions and assumes that the CO_2 emissions derived from the combustion of biofuels are zero.

Using biofuels to reduce emissions

Compatible with most conventional automotive engines (in low-percentage blends), blendable with current transport fuels, and marketable using much of the current fuel distribution and retail infrastructure, biofuels have the potential to reduce GHG emissions and to contribute to energy security by diversifying supply sources for transport. However, the economic, environmental and social benefits of the current generation of biofuels vary.

In order to assess their efficacy in reducing GHG emissions, biofuels can be compared on the basis of their well-to-wheel (WTW)* performance with respect to conventional fossil fuels. When ethanol is derived from corn, the WTW greenhouse-gas reduction with respect to conventional gasoline is typically in the range of 10% to 50%. The reduction is typically much higher for sugarcane-based ethanol from Brazil, reaching an estimated 70% to 120%**. Similarly, oilseed-derived biodiesel typically leads to GHG reductions, on a WTW basis, of 30% to 60% when compared to conventional petroleum diesel.

However, these comparisons do not take into account the possibility that changes in land use caused by biofuel production can result in one-time releases of CO_2 that could be quite large; more research is needed on the impacts of both direct and indirect land-use change, and how to minimise adverse impacts.

New and emerging biofuel technologies, which can use as feedstock biomass residues and energy crops such as fast-growing trees and perennial grasses, have the potential to expand the scope for production of very low-carbon biofuels. However, these biofuel technologies are not yet commercially operational at full scale. The most mature of these technologies are still at the edge between demonstration and first commercial plants.

For both conventional and advanced biofuels, production cost is a main barrier to their larger penetration in the transport fuel mix. Ethanol from sugarcane produced in Brazil has been more or less the only biofuel competitive with petroleum fuels without direct subsidies, although this has changed recently as relatively high sugar prices pushed up production costs for ethanol beyond a level competitive with regulated gasoline prices.

Currently, more than 50 countries have mandated or promoted biofuel blending to displace oil in domestic transport supply. In Brazil, gasoline contains 20% to 25% ethanol, and around 95% of cars sold in Brazil in 2011 were flex-fuel vehicles that can run on either 100% ethanol or on a gasoline/ethanol blend. Depending on the oil price, most drivers are choosing to operate these vehicles mainly on ethanol. In 2007, the United States introduced the Renewable Fuels Standard 2, which sets out blending mandates for different types of biofuels. The total mandated volume stands at 15.2 billion gallons in 2012 and will increase to 36 billion gallons by 2022 (of which more than half will be required to be “advanced biofuels”*** and about one-third cellulosic ethanol****).

In the European Union, the Renewable Energy Directive sets out a mandatory share of 10% renewable energy in transport by 2020. The directive requires for all biofuels that are counted towards the target to meet mandatory sustainability criteria, including minimum GHG emission savings compared to fossil fuels. The use of biofuels produced from wastes, residues or lignocellulosic biomass is counted twice against the targets. Australia (New South Wales and Queensland) and Canada are also mandating the use of biofuels, as are a number of non-OECD countries.

In the future, it is crucial that policies foster innovation and support only sustainable biofuels that can provide considerable emission reductions compared to the use of fossil gasoline and diesel. Continuous monitoring of the environmental, social and economic impacts of biofuel production and use will be important. This includes analysis of suitable land for biofuel cultivation and the potential influence of biofuel production on global food prices taking account of global demand for food, fibre and energy for a steadily growing world population. Support measures should be phased out over time as the commercial viability of biofuels improves as technologies evolve and prices of conventional fossil fuels increase. If well-managed and co-ordinated with investments in infrastructures and agriculture, biofuels can provide an opportunity for increasing land productivity and creating economic development, particularly in rural areas of developing countries.

* Well-to-wheel life cycle analysis refers to the total emissions from the production stage to the consumption stage of the product.

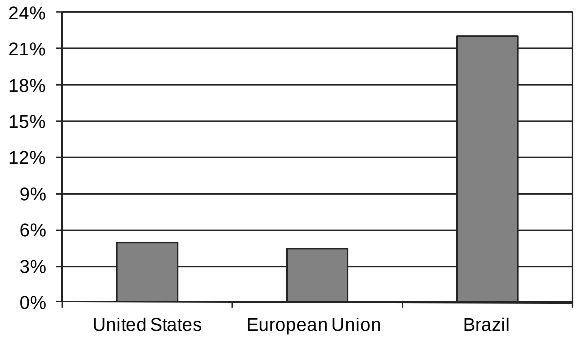
** GHG savings of more than 100% are possible through use of co-products.

*** Advanced biofuels in the US Renewable Fuels Standard refer to biofuels that provide more than 50% life-cycle CO_2 savings compared with gasoline.

**** Cellulose is an organic compound with the formula $C_6H_{10}O_5$ and is the structural component of the primary cell wall of green plants. Lignocellulosic biomass refers to plant biomass that is composed of cellulose, hemicellulose and lignin.

Brazil is the world's largest exporter and consumer of fuel ethanol from sugarcane.[18] In 2009, Brazil produced 450 000 bbl/d of ethanol, up from 410 000 bbl/d in 2008. Currently, cars that can run on either 100% ethanol or a gasoline-anhydrous ethanol blend represent 84% of the new cars purchased in Brazil (an estimated 2.2 million in 2009) and cost the same as cars that can only run on conventional fuel.

Figure 18: Share of biofuels energy in road transport, 2010



Key point: Brazil's relative consumption of biofuels far outstrips that of any other country.

Brazil's profile as an energy producer will be transformed in the medium term, following the discovery in November 2007 of major deepwater oil resources in the Santos Basin, which are now being developed with some fields already in production. However, no new concessions have been awarded since 2007, since future auctions are still subject to congressional approval of a new royalties law, which is expected for 2013. According to the National Petroleum Agency (ANP), Brazil's total proven oil and condensate reserves as of 31 December 2011 were 16.4 billion barrels.

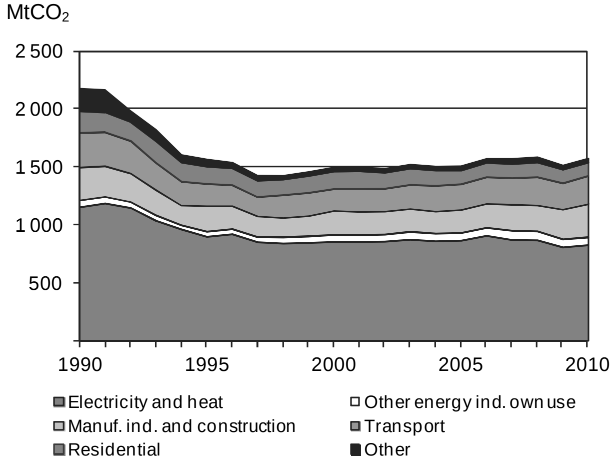
Russian Federation

The Russian Federation is the only BRICS country where CO_2 emissions fell between 1990 and 2010, with a 27% drop over the period (Figure 19). The economic downturn after the break-up of the Former Soviet Union caused emissions to fall by 34% between 1990 and 1998. Yet, CO_2 emissions grew in 1999 (2%) and 2000 (3%) due to the Russian Federation's strong economic recovery, stimulated by the increase in world energy prices. CO_2 emissions remained fairly constant for the next five years. After falling 5% in 2009, largely due to the global financial crisis, CO_2 emissions grew by 4% in 2010, their second-highest annual increase since 1990.

18. In 2005, the United States displaced Brazil as the largest ethanol producer, although mainly derived from corn rather than sugarcane.

The *WEO 2012* New Policies Scenario projects that the Russian Federation CO_2 emissions will continue to increase steadily, and will be 14% under 1990 levels in 2035.

Figure 19. Russian Federation: CO_2 emissions by sector



Key point: CO_2 emissions in the Russian Federation have remained fairly constant over the last ten years.

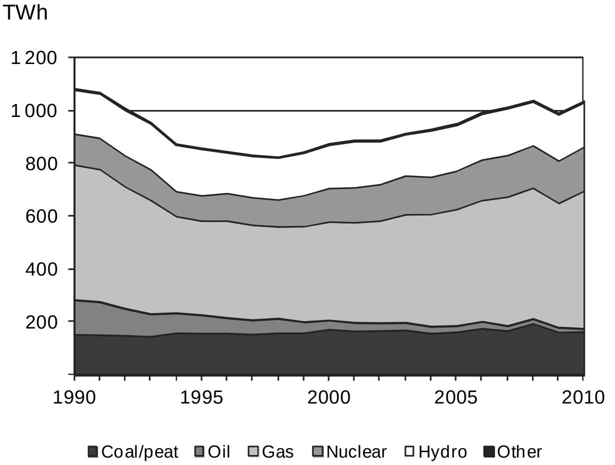
CO_2 emissions from fuel combustion in the Russian Federation have stabilised over the 2000s. However, other sources of greenhouse gases (in particular, CH_4 emissions from leaks in the oil and gas transmission/distribution system and CO_2 emissions from flaring of associated gas) represent an important share of the Russian GHG emissions. To effectively reduce GHG emissions from energy, these two problems would also need to be addressed (IEA, 2006a).

In early 2009, the Russian government passed the resolution "On the Measures Stimulating Reduction of Atmospheric Pollution by Products of Associated Gas Flaring." The document set a target for 2012 and beyond, limiting associated petroleum gas (APG) flaring levels to only 5% of the entire APG output. Starting 1 January 2012, producers are liable to pay increased fees for excessive flaring. The Russian Ministry of Natural Resources estimated that Russian oil companies would pay about USD 500 million in fines in 2012, a dramatic increase over 2011 and a major incentive to install at production facilities the tools to measure and log the actual volumes of APG production, utilisation and flaring. At the time of publication, little or no data were available to assess the impact on gas flaring in Russia.

In 2010, the electricity and heat generation sector represented 53% of Russian CO_2 emissions, compared to a global average of 41%. Within this sector, 50% of the electricity was generated by natural gas, 16% by coal and only 1% by oil (Figure 20).

The Russian government enacted a decree in January 2009 that sets targets to increase the share of electricity generated by renewable energy sources (excluding large hydro) from less than 1% to 4.5% by 2020. This decree could go a long way towards getting the Russian Federation more in line with the global average. However, to stimulate the utilisation of renewable energy sources including wind, biofuels, solar and recovered methane from coal mines (coalmine methane), a range of supporting regulations will be needed to amplify this important framework legislation.

Figure 20. Russian Federation: Electricity generation by fuel



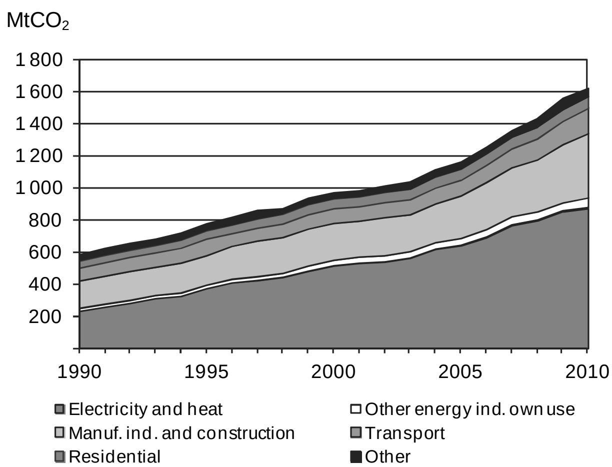
Key point: A large portion of the Russian Federation's electricity and heat generation comes from non-emitting (nuclear and hydro) or low-emitting (natural gas) sources.

Of the BRICS countries, in 2010, the Russian Federation had the highest CO_2 emissions per capita (11.2 tCO_2), which put it slightly above the average of OECD member countries (10.1 tCO_2). In terms of CO_2/GDP, the Russian Federation's economy remains CO_2 intensive with 0.8 $kgCO_2$ per unit of GDP, 2.3 times higher than the OECD average. Canada, whose geography and natural resources are comparable to those of the Russian Federation, has a carbon intensity of 0.4 $kgCO_2$ per unit of GDP – about half of the Russian Federation's level. However, IEA statistics show a reduction of the Russian Federation's energy intensity of GDP of about 5% per year between 1998 and 2008. It is not clear how much this can be attributed to energy efficiency improvements or changes in the sectoral composition of GDP and industrial product mix as opposed to the dramatic increase in GDP due to the country's much higher export earnings from oil and gas. In fact, the energy intensity actually increased by 3.5% in 2009 and remained static in 2010. This is counter-intuitive, as it was in 2009 that Russia adopted its first Federal Law on energy efficiency setting a target of 40% reduction of the Russian energy intensity by 2020 compared to 2007 levels.

India

India emits more than 5% of global CO_2 emissions and shows a clear trend of rapid increase: CO_2 emissions have almost tripled between 1990 and 2010. The *WEO 2012* New Policies Scenario projects that CO_2 emissions in India increase by 3.5% per year from 2010 to 2035, at which time India would account for 10% of global emissions. A large share of these emissions are produced by the electricity and heat sector, which represented 54% of CO_2 in 2010, up from 40% in 1990. CO_2 emissions in the transport sector accounted for only 10% of total emissions in 2010, but transport is one of the fastest-growing sectors (Figure 21).

Figure 21. India: CO_2 emissions by sector

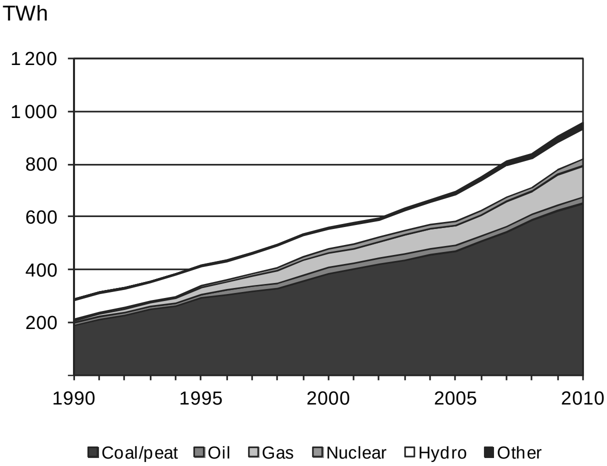


Key point: The bulk of CO_2 emissions in India comes from the electricity and heat generation sector, the share of which continues to grow.

In 2010, 68% of electricity in India came from coal, 12% from natural gas and 3% from oil (Figure 22). The share of fossil fuels in the generation mix grew from 73% in 1990 to 85% in 2002. Since 2002 the share of fossil fuels remained fairly steady, representing 83% in 2010. Although electricity produced from hydro has actually risen during this period, the share fell from 25% in 1990 to 12% in 2010, largely due to more rapid increases in coal-fired generation.

India's renewable power generation continues its strong growth reaching 23 GW in January 2012, equivalent to nearly 12% of total power capacity (MNRE, 2012; CEA, 2012). Wind comprises the largest capacity with 16 GW or 70% of total renewable capacity, followed by small hydro at 14% and bagasse co-generation at 9%. Currently, solar PV with 481 MW of capacity represents only 2% of total renewable installation, but is expected to grow strongly in the medium and long term. One notable encouraging aspect of renewable power in India is the high proportion of private ownership, accounting for 86% in March 2012.

Figure 22. India: electricity generation by fuel



Key point: About two-thirds of India's electricity comes from coal.

Of the BRICS countries, India has the lowest CO_2 emissions per capita (1.4 tCO_2 in 2010), about one-third that of the world average. Due to the recent large increases in emissions, however, the Indian ratio is more than two times that of its ratio in 1990 and will continue to grow. In 2035, India is projected to be the world's most populous nation with 1.5 billion people. Yet according to the *WEO 2012* New Policies Scenario, its carbon emissions of 2.5 tCO_2 per capita will still be substantially lower than the world average of 4.3 tCO_2 per capita in the same year.

In terms of CO_2/GDP, India has continuously improved the efficiency of its economy and reduced the CO_2 emissions per unit of GDP by 22% between 1990 and 2010. India aims to further reduce emissions intensity of GDP by 20% to 25% by 2020 compared with the 2005 level.[19]

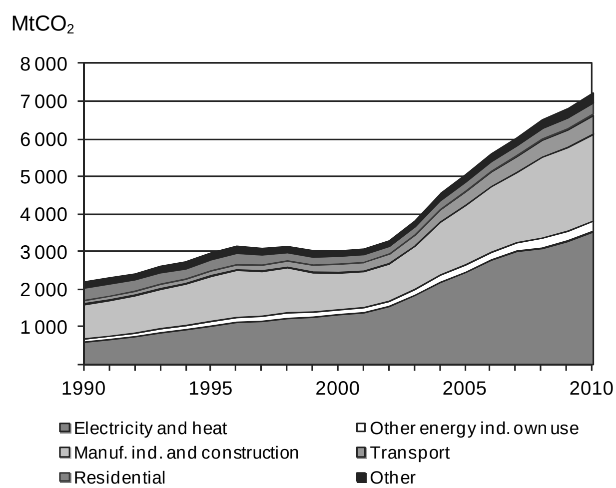
19. As per its stated goal in association with the Copenhagen Accord.

China

With over 7 billion tonnes of CO_2 in 2010, Chinese emissions far surpass those of the other BRICS countries and account for 24% of global emissions. In fact, China overtook the United States in 2007 as the world's largest annual emitter of energy-related CO_2, although in cumulative and per-capita terms the United States remains the larger. Chinese CO_2 emissions more than tripled between 1990 and 2010. The increases were especially large during the surge of economic growth and consequent higher energy demand in the middle of the last decade. Due to the global economic crisis, however, the rate of emissions growth slowed to 3% in 2008 before returning to higher levels in 2009 (5%) and 2010 (7%). The *WEO 2012* New Policies Scenario projects that the growth in Chinese emissions could slow down even further to 1.4% per year between 2010 and 2035. Even with this steady decline, emissions in 2035 would be more than 40% higher than current levels.

Since 1990, emissions in the electricity and heat generation sector grew the most, representing 50% of Chinese CO_2 emissions in 2010 (Figure 23). Emissions in the transport sector also grew rapidly, but from a much smaller base; they represented 7% of CO_2 emissions in 2010. The *WEO 2012* New Policies Scenario projects that emissions from the transport sector will continue to grow, potentially accounting for 13% of total emissions in 2035. A key challenge is that switching to low- or zero-carbon energy sources is much more difficult in transport than in other sectors.

Figure 23. China: CO_2 emissions by sector

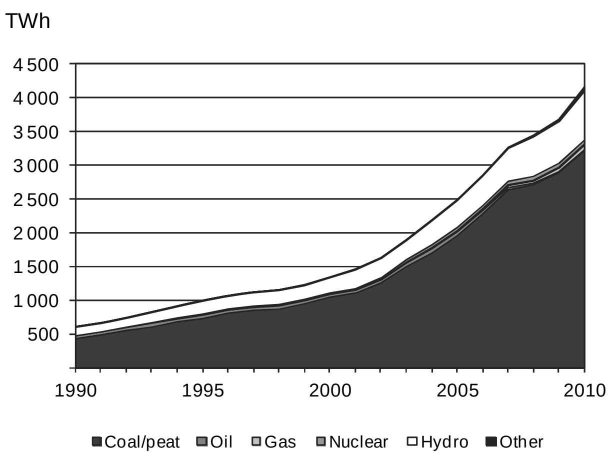


Key point: In recent years, and in line with vigorous economic expansion, China showed dramatic growth in CO_2 emissions from electricity and heat generation.

Chinese demand for electricity was the largest driver of the rise in emissions. The rate of capacity additions peaked in 2006, but in 2010 China's installed capacity rose by a net 92 GW (China Electricity Council, 2011), slightly less than the total installed capacity of the United Kingdom. At the same time, China closed nearly 17 GW of small, inefficient fossil fuel-fired plants, roughly equivalent to Finland's installed capacity.

Coal played a major role in supporting the growing demand for electricity generation (Figure 24). Nearly all of the 1990-2010 emissions growth from power generation derived from coal, although the emissions performance of coal-fired power generation continued to improve significantly (IEA, 2009), and China is promoting natural gas (electricity generated from natural gas doubled between 2008 and 2010).

Figure 24. China: electricity generation by fuel



Key point: Coal dominates China's electricity generation and is responsible for the very fast growth in CO_2 emissions.

In the past few decades, China experienced a rapid decoupling of energy consumption and CO_2 emissions from economic growth. During the 1980s, the central government in China reduced industrial energy intensity by establishing standards and quotas for the energy supplied to firms, and had the authority to shut off the power supply when enterprises exceeded their limits (Lin, 2005). However, as the Chinese economy has moved towards an open-market operation, state-directed investment in energy conservation as a percentage of total energy investment gradually declined (IEA, 2006b), though efficiency remains a policy priority.

The rapid expansion since 2003 of heavy industrial sectors to serve huge infrastructure investments and burgeoning demand for Chinese products from domestic and overseas consumers pushed up demand for fossil fuels. As a result, CO_2 emissions per unit of GDP actually rose from 2003 to 2005. Still, at 0.79 $kgCO_2$ per unit of GDP, the 2010 CO_2/GDP is 55% lower than in 1990 (1.77 $kgCO_2$ per unit of GDP), and a recent push by the government to reduce energy intensity has helped to resume the long-term intensity decline, albeit at a much slower rate than in the past. Despite having made some of the world's largest investments in renewables, China's increasing share of coal in power generation means that a small decline in energy intensity may still be paired with an increase in emissions intensity, as was the case from 2003 to 2005.

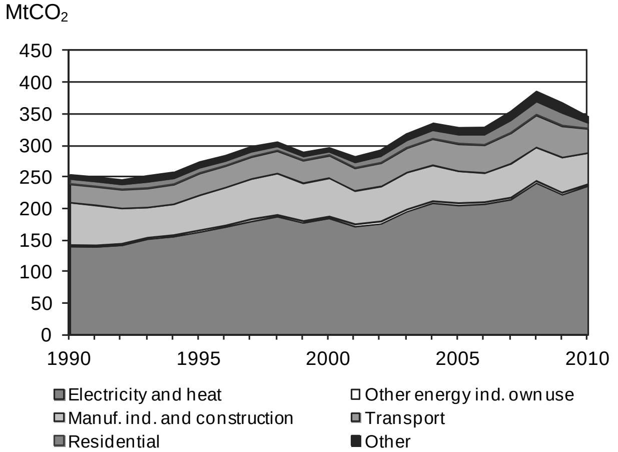
Although per-capita emissions in China in 2010 were only about one-half that of the OECD average, they have increased more than 2.5 times since 1990, with many of the largest increases occurring in the last eight years. The country is seeking ways to limit growth in CO_2 emissions, though, and is requiring all provincial and local governments to participate in implementing the 12^{th} Five-Year Plan target of lowering CO_2 emissions per unit of GDP by 17% in 2015 compared to 2010. Regional pilot projects are underway to find practical ways of reaching this target, as well as the national pledge, announced in late 2009 under the Copenhagen Accord, to reduce CO_2 emissions per unit of GDP by 40% to 45% in 2020 compared to 2005.

South Africa

South Africa currently relies heavily on fossil fuels as a primary energy source (87% in 2010); with coal providing 74% of it. Although South Africa accounted for 37% of CO_2 emissions from fuel combustion across all of Africa in 2010, it represented only 1% of the global total. The electricity and heat sector produced 69% of South Africa's CO_2 emissions in 2010 (Figure 25).

Coal dominates the South African energy system, accounting for 74% of primary energy supply and 23% of final energy consumption. In 2010, South Africa generated 94% of its electricity using coal (Figure 26). In South Africa's Long-Term Mitigation Scenarios (LTMS), in the absence of radical energy-choice changes, emissions would quadruple between 2003 and 2050, dominated by energy-related emissions (notably from the electricity, industrial and transport sectors).

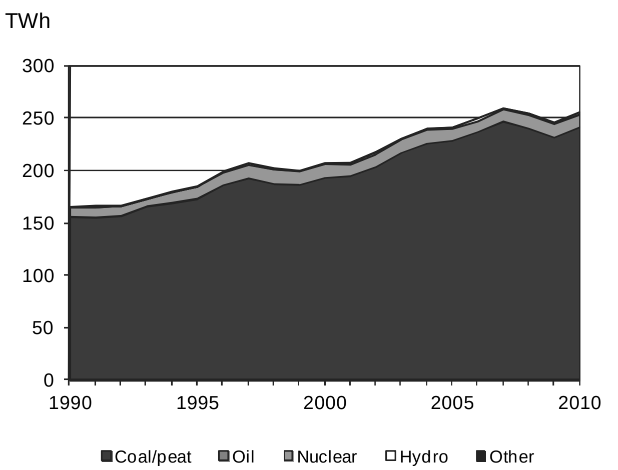
Figure 25. South Africa: CO_2 emissions by sector



Key point: The largest share of CO_2 emissions in South Africa comes from the electricity and heat sector, but growth remains moderate compared to some of the other BRICS countries.

One of the major climate change mitigation issues facing South Africa is the need to reduce GHG emissions from the power sector, primarily by reducing reliance on coal. South Africa is already taking steps to expand the use of both renewable and nuclear energy, to explore the use of carbon capture and storage (CCS) technologies, and to reduce energy demand through a nationwide energy efficiency programme. South Africa's public utility, Eskom, also has a target to reduce dependence on conventional coal to 70% by 2025 and reduce GHG emissions in absolute terms by 2050 (including increasing capacity from renewables). South Africa's current target is to reach 3 625 MW of generation capacity from renewables by 2013.

Figure 26. South Africa: electricity generation by fuel



Key point: South Africa relies almost solely on coal to produce its electricity.

The prices of commercial forms of energy in South Africa are, in general, quite low by international standards. Given the relatively lower rate of electrification (about 88% in urban areas and only 55% in rural areas in 2008), direct use of commercial forms of energy by households is limited. Traditional biofuels (especially wood) dominate energy use by rural households, causing health and safety problems, as well as concerns about the sustainability of wood supplies. Over the last 21 years, per-capita CO_2 emissions in South Africa have remained fairly constant while emissions per unit of GDP have decreased by 19%. South Africa aims to reduce GHG emissions to 34% below its business-as-usual (BAU) growth trajectory by 2020, increasing to 42% below the BAU trajectory by 2025.

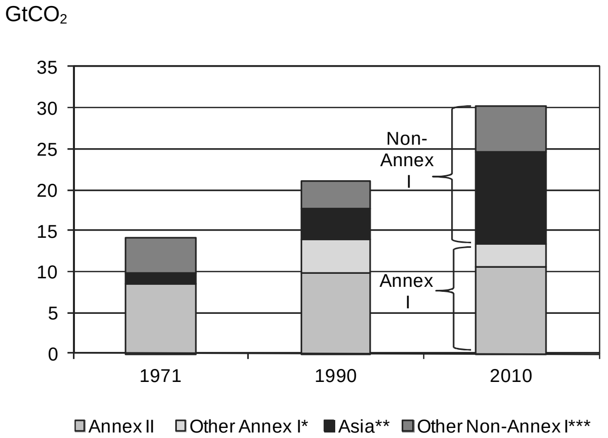
Sustainable energy use requires global engagement

Trends in CO_2 emissions from fuel combustion illustrate the need for all countries to shape a more sustainable energy future. Special emphasis should first be on the industrialised nations that have the highest per-capita incomes and that are responsible for the bulk of cumulative emissions. However, with the rapidly growing energy demand of developing countries, it is important that they also strive to use energy in a sustainable way. *ETP 2012* shows that enhancing energy efficiency and reducing the carbon intensity of energy supply, which is largely reliant on fossil fuels, are both fundamental steps towards a global low-carbon energy system.

Between 1971 and 2010, global CO_2 emissions more than doubled, with a brief dip in 2009. However, two important turning points occurred in 2008: for the first time, emissions from non-Annex I countries surpassed those in Annex I and the emission levels of Annex I countries fell below 1990 levels due to economic contraction arising from the recession and high oil prices.

The share of Annex I countries in global CO_2 emissions progressively shrank (66% in 1990 and 44% in 2010), as emissions in developing countries (led by Asia) increased at a much faster rate. The growth in Asian emissions reflects a striking rate of economic development, particularly within China and India. Between 1990 and 2010, CO_2 emissions rose by 145% for non-Annex I countries as a whole and tripled for Asia. This is in contrast to the reduction in emissions below 1990 levels that occurred in the Annex I countries (emissions in 2010 were 3.7% lower than in 1990).

Figure 27. Trends in regional CO_2 emissions



* Other Annex I includes Annex I EIT, Malta and Turkey.

** Asia includes Korea and excludes Japan (which is included in Annex II).

*** Other non-Annex I includes Africa, Latin America, Middle East, non-Annex I, non-OECD Europe and Eurasia, international bunkers, and, for 1971, Other Annex I.

Key point: In 2010, CO_2 emissions from Annex I countries were below 1990 levels, while emissions from non-Annex I countries continued to grow.

Emission trends within Annex I countries were very different. Emissions of CO_2 in Annex II countries in 2010 were 7% higher than in 1990. In Annex I EIT countries, emissions were 34% lower due to a rapid decline in industrial productivity that followed the collapse of their centrally planned economies in 1989.

Since the Industrial Revolution, the bulk of annual CO_2 emissions have originated from industrialised countries. Given the size of some developing economies and the rapid growth in their energy needs, this long period of dominance will soon end. Effective emissions mitigation will require all countries, regardless of energy demand and infrastructure, to use energy in a sustainable manner.

References

CEA (Central Electricity Authority) (2012), *Monthly Report: All India Installed Capacity-state wise/utility wise*, New Delhi as of 31 March 2012.

China Electricity Council (2011), *Summary of Developments in the Electricity Sector in 2010*, China Electricity Council, Beijing.

IEA (International Energy Agency) (2006a), *Optimising Russian Natural Gas: Reform and Climate Policy*, OECD/IEA, Paris.

IEA (2006b), *China's Power Sector Reforms: Where to Next?* OECD/IEA, Paris.

IEA (2009), *Cleaner Coal in China*, OECD/IEA, Paris.

IEA (2012a), *Energy Technology Perspectives 2012*, OECD/IEA, Paris.

IEA (2012b), *World Energy Outlook 2012*, OECD/IEA, Paris.

IPCC (Intergovernmental Panel on Climate Change) (2007), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (1996 IPCC Guidelines), IPCC, Bracknell, UK.

Lin, J. (2005), *Trends in Energy Efficiency Investments in China and the US*, Lawrence Berkeley National Laboratory, Berkeley, CA.

MNRE (Ministry of New and Renewable Energy) 2012; *Annual Report 2011-2012*, New Delhi.

Zhang G.B. (ed.) (2010), *Report on China's Energy Development for 2010*, Economic Science Press, Beijing.

3. IEA EMISSIONS ESTIMATES

The estimates of CO_2 emissions from fuel combustion presented in this publication are calculated using the IEA energy data[20] and the default methods and emission factors from the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, IPCC/OECD/IEA, Paris, 1997 (*1996 IPCC Guidelines*).

Although the IPCC approved the *2006 Guidelines* at the 25th session of the IPCC in April 2006 in Mauritius, many countries (as well as the IEA Secretariat) are still calculating their inventories using the *1996 IPCC Guidelines* since this was the version used for the Kyoto Protocol. In December 2011 in Durban, the Parties adopted Decision 15/CP.17 to update their reporting tables so as to implement the *2006 Guidelines*. These tables are currently under development and there will be a trial period that runs until end May 2013. The new reporting tables will be mandatory from 15 April 2015.

The IEA Secretariat reviews its energy databases each year. In the light of new assessments, important revisions may be made to the time series of individual countries. Therefore, certain data in this publication may have been revised with respect to previous editions.

Inventory quality

The *IPCC Guidelines* allow Parties under the UNFCCC to prepare and periodically update national inventories that are accurate, complete, comparable and transparent. Inventory quality is an important issue since countries are now implementing legally-binding commitments.

One way to assess inventory quality is to do comparisons among inventories, methodologies and input data. The *IPCC Guidelines* recommend that countries which have used a detailed Sectoral Approach for CO_2 emissions from energy combustion also use the Reference Approach for verification purposes. This will identify areas where a full accounting of emissions may not have been made (see Chapter 5, IPCC methodologies).

Reference Approach vs. Sectoral Approach

The Reference Approach and the Sectoral Approach often give different results because the Reference Approach is a top-down approach using a country's energy supply data and has no detailed information on how the individual fuels are used in each sector.

The Reference Approach provides estimates of CO_2 to compare with estimates derived using a Sectoral Approach. Theoretically, it indicates an upper bound to the Sectoral Approach "1A fuel combustion", because some of the carbon in the fuel is not combusted but will be emitted as fugitive emissions (as leakage or evaporation in the production and/or transformation stage).

Calculating CO_2 emissions inventories with the two approaches can lead to different results for some countries. In general the gap between the two approaches is relatively small (5 per cent or less) when compared to the total carbon flows involved. In cases where 1) fugitive emissions are proportional to the mass flows entering production and/or transformation processes, 2) stock changes at the level of the final consumer are not significant and 3) statistical differences in the energy data are limited, the Reference Approach and the Sectoral Approach should lead to similar evaluations of the CO_2 emissions trends.

When significant discrepancies and/or large time-series deviations do occur, they may be due to various reasons such as:

20. Published in *Energy Statistics of OECD Countries*, *Energy Balances of OECD Countries*, *Energy Statistics of Non-OECD Countries* and *Energy Balances of Non-OECD Countries*, IEA, Paris, 2012.

Large statistical differences between the energy supply and the energy consumption in the basic energy data. Statistical differences arise from the collection of data from different parts of the fuel flow from its supply origins to the various stages of downstream conversion and use. They are a normal part of a fuel balance. Large random statistical differences must always be examined to determine the reason for the difference, but equally importantly smaller statistical differences which systematically show an excess of supply over demand (or vice versa) should be pursued.

Significant mass imbalances between crude oil and other feedstock entering refineries and the (gross) oil products manufactured.

The use of aggregate net calorific and carbon content values for primary fuels which are converted rather than combusted. For example, it may appear that there is not conservation of energy or carbon depending on the calorific value and/or the carbon content chosen for the crude oil entering refineries and for the mix of products produced from the refinery for a particular year. This may cause an overestimation or underestimation of the emissions associated with the Reference Approach.

The misallocation of the quantities of fuels used for conversion into derived products (other than power or heat) ***or quantities combusted in energy industry own use***. When reconciling differences between the Reference Approach and a Sectoral Approach it is important to ensure that the quantities reported in transformation and energy industry own use (e.g. for coke ovens) reflect correctly the quantities used for conversion and for fuel use, respectively, and that no misallocation has occurred. Note that the quantities of fuels converted to derived products should have been reported in transformation in the energy balance. If any derived products are used to fuel the conversion process, the amounts involved should have been reported in energy industry own use of the energy balance. In a Sectoral Approach the inputs to transformation should not be included in the activity data used to estimate emissions.

Missing information on certain transformation outputs. Emissions from combustion of secondary fuels produced in integrated processes (for example, coke oven gas) may be overlooked in a Tier 1 Sectoral Approach if data are poor or unavailable. The use of secondary fuels (the output from the transformation process) should be included in the Sectoral Approach. Failure to do so will result in an underestimation of the Sectoral Approach.

Simplifications in the Reference Approach. Certain quantities of carbon should be included in the Reference Approach because their emissions fall under fuel combustion. These quantities have been excluded where the flows are small or not represented by a major statistic available within energy data. Examples of quantities not accounted for in the Reference Approach include lubricants used in two-stroke engines, blast furnace and other by-product gases which are used for fuel combustion outside their source category of production and combustion of waxed products in waste plants with heat recovery. On the other hand, certain flows of carbon should be excluded from the Reference Approach, but for reasons similar to the above no practical means can be found to exclude them without over complicating the calculations. These include coals and other hydrocarbons injected into blast furnaces as well as cokes used as reductants in the manufacture of inorganic chemicals. These simplifications will determine discrepancies between the Reference Approach and a Sectoral Approach. If data are available, the magnitudes of these effects can be estimated.

Missing information on stock changes that may occur at the final consumer level. The relevance of consumer stocks depends on the method used for the Sectoral Approach. If delivery figures are used (this is often the case) then changes in consumers' stocks are irrelevant. If, however, the Sectoral Approach is using actual consumption of the fuel, then this could cause either an overestimation or an underestimation of the Reference Approach.

High distribution losses or unrecorded consumption for natural gas may mean that the emissions are overestimated by the Reference Approach or underestimated by the Sectoral Approach.

The treatment of transfers and reclassifications of energy products may cause a difference in the Sectoral Approach estimation since different net calorific values and emission factors may be used depending on how the fuel is classified.

Differences between IEA estimates and UNFCCC submissions

It is possible to use the IEA CO_2 estimates for comparison with the greenhouse-gas (GHG) inventories reported by countries to the UNFCCC Secretariat. In this way, problems in methods, input data or emission factors may become apparent. However, care should be used in interpreting the results of any comparison since the IEA estimates may differ from a country's official submission for many reasons.

A recent comparison of the IEA estimates with the inventories submitted to the UNFCCC showed that for most Annex II countries, the two calculations were within 5-10% depending on the coverage of the fuel combustion sector in the national inventory. For some EIT and non-Annex I countries, differences between the IEA estimates and national inventories were larger. In some of the countries the underlying energy data were different, suggesting that more work is needed on the collecting and reporting of energy statistics for those countries.

Some countries have incorrectly defined bunkers as fuel used abroad by their own ships and planes. Still other countries have made calculation errors for carbon oxidation or have included international bunkers in their totals. Since all of the above will affect the national totals of CO_2 emissions from fuel combustion, a systematic comparison with the IEA estimates would allow countries to verify their calculations and produce more internationally comparable inventories.

In addition, the main bias in the energy data and emission factors will probably be systematic and not random. This means that the emission trends will usually be more reliable than the absolute emission levels. By comparing trends in the IEA estimates with trends in emissions as reported to the UNFCCC, it should be possible to identify definition problems or changes in the calculations, which were not reflected in the base year.

For many reasons the IEA estimates may differ from the numbers that a country submits to the UNFCCC, even if a country has accounted for all of its energy use and correctly applied the *IPCC Guidelines*. No attempt has been made to quantify the effects of these differences. In most cases these differences will be relatively small. Some of the reasons for these differences are:

- **The IEA uses a Tier 1 method.**

The IEA uses a Tier 1 Sectoral Approach based on the *1996 IPCC Guidelines*. Countries may be using a Tier 2 or Tier 3 method that takes into account different technologies.

- **The IEA is using the *1996 IPCC Guidelines*.**

The IEA continues to use the *1996 IPCC Guidelines*. Some countries may have already started using the *2006 IPCC Guidelines*.

- **Energy activity data are extracted from the IEA energy balances and may differ from those used for the UNFCCC calculations.**

Countries often have several "official" data sources such as a Ministry, a Central Bureau of Statistics, a nationalised electricity company, etc. Data can also be collected from the energy suppliers, the energy consumers or customs statistics. The IEA Secretariat tries to collect the most accurate data, but does not necessarily have access to the complete data set that may be available to national experts calculating emission inventories for the UNFCCC. In addition to different sources, the methodology used by the national bodies providing the data to the IEA and to the UNFCCC may differ. For example, general surveys, specific surveys, questionnaires, estimations, combined methods and classifications of data used in national statistics and in their subsequent reclassification according to international standards may result in different series.

- **The IEA uses average net calorific values.**

The IEA uses an average net calorific value (NCV) for each secondary oil product. These NCVs are region-specific and constant over time. Country-specific NCVs that can vary over time are used for NGL, refinery feedstocks and additives. Crude oil NCVs are further split into production, imports, exports and average. Different coal types have specific NCVs for production, imports, exports, inputs to main activity power plants and coal used in coke ovens, blast furnaces and industry, and can vary over time for each country.

Country experts may have the possibility of going into much more detail when calculating the heat content of the fuels. This in turn could produce different values than the IEA.

- **The IEA uses average emission factors.**

The IEA uses the default emission factors which are given in the *1996 IPCC Guidelines*. Country experts may have better information available.

- **The IEA does not have detailed information for the stored carbon calculation.**

The IEA does not have complete information on the non-energy use of fuels. The amount of carbon stored is estimated using the default values given in the *1996 IPCC Guidelines*. For "other products" in the stored carbon calculation, the IEA assumes that 100% of kerosene, white spirit and petroleum coke that is reported as non-energy use in the energy balance is also stored. Country experts calculating the inventories may have more detailed information.

- **The IEA cannot allocate emissions from autoproducers into the end-use sectors.**

The *1996 IPCC Guidelines* recommend that emissions from autoproduction should be included with emissions from other fuel use by end-consumers. At the same time, the emissions from the autoproduction of electricity and heat should be excluded from the energy transformation source category to avoid double counting. The IEA is not able to allocate the fuel use from autoproducers between industry and *other*. Therefore, this publication shows a category called "Unallocated autoproducers". However, this should not affect the total emissions for a country.

- **Military emissions may be treated differently.**

According to the *1996 IPCC Guidelines*, military emissions should be reported in Source/Sink Category 1 A 5, *Other (not elsewhere specified)*. Previously, the IEA questionnaires requested that warships be included in international marine bunkers and that the military use of aviation fuels be included in domestic air. All other military use should have been reported in *non-specified other*.

At the IEA/Eurostat/UNECE Energy Statistics Working Group meeting (Paris, November 2004), participants decided to harmonise the definitions used to collect energy data on the joint IEA/Eurostat/UNECE questionnaires with those used by the IPCC to report GHG inventories. As a result, starting in the 2006 edition of this publication, all military consumption should be reported in *non-specified other*. Sea-going versus coastal is no longer a criterion for splitting international and domestic navigation.

However, it is not clear whether countries are reporting on the new basis, and if they are, whether they will be able to revise their historical data. The IEA has found that in practice most countries consider information on military consumption as confidential and therefore either combine it with other information or do not include it at all.

- **The IEA estimates include emissions from coke inputs into blast furnaces. Countries may have included these emissions in the IPCC category industrial processes.**

National GHG inventories submitted to the UNFCCC divide emissions according to source categories. Two of these IPCC Source/Sink Categories are energy and industrial processes. The IPCC Reference Approach estimates national emissions from fuel combustion based on the supply of fuel to a country and by implication includes emissions from coke inputs to blast furnaces in energy industry own use. However, within detailed sectoral calculations certain non-energy processes can be distinguished. In the reduction of iron in a blast furnace through the combustion of coke, the primary purpose of coke oxidation is to produce pig iron and the emissions can be considered as an industrial process. Care must be taken not to double count these emissions in both energy and industrial processes. The IEA estimates of emissions from fuel combustion in this publication include the coke inputs to blast furnaces.

- **The units may be different.**

The *1996 IPCC Guidelines* and the UNFCCC *Reporting Guidelines on Annual Inventories* both ask that CO_2 emissions be reported in Gg of CO_2. A million tonnes of CO_2 is equal to 1 000 Gg of CO_2, so to compare the numbers in this publication with national inventories expressed in Gg, the IEA emissions must be multiplied by 1 000.

Key sources

In May 2000, the IPCC Plenary accepted the report on *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. The report provides good practice guidance to assist countries in determining their key source categories. By identifying these key sources in the national inventory, inventory agencies can prioritise their efforts and improve their overall estimates.

The *Good Practice Guidance* identifies a key source category as one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both.

For a more complete description of the IPCC methodology for determining key sources, see Chapter 5, IPCC methodologies.

In the *Good Practice Guidance*, the recommendation for choosing the level of the key source analysis is to "disaggregate to the level where emission factors are distinguished. In most inventories, this will be the main fuel types. If emission factors are determined independently for some sub-source categories, these should be distinguished in the analysis."

Since the emission estimates in this publication were produced using the default emission factors from the *1996 IPCC* Guidelines, this means that the fuel combustion categories would have been divided into:

stationary combustion – coal
stationary combustion – oil
stationary combustion – gas
mobile combustion – coal
mobile combustion – oil
mobile combustion – gas

Clearly this level of aggregation is not particularly useful in identifying where additional work is needed in refining the inventory. It does not take into account the possibility of improving data collection methods, improving emission factors or using a higher tier calculation for certain key sectors within the energy from fuel combustion source category. For this reason the IEA has disaggregated the key source analysis to the same level of detail presented in the country tables of this publication. For each country, the 11 largest sources, split by coal, oil, gas and other, are shown in the key sources table.

To calculate the level assessment, the IEA has started with the CO_2 emissions from fuel combustion as calculated by the IEA. To supplement this, where possible, the IEA has used the emissions that were submitted by the Annex I Parties to the UNFCCC in the 2012 submission of the Common Reporting Format for CO_2 (only fugitive), CH_4, N_2O, HFCs, PFCs and SF_6, not taking into account CO_2 emissions/removals from land use, land use change and forestry.[21]

For the non-Annex I Parties, CO_2 emissions from fuel combustion were from the IEA and the rest of the 2010 emissions were estimated by PBL.

The cumulative contribution only includes the 11 largest key sources of CO_2 from fuel combustion. As a result, in most cases the cumulative contribution will not be 95% as recommended in the *Good Practice Guidance* and key sources from fugitive emissions, industrial processes, solvents, agriculture and waste will not be shown. The percentage of CO_2 emissions from fuel combustion in total GHG emissions has been included as a memo item at the bottom of the table.

Notes on tables and graphs

Table of CO_2 emissions by sector

Row 1: *Sectoral Approach* contains total CO_2 emissions from fuel combustion as calculated using the IPCC Tier 1 Sectoral Approach and corresponds to IPCC Source/Sink Category 1 A. Emissions calculated using a Sectoral Approach include emissions only when the fuel is actually combusted.

Row 2: *Main activity producer electricity and heat* contains the sum of emissions from main activity producer electricity generation, combined heat and power generation and heat plants. Main activity producers are defined as those undertakings whose primary activity is to supply the public. They may be publicly or privately owned. Emissions from own on-site use of fuel are included. This corresponds to IPCC Source/Sink Category 1 A 1 a.

Row 3: *Unallocated autoproducers* contains the emissions from the generation of electricity and/or heat by autoproducers. Autoproducers are defined as undertakings that generate electricity and/or heat, wholly or partly for their own use as an activity which supports their primary activity. They may be privately or publicly owned. In the *1996 IPCC Guidelines*, these emissions would normally be distributed between industry, transport and *other*.

Row 4: *Other energy industry own use* contains emissions from fuel combusted in oil refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries. This corresponds to the IPCC Source/Sink Categories 1 A 1 b and 1 A 1 c. According to the *1996 IPCC Guidelines*, emissions from coke inputs to blast furnaces can either be counted here or in the industrial processes source/sink category. Within detailed sectoral calculations, certain non-energy processes can be distinguished. In the reduction of iron in a blast furnace through the combustion of coke, the primary purpose of the coke oxidation is to produce pig iron and the emissions can be considered as an industrial process. Care must be taken not to double count these emissions in both energy and industrial processes. In the IEA estimations, emissions from energy industry own use in blast furnaces have been included in this category.

Row 5: *Manufacturing industries and construction* contains the emissions from combustion of fuels in industry. The IPCC Source/Sink Category 1 A 2 includes these emissions. However, in the *1996 IPCC Guidelines,* the IPCC category also includes emissions from industry autoproducers that generate electricity and/or heat. The IEA data are not collected in a way that allows the energy consumption to be split by specific end-use and therefore, this publication shows autoproducers as a separate item. See Row 3, *Unallocated autoproducers*. *Manufacturing industries and construction* also includes some emissions from coke inputs into blast furnaces, which may be reported either in transformation, energy industry own use, industry or the separate IPCC Source/Sink Category 2, industrial processes.

Row 6: *Transport* contains emissions from the combustion of fuel for all transport activity, regardless of the sector, except for international marine and aviation bunkers. This includes domestic aviation, domestic

21. As recommended in the *Good Practice Guidance*.

navigation, road, rail and pipeline transport, and corresponds to IPCC Source/Sink Category 1 A 3. In addition, the IEA data are not collected in a way that allows the autoproducer consumption to be split by specific end-use and therefore, this publication shows autoproducers as a separate item. See Row 3, *Unallocated autoproducers*.

Note: Starting in the 2006 edition, military consumption previously included in *domestic aviation* and in *road* should be in *non-specified other*. See the section on Differences between IEA estimates and UNFCCC submissions, for further details.

Row 7: *Road* contains the emissions arising from fuel use in road vehicles, including the use of agricultural vehicles on highways. This corresponds to the IPCC Source/Sink Category 1 A 3 b.

Row 8: *Other* contains the emissions from commercial/institutional activities, agriculture/forestry, fishing, residential and other emissions not specified elsewhere that are included in the IPCC Source/Sink Categories 1 A 4 and 1 A 5. In the *1996 IPCC Guidelines*, the category also includes emissions from autoproducers in commercial/public services, residential and agriculture that generate electricity and/or heat. The IEA data are not collected in a way that allows the energy consumption to be split by specific end-use, and therefore, this publication shows autoproducers as a separate item. See Row 3, *Unallocated autoproducers*.

Row 9: *Residential* contains all emissions from fuel combustion in households. This corresponds to IPCC Source/Sink Category 1 A 4 b.

Row 10: *Reference Approach* contains total CO_2 emissions from fuel combustion as calculated using the IPCC Reference Approach. The Reference Approach is based on the supply of energy in a country and as a result, all inventories calculated using this method include fugitive emissions from energy transformation (e.g. from oil refineries) which are normally included in Category 1 B. For this reason, Reference Approach estimates are likely to overestimate national CO_2 emissions. In these tables, the difference between the Sectoral Approach and the Reference Approach includes statistical differences, product transfers, transformation losses and distribution losses.

Row 11: *Differences due to losses and/or transformation* contains emissions that result from the transformation of energy from a primary fuel to a secondary or tertiary fuel. Included here are solid fuel transformation, oil refineries, gas works and other fuel transformation industries. These emissions are normally reported as fugitive emissions in the IPCC Source/Sink Category 1 B, but will be included in 1 A in inventories that are calculated using the IPCC Reference Approach. Theoretically, this category should show relatively small emissions representing the loss of carbon by other ways than combustion, such as evaporation or leakage.

Negative emissions for one product and positive emissions for another product would imply a change in the classification of the emission source as a result of an energy transformation between coal and gas, between coal and oil, etc. In practice, however, it often proves difficult to correctly account for all inputs and outputs in energy transformation industries, and to separate energy that is transformed from energy that is combusted. Therefore, the row *Differences due to losses and/or transformation* sometimes shows quite large positive emissions or even negative ones due to problems in the underlying energy data.

Row 12: *Statistical differences* can be due to unexplained discrepancies in the underlying energy data. They can also be caused by differences between emissions calculated using the Reference Approach and the Sectoral Approach.

Row 13: *International marine bunkers* contains emissions from fuels burned by ships of all flags that are engaged in international navigation. The international navigation may take place at sea, on inland lakes and waterways, and in coastal waters. Consumption by ships engaged in domestic navigation is excluded. The domestic/international split is determined on the basis of port of departure and port of arrival, and not by the flag or nationality of the ship. Consumption by fishing vessels and by military forces is also excluded. Emissions from international marine bunkers should be excluded from the national totals. This corresponds to IPCC Source/Sink Category 1 A 3 d i.

Row 14: *International aviation bunkers* contains emissions from fuels used by aircraft for international aviation. Fuels used by airlines for their road vehicles are excluded. The domestic/international split should be determined on the basis of departure and landing locations and not by the nationality of the airline. Emissions from international aviation should be excluded from the national totals. This corresponds to IPCC Source/Sink Category 1 A 3 a i.

Figures 2 and 3: Emissions by sector

Other includes emissions from commercial/public services, agriculture/forestry and fishing. Emissions from unallocated autoproducers are included in *Electricity and heat*.

Figure 5: Electricity generation by fuel

The product *other* includes geothermal, solar, wind, combustibl*e* renewables and waste, etc. Electricity generation includes both main activity producer and autoproducer electricity.

Country notes

People's Republic of China

In 2012, the National Bureau of Statistics (NBS) revised the format and detail of their energy balance. Data for new products and flows were added. However, for the purposes of this publication, the old time series format was kept and updated for 2010. Over the next year, the IEA Secretariat plans to work with NBS to incorporate the new format.

Cuba

International marine bunkers for residual fuel oil in the period 1971-1983 were estimated on the basis of 1984 figures and the data reported as domestic navigation in the energy balance.

Estonia

The data reported as lignite in the energy balance represent oil shale.

France

The methodology for calculating main activity electricity and heat production from gas changed in 2000.

Italy

Prior to 1990, gas use in commercial/public services was included in residential.

Japan

Between 2004 and 2007, the IEA received revisions from the Japanese Administration. The first set of revisions received in 2004 increased the 1990 supply by 5% for coal, 2% for natural gas and 0.7% for oil compared to the previous data. This led to an increase of 2.5% in 1990 CO_2 emissions calculated using the Reference Approach while the Sectoral Approach remained fairly constant. For the 2006 edition, the IEA received revisions to the coal and oil data which had a significant impact on both the energy data and the CO_2 emissions. The most significant revisions occurred for coke oven coke, naphtha, blast furnace gas and petroleum coke. These revisions affected consumption rather than supply in the years concerned. As a result, the sectoral approach CO_2 emissions increased for all the years, however at different rates. For example, the sectoral approach CO_2 emissions for 1990 were 4.6% higher than those calculated for the 2005 edition while the 2003 emissions were 1.1% higher than those of the previous edition. Due to the impact these successive revisions have had on the final energy balance as well as on CO_2 emissions, the IEA was in close contact with the Japanese Administration to better understand the reasons behind these changes. These changes are mainly due to the Government of Japan's efforts to improve the input-output balances in the production of oil products and coal products in response to inquiries from the UNFCCC Secretariat. To cope with this issue, the Japanese Administration established a working group in March 2004. The working group completed its work in April 2006. Many of its conclusions were incorporated in the 2006 edition but some further revisions to the time series (especially in industry and *other*) were submitted for the 2007 edition.

Netherlands Antilles

Prior to 1992, the Reference Approach overstates emissions since data for lubricants and bitumen (which store carbon) are not available.

Norway

Discrepancies between Reference and Sectoral Approach estimates and the difference in the resulting growth rates arise from statistical differences between supply and consumption data for oil and natural gas. For Norway, supply of these fuels is the residual of two very large and opposite terms, production and exports.

Switzerland

The sectoral breakdown for gas/diesel oil used in residential before 1978 was estimated on the basis of commercial and residential consumption in 1978 and the data reported as commercial consumption in the energy balance in previous years.

Ukraine

To provide a better Reference Approach estimate of CO_2 emissions in 2010, for the purposes of this publication, the IEA Secretariat has adjusted the stock change and statistical difference of natural gas to better match international definitions.

United Kingdom

For reasons of confidentiality, gas for main activity electricity is included in autoproducers for 1990.

Vietnam

A detailed sectoral breakdown is available starting in 1980.

4. INDICATOR SOURCES AND METHODS

Population

The main source of the 1970 to 2010 population data for the OECD member countries is *National Accounts of OECD Countries, Volume 1*, OECD, Paris, 2012. Data for 1960 to 1969 have been estimated using the growth rates from the population series published in the *OECD Economic Outlook No. 76*. For the **Czech Republic**, **Hungary** and **Poland** (1960 to 1969) and **Mexico** (1960 to 1962), the data are estimated using the growth rates from the population series from the World Bank published in the *World Development Indicators CD-ROM*. For the **Slovak Republic**, population data for 1960 to 1989 are from the Demographic Research Centre, Infostat, Slovak Republic.

The main source of the population data for the OECD non-member countries is *World Development Indicators*, World Bank, Washington D.C., 2012. Population data for **Chinese Taipei**, **Gibraltar**, **Iraq** and a few countries within the regions **Other Africa**, **Other Non-OECD Americas** and **Other Asia** are based on the CHELEM-CEPII online database, 2012. Population data for 2010 for **Cyprus** were calculated using the population growth rate supplied by Eurostat, 2012.

GDP and GDP PPP

In this edition, the GDP and GDP PPP series have been rebased from 2000 USD to 2005 USD. As a result, those series and all associated ratios now refer to 2005 USD.

The main source of the 1970 to 2010 GDP series for the OECD member countries is *National Accounts of OECD Countries, Volume 1*, 2012. For the OECD member countries, the PPPs selected to convert the GDP from national currencies to US dollars come from the OECD Secretariat and were aggregated using the Geary-Khamis (GK) method and rebased on the United States. For a more detailed description of the methodology please see *Methodological Manual of Purchasing Power Parities*, Eurostat/OECD, 2006. The PPPs for the other countries come from the World Bank and CHELEM-CEPII. [22]

GDP data for **Australia**, **France**, **Greece** and **Sweden** for 1960 to 1969 and **Denmark** for 1966 to 1969 as well as for **Netherlands** for 1969 come directly from the most recent volume of *National Accounts*. GDP data for 1960 to 1969 for the other countries have been estimated using the growth rates from the series in the *OECD Economic Outlook No. 76* and data previously published by the OECD Secretariat. Data prior to 1986 for **Chile**, prior to 1990 for the **Czech Republic** and **Poland**, prior to 1991 for **Hungary**, and prior to 1992 for the **Slovak Republic** are IEA Secretariat estimates based on GDP growth rates from the World Bank.

The main source of the GDP series for the non-OECD member countries is *World Development Indicators*, World Bank, Washington D.C., 2012. The GDP data have been compiled for individual countries at market prices in local currency and annual rates. These data have been scaled up/down to the price levels of 2005 and then converted to US dollars using the yearly average 2005 exchange rates and purchasing power parities (PPPs).

22. Purchasing power parities are the rates of currency conversion that equalise the purchasing power of different currencies. A given sum of money, when converted into different currencies at the PPP rates, buys the same basket of goods and services in all countries. In other words, PPPs are the rates of currency conversion which eliminate the differences in price levels between different countries.

Prior to 1980, GDP figures for all non-OECD countries are based on the CHELEM-CEPII online databases, 2012. In addition, the following countries have also been based on the CHELEM-CEPII databases for the specified time periods. **Angola** (1980-1984), **Bahrain** (2009-2010), **Bosnia and Herzegovina** (1990-1993), **Brunei Darussalam** (2010), **Chinese Taipei**, **Cuba**, **Ethiopia** (1980), **Gibraltar**, **Haiti** (1980-1990), **Islamic Republic of Iran** (2010), **Iraq** (1980-1996), **North Korea**, **Kuwait** (1990-1991 and 2008-2010), **Lebanon** (1980-1987), **Libya** (1980-1998 and 2010), **Netherlands Antilles**, **Oman** (2010), **Qatar** (1980-1999 and 2010), **Senegal** (1980), **Tanzania** (1980-1987)**, Vietnam** (1980-1983), **Yemen** (1980-1989 and 2010), **Zimbabwe**, **Former Soviet Union** (1980-1989), **Former Yugoslavia** (1980-1989) and a few countries within the regions[23] **Other Africa**, **Other Non-OECD Americas** and **Other Asia**.

The World Bank GDP figures for **Kosovo** are available starting in 2000. The GDP PPP figures have been estimated using the World Bank ratio of exchange rate to PPP in 2005 for Serbia since the ratio for Kosovo was not available.

Please note: the GDP and GDP PPP series contained in this publication have been slightly revised in October 2012 after the original publication of the paper copy of Energy Balances of Non-OECD Countries.

CO_2 emissions

The estimates of CO_2 emissions in this publication are based on the *1996 IPCC Guidelines* and represent the total emissions from fuel combustion. Emissions have been calculated using both the IPCC Reference Approach and the IPCC Sectoral Approach (which corresponds to IPCC Source/Sink Category 1 A). Reference Approach totals may include certain fugitive emissions from energy transformation which should normally be included in Category 1 B. National totals do not include emissions from international marine and aviation bunkers. See the Country Notes in Chapter 1 for further details.

23. Due to lack of complete time series, figures for population and for GDP of Other Non-OECD Americas do not include British Virgin Islands, Cayman Islands, Falkland Islands, Martinique, Montserrat, Saint Pierre and Miquelon, and Turks and Caicos Islands; and figures for population and GDP of Other Asia do not include Cook Islands.

Total primary energy supply

Total primary energy supply (TPES) is made up of production + imports - exports - international marine bunkers - ***international aviation bunkers*** ± stock changes.

Please note: the TPES series (and underlying energy data) contained in this publication have been slightly revised in October 2012 after the original publication of the paper copy of Energy Balances of Non-OECD Countries. Countries that were revised include Bosnia and Herzegovina, Côte d'Ivoire, People's Republic of China, Qatar, Singapore, Ukraine and Other Africa.

Electricity output

Total output (shown in the summary tables section) includes electricity generated using fossil fuels, nuclear, hydro (excluding pumped storage), geothermal, solar, biofuels, etc.

Both **main activity**[24] **producer** and **autoproducer**[25] **plants** have been included where available.

Data include the total amount of electricity in TWh generated by both **electricity plants** and **CHP plants**. Heat production from CHP plants is not included.

CO_2 / TPES

This ratio is expressed in tonnes of CO_2 per terajoule. It has been calculated using the Sectoral Approach CO_2 emissions and total primary energy supply (including biofuels and other non-fossil forms of energy).

CO_2 / GDP

This ratio is expressed in kilogrammes of CO_2 per 2005 US dollar. It has been calculated using the Sectoral Approach CO_2 emissions and is shown with

24. Main activity producers generate electricity and/or heat for sale to third parties, *as their primary activity*. They may be privately or publicly owned. Note that the sale need not take place through the public grid.
25. Autoproducer undertakings generate electricity and/or heat, wholly or partly for their own use as an activity which supports their primary activity. They may be privately or publicly owned.

both GDP calculated using exchange rates and GDP calculated using purchasing power parities.

CO_2 / population

This ratio is expressed in tonnes of CO_2 per capita. It has been calculated using the Sectoral Approach CO_2 emissions.

Per capita CO_2 emissions by sector

These ratios are expressed in kilogrammes of CO_2 per capita. They have been calculated in two different ways. In the first ratio, the emissions from electricity and heat production are shown separately. In the second ratio, the emissions from electricity and heat have been allocated to final consuming sectors in proportion to the electricity and heat consumed by those sectors.

CO_2 emissions per kWh

Coverage

In the first table on CO_2 emissions per kWh, the CO_2 emissions in the numerator include emissions from fossil fuels, industrial waste and non-renewable municipal waste that are consumed for electricity generation and electricity output in the denominator includes electricity generated from fossil fuels, nuclear, hydro (excluding pumped storage), geothermal, solar, biofuels, etc. As a result, the emissions per kWh can vary from year to year depending on the generation mix.

In the ratios of CO_2 emissions per kWh **by fuel**:

- Coal/peat includes primary and secondary coal, peat and coal gases.
- Oil includes oil products (and small amounts of crude oil for some countries).
- Gas represents natural gas.

Note: Emissions per kWh should be used with caution due to data quality problems relating to electricity efficiencies for some countries.

Background on this indicator

In previous editions of this publication, the IEA has published an indicator for CO_2 emissions per kWh for the electricity and heat generating industries. The indicator is useful as an overall carbon intensity measure of a country's electricity and heat generating sectors, and it is easy to calculate. However, the indicator has a number of drawbacks. As the efficiency of heat generation is almost always higher than electricity generation, countries with large amounts of district heating (generally colder countries) will see a higher efficiency (therefore lower CO_2 intensity) than warmer countries with less district heating. Further, the applications of an indicator for electricity and heat are limited; many users have been searching for an electricity-only carbon intensity indicator.

It is not possible to obtain such an indicator directly from IEA energy balance data. For combined heat and power (CHP) plants, outputs of both electricity and heat exist, but there is only one input amount. While various methods exist to allocate this input amount between electricity and heat, none has previously been used by the IEA for the purposes of calculating a carbon intensity indicator. It would be possible to calculate an electricity-only indicator using data for electricity-only plants, which would not encounter the problem of assigning CHP inputs between electricity and heat. But this would not give a true comparison between countries; some countries get a majority of their electricity from CHP, while for others 100% of electricity comes from electricity-only plants. As non-thermal renewables are solely electricity-only plants, and over 99% of non-emitting global nuclear generation is from electricity-only plants, then calculating this electricity-only plants indicator would significantly understate the carbon intensity for many countries.

Allocation of emissions from CHP plants

After deciding that it was best to allocate the CHP inputs, a method had to be chosen. The simplest one would be to use the **proportionality approach** that is used by the IEA electricity questionnaire, which allocates inputs based upon the proportion of electricity and heat in the output. This is equivalent to fixing the efficiency of electricity and heat to be equal. This method has the advantage of simplicity and transparency. The disadvantage, however, is that the proportionality approach usually overstates electricity efficiency and understates heat efficiency. For CHP generation in OECD countries, total efficiency is around 60%. Applying this 60% to electricity generation is inaccurate, given that the OECD's total electricity-only plant efficiency is around 41% (and this includes 100% efficiency hydro and other renewables). Similarly, 60% is quite low for heat generation (given typical heat-only plant efficiencies of 80-95%), so a better allocation method was sought.

One way of avoiding the unrealistic efficiencies is to use a **fixed-heat-efficiency approach** which fixes the efficiency of the heat part of the generation, and calculates the electricity part of the input accordingly. As a typical heat boiler has an efficiency of 90%, it was decided to use this as the standard heat efficiency (except when the total CHP efficiency was greater than 90%, in which case the observed efficiency would be used). Of course in certain circumstances, this may be overstating the actual heat efficiency. Employing this method gave results that attributed more emissions to the electricity than when the proportionality approach is used, but that were much closer to those of electricity-only plants. Already the IEA has used the fixed-heat-efficiency approach for the last two editions of *World Energy Outlook*.

Fixed-heat-efficiency approach

$$\mathrm{CO2kWh} = \frac{\mathrm{CO2_{ELE}} + (\mathrm{CO2_{CHP}} \times \%\ \text{from elec.}) + \mathrm{OWNUSE_{ELE}}}{\mathrm{ELoutput_{ELE}} + \mathrm{ELoutput_{CHP}}}$$

where:

$$\%\ \text{from elec.} = \frac{\mathrm{CHPinputs} - ((\mathrm{HEoutput_{CHP}} \times 0.02388) \div \mathrm{EFF_{HEAT}})}{\mathrm{CHPinputs}}$$

and:

$$\mathrm{OWNUSE_{ELE}} = \mathrm{OWNUSE} \times \frac{\mathrm{ELoutput}}{\mathrm{ELoutput} + (\mathrm{HEoutput} \div 3.6)}$$

$CO2_{ELE}$ = CO_2 emissions from electricity only plants in $ktCO_2$
$CO2_{CHP}$ = CO_2 emissions from CHP plants in $ktCO_2$
OWNUSE = CO_2 emissions from own use in electricity, CHP and heat plants in $ktCO_2$

ELoutput = total electricity output from electricity and CHP plants in GWh
$ELoutput_{ELE}$ = electricity output from electricity only plants in GWh
$ELoutput_{CHP}$ = electricity output from CHP plants in GWh
HEoutput = total heat output from CHP and heat plants in TJ
$HEoutput_{CHP}$ = heat output from CHP plants in TJ

CHPinputs = energy inputs to CHP plants in ktoe
EFF_{HEAT} is assumed to be 0.9 (*i.e.* 90%) except when the efficiency of CHP generation is higher than 90%, in which case it is set at the higher value

Comparison with the previous ratio

Applying this new methodology, the new electricity indicator is not significantly different from the previous electricity and heat indicator for the majority of OECD countries; for the OECD total in 2010, the new indicator is 3.2% higher. In this year, 20 of the OECD's 34 countries saw a change of 5% or less. Of the 14 countries changing more than 5%, six countries had large amounts of non-emitting electricity generation, giving them a small ratio to begin with (thus more prone to change). In addition, non-emitting generation is generally electricity-only, and so when the heat-only and heat CHP emissions are removed from the calculation, greater weight is attached to the non-emitting generation, thus lowering the indicator.

The countries in the OECD that saw larger increases to their ratio with the new method were generally coal-intensive countries with large amounts of heat generation; as mentioned, in general, heat plants are more efficient than electricity-only (or indeed CHP) plants and so excluding heat plants from the calculation increases CO_2 intensity. The same is true if we allocate a high efficiency to the heat part of CHP generation; this decreases the efficiency of the electricity part and thus increases electricity's carbon intensity. Further, CHP and heat plants are more likely to be powered by CO_2-light natural gas while electricity-only plants tend to be powered by CO_2-heavy coal, making the new ratio more CO_2 intensive for these countries.

Specific country examples

The country that increased its ratio the most within the OECD was **Estonia**; in 2010 the new electricity indicator was 38% higher than the previous electricity and heat indicator. This can be explained by the majority of electricity-only generation coming from oil shale, a fuel with a relatively high carbon emission factor, while heat plants (with a relatively large share of output) are largely fuelled by natural gas.

Another OECD country with a high ratio increase was **Denmark** (32% higher in 2010). The majority of fossil generation in Denmark is from CHP and the output from these plants is approximately half electricity and half heat. In addition, CHP plants in Denmark have efficiencies of 60-70%. When the heat part of CHP is set to be 90%, the efficiency of the electricity generation is lowered and thus moves the new indicator upwards.

In many non-member countries, heat data are either zero or not available, which leads to changes of less than 1% in three-quarters of the non-member countries in 2010. The majority of countries which do change are the European and former Soviet Union countries (where district heating is often present).

As **China** has no (reported) CHP generation, the current IEA energy balance shows electricity-only and heat-only plants, not CHP plants. Heat-only plants are in general much more efficient per unit of energy than electricity-only plants and this explains why the new ratio is 8% higher in 2010.

In the **Russian Federation**, a large amount (33% of total power output) comes from heat-only plants, whose relatively efficient generation is excluded from the new ratio. The large amount of heat output generated by CHP plants also explains why the new ratio is 108% higher in 2010.

The ratios for the following non-member countries are also lower than the previous estimates: **Georgia**, **Kyrgyzstan** and **Tajikistan**. This is because their electricity production is exclusively clean hydro, while their CHP and heat-only are exclusively fossil based. Implementing the new electricity-only indicator using the fixed-heat-efficiency approach increased hydro's weight (therefore decreasing the carbon intensity).

Implied emission factors from electricity generation

Summary tables presenting CO_2 emissions per kWh from electricity generation by country are presented in Part II. However, these values will vary enormously depending on the fuel mix of individual countries. Average implied emission factors by individual product for this sector are presented below. These values represent the average grammes of CO_2 per kWh of electricity produced in the OECD member countries between 2008 and 2010. These figures will reflect any problems that may occur in net calorific values or in input/output efficiencies. Consequently, these values are given as an approximation and actual values may vary considerably.

Fuel	gCO_2 / kWh
Anthracite *	920
Coking coal *	780
Other bituminous coal	860
Sub-bituminous coal	920
Lignite	990
Coke oven coke *	770
Coal tar *	720
BKB/peat briquettes *	800-1500
Gas works gas *	420
Coke oven gas *	420
Blast furnace gas *	2200
Other recovered gases *	2000
Natural gas	400
Crude oil *	630
Natural gas liquids *	480
Refinery gas *	400
Liquefied petroleum gases *	500
Kerosene *	650
Gas/diesel oil *	690
Fuel oil	670
Petroleum coke *	1000
Peat *	750
Industrial waste *	400-2000
Municipal waste (non-renewable)*	450-3500

* These fuels represent less than 1% of electricity output in the OECD. Values will be less reliable and should be used with caution.

5. GEOGRAPHICAL COVERAGE

Africa includes Algeria, Angola, Benin, Botswana (from 1981), Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Libyan Arab Jamahiriya, Morocco, Mozambique, Namibia (from 1991), Nigeria, Senegal, South Africa, Sudan, United Republic of Tanzania, Togo, Tunisia, Zambia, Zimbabwe and **Other Africa**.

Other Africa includes Botswana (until 1980), Burkina Faso, Burundi, Cape Verde, Central African Republic, Chad, Comoros, Djibouti, Equatorial Guinea, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Namibia (until 1990), Niger, Reunion, Rwanda, Sao Tome and Principe, Seychelles, Sierra Leone, Somalia, Swaziland, Uganda and Western Sahara (from 1990).

Middle East includes Bahrain, Islamic Republic of Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates and Yemen.

Non-OECD Europe and Eurasia includes Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus[26], Georgia, Gibraltar, Kazakhstan, Kosovo, Kyrgyzstan, Latvia, Lithuania, Former Yugoslav Republic of Macedonia (FYROM), Malta, Republic of Moldova, Montenegro, Romania, Russian Federation, Serbia[27], Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Former Soviet Union[28] (prior to 1990) and Former Yugoslavia[28] (prior to 1990).

Non-OECD Americas includes Argentina, Bolivia, Brazil, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles[29], Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela and **Other Non-OECD Americas**.

Other Non-OECD Americas includes Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands, French Guyana, Grenada, Guadeloupe, Guyana, Martinique, Montserrat, Puerto Rico[30] (for natural gas and electricity), St. Kitts and Nevis, Saint Lucia, Saint Pierre et Miquelon, St. Vincent and the Grenadines, Suriname and Turks/Caicos Islands.

China includes the People's Republic of China and Hong Kong (China).

Asia includes Bangladesh, Brunei Darussalam, Cambodia (from 1995), Chinese Taipei, India, Indonesia, DPR of Korea, Malaysia, Mongolia (from 1985),

26. Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus" issue.
Note by all the European Union Member States of the OECD and the European Commission: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this report relates to the area under the effective control of the Government of the Republic of Cyprus.

27. Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

28. Prior to 1990, Former Soviet Union includes Estonia and Former Yugoslavia includes Kosovo, Montenegro and Slovenia.

29. The Netherlands Antilles was dissolved on 10 October 2010 resulting in two new constituent countries, Curaçao and Saint Maarten, with the other islands joining the Netherlands. However, due to lack of detailed data, the IEA data and estimates under Netherlands Antilles cover the whole territory of the Netherlands Antilles.

30. Oil statistics as well as coal trade statistics for Puerto Rico are included under the United States.

Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Vietnam and **Other Asia**.

Other Asia includes Afghanistan, Bhutan, Cambodia (until 1994), Cook Islands, East Timor, Fiji, French Polynesia, Kiribati, Laos, Macau, Maldives, Mongolia (until 1984), New Caledonia, Palau (from 1994), Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu.

The **Organisation for Economic Co-Operation and Development (OECD)** includes Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia[31], Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel[32], Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia[12], Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

Within the **OECD**:

Australia excludes the overseas territories.

Denmark excludes Greenland and the Danish Faroes, except prior to 1990, where data on oil for Greenland were included with the Danish statistics. The National Administration is planning to revise the series back to 1974 to exclude these amounts.

France includes Monaco, and excludes the following overseas departments and territories (Guadeloupe, Guyana, Martinique, New Caledonia, French Polynesia, Reunion and St.-Pierre and Miquelon).

Germany includes the new federal states of Germany from 1970 onwards.

The statistical data for **Israel** are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Italy includes San Marino and the Vatican.

Japan includes Okinawa.

The **Netherlands** excludes Suriname and the Netherlands Antilles.

31. Estonia and Slovenia are included in OECD totals starting in 1990. Prior to 1990, data for Estonia are included in Former Soviet Union and data for Slovenia in Former Yugoslavia.

32. The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Portugal includes the Azores and Madeira.

Spain includes the Canary Islands.

Switzerland includes Liechtenstein for oil data only. Data for other fuels do not include Liechtenstein.

Shipments of coal and oil to the Channel Islands and the Isle of Man from the **United Kingdom** are not classed as exports. Supplies of coal and oil to these islands are, therefore, included as part of UK supply. Exports of natural gas to the Isle of Man are included with the exports to Ireland.

United States includes the 50 states and the District of Columbia. Oil statistics as well as coal trade statistics also include Puerto Rico[33], Guam, the Virgin Islands, American Samoa, Johnston Atoll, Midway Islands, Wake Island and the Northern Mariana Islands.

The **European Union - 27 (EU-27)** includes Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, the Slovak Republic, Slovenia, Spain, Sweden and the United Kingdom.

The **International Energy Agency (IEA)** includes Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

Annex I Parties include Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, the Czech Republic[34], Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein (not available in this publication), Lithuania, Luxembourg, Malta, Monaco (included with France), the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, the Slovak Republic[34], Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, the United Kingdom and the United States.

The countries that are listed above are included in Annex I of the United Nations Framework Convention on Climate Change as amended on 11 December 1997 by the 12th Plenary meeting of the Third Conference of the Parties in Decision 4/CP.3. This includes the

33. Natural gas and electricity data for Puerto Rico are included under Other Non-OECD Americas.

34. Czechoslovakia was in the original list of Annex I countries.

countries that were members of the OECD at the time of the signing of the Convention, the EEC, and fourteen countries in Central and Eastern Europe and the Former Soviet Union that were undergoing the process of transition to market economies. At its fifteenth session, the Conference of the Parties decided to amend Annex I to the Convention to include Malta (Decision 3/CP.15). The amendment entered into force on 26 October 2010.

Annex II Parties include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States.

According to Decision 26/CP.7 in document FCCC/CP/2001/13/Add.4, Turkey has been deleted from the list of Annex II countries to the Convention. This amendment entered into force on 28 June 2002.

Economies in Transition (EITs) are those countries in Annex I that were undergoing the process of transition to a market economy. This includes Belarus, Bulgaria, Croatia, the Czech Republic[35], Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Russian Federation, the Slovak Republic[35], Slovenia and Ukraine.

Annex I Kyoto Parties include Australia, Austria, Belgium, Bulgaria, Canada, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein (not available in this publication), Lithuania, Luxembourg, Monaco (included with France), the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine and the United Kingdom.

Membership in the Kyoto Protocol is almost identical to that of Annex I, except for Malta, Turkey and Belarus which did not agree to a target under the Protocol, and the United States which has expressed the intention not to ratify the Protocol. Australia ratified the Protocol on 12 December 2007 and has been included in the Kyoto aggregate in this edition.

In accordance with article 27 (1) of the Kyoto Protocol to the UNFCC, the Government of Canada notified the Secretary-General of the United Nations that it has decided to withdraw from the Kyoto Protocol. The action will become effective for Canada on 15 December 2012 in accordance with article 27 (2). For the purposes of this edition, Canada is still included in the Annex I and Annex II Kyoto Parties.

Please note that the following countries have not been considered due to lack of data:

Africa: Saint Helena.

Asia and Oceania: Christmas Island, Nauru and Niue.

Non-OECD Americas: Anguilla.

Non-OECD Europe and Eurasia: Liechtenstein[36] (except for oil data).

35. Czechoslovakia was in the original list of Annex I EIT countries.

36. Oil data for Liechtenstein are included under Switzerland.

6. SUMMARY TABLES

CO_2 emissions: Sectoral Approach

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World *	**14 064.8**	**15 668.5**	**18 042.2**	**18 623.5**	**20 973.9**	**21 843.8**	**23 509.1**	**27 187.4**	**29 483.0**	**28 946.7**	**30 276.1**	**44.4%**
Annex I Parties	*..*	*..*	*..*	*..*	*13 906.7*	*13 177.7*	*13 762.0*	*14 129.1*	*13 904.3*	*12 972.7*	*13 398.1*	*-3.7%*
Annex II Parties	*8 607.3*	*8 884.4*	*9 544.5*	*9 172.8*	*9 802.1*	*10 202.5*	*11 006.1*	*11 305.2*	*10 945.8*	*10 214.3*	*10 519.3*	*7.3%*
North America	*4 630.9*	*4 738.2*	*5 088.7*	*4 948.2*	*5 301.5*	*5 604.5*	*6 231.4*	*6 331.0*	*6 137.3*	*5 710.3*	*5 905.3*	*11.4%*
Europe	*3 059.8*	*3 092.8*	*3 350.7*	*3 105.9*	*3 152.8*	*3 138.3*	*3 220.9*	*3 350.4*	*3 234.5*	*2 993.2*	*3 056.6*	*-3.1%*
Asia Oceania	*916.7*	*1 053.4*	*1 105.1*	*1 118.7*	*1 347.8*	*1 459.7*	*1 553.7*	*1 623.8*	*1 574.0*	*1 510.8*	*1 557.4*	*15.6%*
Annex I EIT	*..*	*..*	*..*	*..*	*3 975.4*	*2 820.2*	*2 553.2*	*2 604.9*	*2 692.5*	*2 499.6*	*2 610.5*	*-34.3%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*6 449.4*	*7 959.8*	*8 908.3*	*12 078.7*	*14 511.3*	*14 944.6*	*15 779.0*	*144.7%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*8 784.3*	*7 822.6*	*7 802.5*	*8 076.4*	*7 987.0*	*7 466.8*	*7 695.8*	*-12.4%*
Intl. marine bunkers	**344.2**	**331.7**	**347.9**	**297.7**	**362.5**	**419.5**	**488.8**	**565.8**	**620.2**	**601.8**	**643.7**	**77.6%**
Intl. aviation bunkers	**167.3**	**171.8**	**199.7**	**222.0**	**255.3**	**286.8**	**350.1**	**413.8**	**447.1**	**427.6**	**455.3**	**78.3%**
Non-OECD Total **	**4 183.1**	**5 366.5**	**6 783.9**	**7 659.6**	**9 199.3**	**9 459.5**	**10 035.8**	**13 175.3**	**15 628.6**	**15 894.3**	**16 736.8**	**81.9%**
OECD Total ***	**9 370.1**	**9 798.5**	**10 710.6**	**10 444.1**	**11 156.8**	**11 678.0**	**12 634.4**	**13 032.5**	**12 787.0**	**12 023.0**	**12 440.3**	**11.5%**
Canada	339.6	377.4	427.1	402.5	432.9	465.8	533.3	559.4	550.5	525.5	536.6	24.0%
Chile	20.8	17.0	21.2	19.4	31.0	38.9	52.5	58.2	68.5	65.4	69.7	124.6%
Mexico	97.1	138.8	212.1	251.6	264.9	296.6	349.3	385.5	403.7	399.7	416.9	57.4%
United States	4 291.3	4 360.8	4 661.6	4 545.7	4 868.7	5 138.7	5 698.1	5 771.7	5 586.8	5 184.8	5 368.6	10.3%
OECD Americas	**4 748.8**	**4 894.0**	**5 322.0**	**5 219.2**	**5 597.4**	**5 940.0**	**6 633.3**	**6 774.7**	**6 609.5**	**6 175.4**	**6 391.9**	**14.2%**
Australia	144.1	180.0	208.0	221.0	260.0	285.4	338.8	369.2	385.8	384.0	383.5	47.5%
Israel	14.4	17.1	19.6	24.5	33.5	46.3	55.2	58.7	64.3	63.5	68.1	103.0%
Japan	758.8	856.3	880.7	878.1	1 064.4	1 147.9	1 184.0	1 220.7	1 154.3	1 095.7	1 143.1	7.4%
Korea	52.1	76.8	124.4	153.3	229.3	358.6	437.7	469.1	501.7	515.5	563.1	145.6%
New Zealand	13.7	17.1	16.4	19.6	23.4	26.3	30.9	33.9	34.0	31.1	30.9	31.8%
OECD Asia Oceania	**983.1**	**1 147.2**	**1 249.1**	**1 296.5**	**1 610.6**	**1 864.6**	**2 046.6**	**2 151.6**	**2 140.0**	**2 089.8**	**2 188.6**	**35.9%**
Austria	48.7	50.2	55.7	54.3	56.4	59.4	61.7	74.6	70.6	63.5	69.3	22.9%
Belgium	116.8	115.6	125.7	101.9	107.9	115.2	118.6	112.6	111.0	100.7	106.4	-1.4%
Czech Republic	151.0	152.6	165.8	173.1	155.1	123.7	121.9	119.6	117.3	110.1	114.5	-26.2%
Denmark	55.0	52.5	62.5	60.5	50.4	58.0	50.6	48.3	48.4	46.7	47.0	-6.8%
Estonia	..	..	..	..	36.1	16.1	14.6	16.9	17.7	14.7	18.5	-48.9%
Finland	39.8	44.4	55.2	48.6	54.4	56.0	55.1	55.2	57.0	55.0	62.9	15.7%
France	431.9	430.6	461.4	360.3	352.3	353.8	376.9	388.4	370.2	351.4	357.8	1.6%
Germany	978.6	975.5	1 055.6	1 014.6	949.7	867.8	825.0	809.0	800.1	747.1	761.6	-19.8%
Greece	25.2	34.5	45.3	54.6	70.1	75.8	87.4	95.0	94.3	90.2	84.3	20.2%
Hungary	60.3	70.7	83.7	80.8	66.4	57.3	54.2	56.4	53.0	48.2	48.9	-26.3%
Iceland	1.4	1.6	1.7	1.6	1.9	1.9	2.1	2.2	2.1	2.1	1.9	2.3%
Ireland	21.7	21.1	25.9	26.4	29.8	32.3	40.9	43.6	43.5	39.0	38.7	29.7%
Italy	292.9	319.6	359.8	347.5	397.4	409.4	426.0	460.8	435.1	389.4	398.5	0.3%
Luxembourg	15.4	12.1	11.9	9.9	10.4	8.1	8.1	11.4	10.6	10.0	10.6	1.6%
Netherlands	129.6	140.8	166.7	154.0	155.8	170.9	172.1	182.7	182.8	176.1	187.0	20.0%
Norway	23.5	24.1	28.0	27.2	28.3	32.8	33.5	36.3	37.5	37.0	39.2	38.5%
Poland	286.7	338.2	413.1	419.5	342.1	331.1	290.9	292.9	298.5	287.0	305.1	-10.8%
Portugal	14.4	18.1	23.8	24.6	39.3	48.3	59.4	62.8	53.2	53.1	48.2	22.6%
Slovak Republic	39.1	43.8	55.3	54.4	56.7	40.8	37.4	38.1	36.2	33.2	35.0	-38.3%
Slovenia	..	..	..	..	12.5	13.3	14.1	15.6	16.7	15.2	15.3	22.5%
Spain	119.9	156.5	187.7	175.2	205.2	232.7	283.9	339.4	317.1	282.4	268.3	30.7%
Sweden	82.4	79.4	73.4	58.8	52.8	57.5	52.8	50.3	44.4	41.4	47.6	-9.8%
Switzerland	38.9	36.7	39.2	41.4	41.4	41.6	42.5	44.6	43.8	42.4	43.8	5.9%
Turkey	41.4	59.2	70.9	94.6	126.9	152.7	200.6	216.4	263.5	256.3	265.9	109.5%
United Kingdom	623.5	579.5	571.1	544.5	549.3	516.6	524.3	533.0	512.8	465.5	483.5	-12.0%
OECD Europe ***	**3 638.2**	**3 757.3**	**4 139.5**	**3 928.4**	**3 948.7**	**3 873.3**	**3 954.6**	**4 106.2**	**4 037.6**	**3 757.8**	**3 859.8**	**-2.3%**
European Union - 27	*..*	*..*	*..*	*..*	*4 050.0*	*3 845.2*	*3 830.6*	*3 977.3*	*3 864.8*	*3 570.5*	*3 659.5*	*-9.6%*

* Total world includes non-OECD total, OECD total as well as international marine bunkers and international aviation bunkers.
** Includes Estonia and Slovenia prior to 1990.
*** Excludes Estonia and Slovenia prior to 1990.

CO_2 emissions: Sectoral Approach

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**4 183.1**	**5 366.5**	**6 783.9**	**7 659.6**	**9 199.3**	**9 459.5**	**10 035.8**	**13 175.3**	**15 628.6**	**15 894.3**	**16 736.8**	**81.9%**
Albania	3.9	4.5	7.6	7.2	6.3	1.9	3.1	4.1	3.9	3.5	3.8	-39.9%
Armenia	..	..	..	..	20.5	3.4	3.4	4.1	5.3	4.3	4.0	-80.3%
Azerbaijan	..	..	..	..	65.0	32.2	29.8	32.8	29.5	24.7	24.7	-62.0%
Belarus	..	..	..	..	124.5	61.4	58.7	62.1	64.5	62.3	65.3	-47.5%
Bosnia and Herzegovina	..	..	..	..	23.7	3.2	13.5	15.6	19.9	19.4	19.9	-15.8%
Bulgaria	62.8	72.2	83.8	81.1	74.8	53.2	42.1	45.9	49.0	42.2	43.8	-41.4%
Croatia	..	..	..	..	21.6	15.8	17.7	20.8	21.0	19.8	19.0	-11.9%
Cyprus	1.8	1.7	2.6	2.8	3.8	5.2	6.3	7.0	7.6	7.5	7.2	88.1%
Georgia	..	..	..	..	33.2	8.1	4.6	4.3	4.8	5.4	4.9	-85.1%
Gibraltar	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.5	0.5	0.5	193.9%
Kazakhstan	..	..	..	..	236.4	167.5	113.0	157.1	227.9	197.8	232.1	-1.8%
Kosovo **	..	..	..	..	..	..	5.0	6.5	7.4	8.2	8.5	..
Kyrgyzstan	..	..	..	..	22.5	4.4	4.5	5.0	5.9	7.2	7.0	-68.9%
Latvia	..	..	..	..	18.7	8.9	6.8	7.6	7.9	7.2	8.1	-56.8%
Lithuania	..	..	..	..	33.1	14.2	11.2	13.6	14.3	12.5	13.4	-59.6%
FYR of Macedonia	..	..	..	..	8.5	8.2	8.4	8.8	9.0	8.4	8.2	-3.6%
Malta	0.6	0.6	1.0	1.1	2.3	2.4	2.1	2.7	2.6	2.5	2.5	8.3%
Republic of Moldova	..	..	..	..	30.2	10.9	5.7	6.8	6.4	5.7	6.1	-79.7%
Montenegro **	..	..	..	..	..	..	..	1.4	1.9	1.2	2.1	..
Romania	114.9	140.6	176.1	173.3	167.0	117.0	86.2	93.8	92.8	78.8	75.6	-54.8%
Russian Federation	..	..	..	..	2 178.8	1 574.5	1 505.5	1 516.2	1 593.4	1 520.4	1 581.4	-27.4%
Serbia **	..	..	..	..	61.4	44.0	42.5	49.1	49.9	46.4	46.0	-25.0%
Tajikistan	..	..	..	..	10.9	2.4	2.2	2.3	3.0	2.8	2.7	-74.9%
Turkmenistan	..	..	..	..	45.8	33.9	35.4	45.1	54.7	48.0	52.7	15.1%
Ukraine	..	..	..	..	687.9	392.8	292.0	305.6	310.0	248.3	266.6	-61.2%
Uzbekistan	..	..	..	..	119.8	101.6	117.6	107.8	114.8	103.6	100.2	-16.4%
Former Soviet Union ***	1 995.8	2 567.9	3 056.0	3 197.5	..	..	..	..	..	..	..	..
Former Yugoslavia ***	63.2	75.2	87.6	121.7	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**2 243.2**	**2 862.7**	**3 414.9**	**3 584.8**	**3 996.8**	**2 667.6**	**2 417.5**	**2 526.4**	**2 707.8**	**2 488.3**	**2 606.3**	**-34.8%**
Algeria	8.9	14.0	28.4	43.2	52.7	56.8	63.5	79.6	89.7	99.1	98.6	87.0%
Angola	1.7	2.0	2.7	2.9	4.0	4.0	5.1	7.2	12.8	14.1	16.6	314.4%
Benin	0.3	0.5	0.4	0.5	0.3	0.2	1.4	2.7	3.8	4.2	4.5	+
Botswana	..	..	..	1.6	2.9	3.3	4.2	4.4	4.5	4.3	4.6	56.8%
Cameroon	0.7	1.0	1.7	2.4	2.7	2.5	2.8	2.9	4.3	4.8	5.0	88.2%
Congo	0.6	0.6	0.7	0.8	0.6	0.5	0.5	0.8	1.3	1.5	1.7	168.5%
Dem. Rep. of Congo	2.5	2.6	3.1	3.2	3.0	2.1	1.7	2.3	2.8	2.9	3.1	3.6%
Côte d'Ivoire	2.4	3.0	3.4	3.0	2.6	3.2	6.1	5.8	6.5	6.1	5.8	120.5%
Egypt	20.3	25.6	41.9	64.8	78.4	83.1	101.3	152.6	175.3	172.7	177.6	126.5%
Eritrea	..	..	..	..	..	0.8	0.6	0.6	0.5	0.5	0.5	..
Ethiopia	1.3	1.2	1.4	1.4	2.2	2.4	3.2	4.5	5.7	5.7	5.4	142.8%
Gabon	0.5	0.7	1.3	1.7	0.9	1.3	1.4	2.1	2.3	2.5	2.7	194.0%
Ghana	1.9	2.3	2.3	2.2	2.7	3.3	5.1	6.4	7.4	9.1	9.5	250.1%
Kenya	3.2	3.5	4.5	4.6	5.5	5.6	6.8	7.2	8.6	10.2	10.9	97.7%
Libya	3.7	9.2	18.6	22.5	27.4	35.1	39.7	42.5	47.0	49.8	51.6	88.7%
Morocco	6.8	9.9	14.0	16.5	19.6	26.0	29.4	40.1	43.5	42.7	46.0	134.0%
Mozambique	2.9	2.3	2.3	1.5	1.1	1.1	1.3	1.5	2.0	2.2	2.5	130.9%
Namibia	..	..	..	..	..	1.7	1.8	2.5	3.6	3.3	3.3	..
Nigeria	5.9	11.7	26.7	32.4	29.2	31.1	42.0	55.2	49.6	42.3	45.9	57.4%
Senegal	1.2	1.6	2.0	2.1	2.1	2.5	3.6	4.7	5.1	5.3	5.5	157.4%
South Africa	156.7	201.5	208.8	228.8	253.7	274.5	296.7	329.2	387.1	368.8	346.8	36.7%
Sudan	3.3	3.3	3.7	4.2	5.5	4.6	5.5	9.2	12.4	13.5	13.7	148.8%
United Rep. of Tanzania	1.5	1.5	1.6	1.5	1.7	2.5	2.6	5.1	5.8	5.6	6.0	250.5%
Togo	0.3	0.3	0.4	0.3	0.6	0.6	1.0	1.0	1.1	1.1	1.2	106.2%
Tunisia	3.7	4.8	7.8	9.6	12.1	14.2	18.0	20.2	21.5	21.3	21.9	81.7%
Zambia	3.4	4.4	3.4	2.8	2.6	2.0	1.7	2.1	1.6	1.7	1.9	-25.5%
Zimbabwe	7.2	7.2	8.0	9.6	16.0	14.8	12.7	10.4	7.9	8.4	9.1	-43.3%
Other Africa	7.6	9.2	13.1	11.7	14.4	16.7	19.2	23.3	27.0	27.0	27.9	93.5%
Africa	**248.7**	**324.2**	**401.9**	**475.6**	**544.4**	**596.6**	**678.8**	**826.0**	**940.7**	**930.6**	**929.7**	**70.8%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

CO_2 emissions: Sectoral Approach

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	3.2	4.7	7.2	8.8	13.6	20.5	25.3	36.5	46.4	50.6	53.0	290.5%
Brunei Darussalam	0.4	1.4	2.6	2.9	3.4	4.7	4.6	5.1	7.5	8.1	8.2	144.2%
Cambodia	..	..	..	..	..	1.5	2.0	2.6	3.5	3.6	3.8	..
Chinese Taipei	31.0	42.5	72.9	71.4	114.4	158.2	218.4	262.5	262.9	250.5	270.2	136.3%
India	200.2	241.2	283.3	411.0	582.3	776.6	972.5	1 164.8	1 438.5	1 564.0	1 625.8	179.2%
Indonesia	25.1	38.0	68.9	88.0	146.1	214.4	272.9	335.7	364.5	381.4	410.9	181.4%
DPR of Korea	67.5	76.7	105.6	126.4	114.0	74.9	68.6	73.8	69.0	65.8	63.0	-44.7%
Malaysia	12.7	16.1	24.3	33.7	49.6	82.8	112.7	152.0	184.0	169.4	185.0	272.6%
Mongolia	..	..	..	11.6	12.7	10.1	8.8	9.5	11.2	11.7	11.9	-6.2%
Myanmar	4.6	4.0	5.2	5.9	4.1	6.9	9.4	10.6	7.5	7.0	8.0	97.6%
Nepal	0.2	0.3	0.5	0.5	0.9	1.7	3.1	3.0	2.8	3.4	3.7	313.1%
Pakistan	16.6	20.9	26.1	39.1	58.6	79.5	97.3	117.8	133.5	137.0	134.6	129.8%
Philippines	23.0	29.0	33.3	28.5	38.2	57.2	67.5	70.7	70.4	70.8	76.4	99.9%
Singapore	6.1	8.5	12.7	16.3	29.4	41.7	47.7	50.6	55.1	55.7	62.9	114.1%
Sri Lanka	2.8	2.7	3.7	3.6	3.7	5.5	10.6	13.4	12.2	12.0	13.3	256.4%
Thailand	16.2	21.2	33.6	41.9	80.5	140.5	158.1	216.6	230.4	228.5	248.5	208.7%
Vietnam	16.1	16.7	14.8	17.1	17.2	27.8	44.0	79.8	101.9	113.8	130.5	658.5%
Other Asia	8.4	10.2	16.5	10.1	10.2	9.3	11.2	15.4	17.4	19.6	20.9	104.2%
Asia	**434.1**	**534.0**	**711.1**	**916.9**	**1 278.8**	**1 713.7**	**2 134.8**	**2 620.6**	**3 018.7**	**3 153.0**	**3 330.6**	**160.4%**
People's Rep. of China	800.4	1 051.2	1 405.3	1 704.9	2 211.3	2 986.1	3 037.3	5 062.4	6 506.8	6 800.7	7 217.1	226.4%
Hong Kong, China	9.2	10.8	14.5	22.0	32.8	36.0	39.8	40.7	42.2	45.6	41.5	26.3%
China	**809.6**	**1 062.0**	**1 419.8**	**1 726.9**	**2 244.1**	**3 022.1**	**3 077.2**	**5 103.1**	**6 549.0**	**6 846.3**	**7 258.5**	**223.5%**
Argentina	82.8	85.5	95.6	88.2	99.9	118.0	139.0	151.0	171.7	165.8	170.2	70.5%
Bolivia	2.2	3.2	4.2	4.3	5.1	6.9	7.1	9.5	12.2	12.7	14.1	173.1%
Brazil	91.1	137.2	180.3	168.0	194.3	240.4	303.5	322.5	361.9	338.1	387.7	99.6%
Colombia	26.3	28.4	33.9	38.4	45.0	57.1	58.7	57.5	59.2	61.4	60.7	34.9%
Costa Rica	1.3	1.7	2.2	2.0	2.6	4.4	4.5	5.7	6.6	6.3	6.5	151.4%
Cuba	20.4	23.7	30.2	31.9	33.8	22.2	27.1	25.1	24.9	31.6	30.0	-11.1%
Dominican Republic	3.4	5.2	6.3	6.2	7.7	11.4	17.4	17.5	19.2	18.1	18.6	142.1%
Ecuador	3.7	6.2	10.6	12.1	13.2	16.3	18.2	24.2	26.5	29.2	30.1	128.1%
El Salvador	1.4	2.0	1.7	1.8	2.2	4.6	5.2	6.1	6.2	6.2	5.9	162.8%
Guatemala	2.3	3.0	4.2	3.2	3.2	5.8	8.5	10.5	10.2	11.1	10.3	221.2%
Haiti	0.4	0.4	0.6	0.8	0.9	0.9	1.4	2.0	2.3	2.4	2.1	125.1%
Honduras	1.1	1.3	1.7	1.7	2.2	3.5	4.4	6.9	7.8	7.3	7.3	238.3%
Jamaica	5.5	7.4	6.5	4.6	7.2	8.3	9.7	10.4	11.8	8.3	8.0	10.7%
Netherlands Antilles	14.4	10.2	8.7	4.6	2.7	2.8	4.1	4.2	4.3	5.0	3.8	39.1%
Nicaragua	1.5	1.8	1.8	1.8	1.8	2.5	3.5	4.0	4.1	4.1	4.5	143.6%
Panama	2.5	3.1	2.9	2.7	2.6	4.1	4.9	6.8	6.6	7.8	8.4	228.7%
Paraguay	0.6	0.7	1.4	1.4	1.9	3.4	3.3	3.4	3.8	4.1	4.7	145.2%
Peru	15.6	18.4	20.5	18.2	19.2	23.7	26.5	28.9	35.6	38.2	41.9	118.4%
Trinidad and Tobago	6.1	5.8	7.9	9.6	11.4	12.3	21.1	33.9	39.2	40.2	42.8	276.3%
Uruguay	5.2	5.5	5.6	3.1	3.7	4.5	5.3	5.3	7.7	7.7	6.4	71.9%
Venezuela	52.1	62.8	92.4	95.2	105.1	118.3	126.7	148.2	168.3	168.4	183.0	74.2%
Other Non-OECD Americas	7.8	10.8	10.2	9.2	12.4	13.4	15.1	16.7	17.7	18.0	18.4	48.1%
Non-OECD Americas	**347.7**	**424.5**	**529.5**	**508.9**	**578.1**	**685.1**	**815.3**	**900.2**	**1 008.0**	**992.2**	**1 065.4**	**84.3%**
Bahrain	3.0	5.3	7.4	10.4	11.7	11.6	14.1	18.1	22.3	22.8	23.6	101.8%
Islamic Republic of Iran	41.7	71.5	90.2	146.4	178.7	251.3	315.1	421.6	497.7	513.9	509.0	184.9%
Iraq	10.4	15.5	27.0	36.8	53.4	97.5	70.3	74.9	73.4	91.9	104.5	95.6%
Jordan	1.3	2.1	4.3	7.4	9.2	12.2	14.4	18.0	18.5	19.3	18.6	101.5%
Kuwait	14.0	15.1	26.6	37.1	28.7	36.1	49.1	70.1	73.9	80.7	87.4	204.3%
Lebanon	4.5	5.6	6.6	6.5	5.5	12.8	14.1	14.5	15.8	19.1	18.6	241.2%
Oman	0.3	0.7	2.2	5.7	10.2	14.7	20.2	28.2	36.5	40.0	40.3	293.4%
Qatar	2.2	4.9	7.7	12.1	14.1	18.7	23.7	37.6	49.8	56.4	64.9	361.7%
Saudi Arabia	12.7	22.5	99.1	122.6	159.1	207.8	252.8	333.8	387.1	411.4	446.0	180.3%
Syrian Arab Republic	6.0	9.0	13.1	21.1	28.2	32.8	39.8	54.9	62.7	57.2	57.8	105.1%
United Arab Emirates	2.4	4.9	19.1	35.6	51.9	69.6	85.6	108.4	145.6	149.4	154.0	196.8%
Yemen	1.2	1.7	3.4	4.8	6.4	9.3	13.2	18.8	21.1	21.6	21.7	236.7%
Middle East	**99.8**	**159.0**	**306.7**	**446.6**	**557.1**	**774.5**	**912.3**	**1 198.9**	**1 404.4**	**1 483.8**	**1 546.3**	**177.6%**

CO_2 emissions: Sectoral Approach - Coal/peat

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World *	**5 181.0**	**5 596.8**	**6 549.3**	**7 366.5**	**8 302.3**	**8 540.1**	**8 832.4**	**10 999.1**	**12 619.1**	**12 458.0**	**13 065.9**	**57.4%**
Annex I Parties	*..*	*..*	*..*	*..*	*5 110.7*	*4 596.9*	*4 713.3*	*4 744.2*	*4 697.3*	*4 219.2*	*4 407.5*	*-13.8%*
Annex II Parties	*2 646.0*	*2 605.0*	*2 962.9*	*3 318.4*	*3 486.5*	*3 402.0*	*3 658.6*	*3 729.5*	*3 614.8*	*3 215.9*	*3 375.8*	*-3.2%*
North America	*1 140.6*	*1 253.2*	*1 481.4*	*1 725.2*	*1 896.7*	*2 000.2*	*2 252.7*	*2 240.1*	*2 192.3*	*1 927.8*	*2 036.5*	*7.4%*
Europe	*1 233.9*	*1 058.9*	*1 182.7*	*1 223.8*	*1 154.8*	*925.1*	*843.1*	*849.8*	*795.9*	*685.2*	*709.4*	*-38.6%*
Asia Oceania	*271.5*	*292.9*	*298.7*	*369.4*	*434.9*	*476.7*	*562.8*	*639.6*	*626.6*	*602.9*	*629.9*	*44.8%*
Annex I EIT	*..*	*..*	*..*	*..*	*1 565.7*	*1 134.1*	*965.8*	*928.5*	*967.0*	*891.1*	*912.0*	*-41.7%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*3 191.6*	*3 943.2*	*4 119.1*	*6 254.9*	*7 921.8*	*8 238.8*	*8 658.4*	*171.3%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*3 245.6*	*2 634.5*	*2 495.7*	*2 532.0*	*2 494.2*	*2 273.0*	*2 345.0*	*-27.7%*
Intl. marine bunkers	**0.1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Intl. aviation bunkers	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Non-OECD Total **	**2 047.5**	**2 462.4**	**2 950.7**	**3 335.5**	**4 147.8**	**4 514.2**	**4 500.1**	**6 582.8**	**8 252.8**	**8 495.3**	**8 884.4**	**114.2%**
OECD Total ***	**3 133.5**	**3 134.4**	**3 598.7**	**4 031.1**	**4 154.6**	**4 025.9**	**4 332.3**	**4 416.3**	**4 366.4**	**3 962.7**	**4 181.5**	**0.6%**
Canada	61.9	56.9	80.8	99.7	99.3	103.8	127.5	116.4	106.6	95.6	95.8	-3.6%
Chile	5.0	3.5	4.7	4.8	9.8	9.0	11.8	10.0	16.5	14.9	17.2	75.3%
Mexico	5.2	6.6	7.2	11.6	14.2	25.4	26.6	37.8	27.1	33.7	38.5	170.8%
United States	1 078.7	1 196.4	1 400.7	1 625.5	1 797.4	1 896.4	2 125.1	2 123.7	2 085.7	1 832.1	1 940.7	8.0%
OECD Americas	**1 150.7**	**1 263.4**	**1 493.4**	**1 741.6**	**1 920.7**	**2 034.6**	**2 291.1**	**2 287.9**	**2 235.8**	**1 976.3**	**2 092.2**	**8.9%**
Australia	73.2	90.3	104.0	116.7	137.1	152.3	189.3	201.2	204.0	204.3	199.2	45.3%
Israel	0.0	0.0	0.0	7.2	9.3	16.1	25.0	28.9	29.6	28.6	28.8	210.6%
Japan	194.1	197.7	190.8	248.8	293.4	319.9	369.1	429.8	414.5	392.5	425.4	45.0%
Korea	21.2	30.6	48.1	80.2	86.3	101.6	173.6	195.0	236.5	252.5	276.3	220.0%
New Zealand	4.2	4.8	3.8	3.9	4.4	4.4	4.3	8.7	8.1	6.1	5.3	19.9%
OECD Asia Oceania	**292.7**	**323.5**	**346.9**	**456.7**	**530.6**	**594.4**	**761.4**	**863.5**	**892.8**	**884.0**	**935.0**	**76.2%**
Austria	15.9	13.5	13.7	16.9	16.1	13.8	14.4	15.9	16.0	11.6	14.5	-9.8%
Belgium	42.2	37.0	40.2	37.8	39.0	33.4	29.0	19.1	16.7	10.6	11.4	-70.7%
Czech Republic	129.2	121.7	129.5	136.1	120.7	88.5	83.9	76.2	75.2	70.3	73.4	-39.2%
Denmark	6.0	8.0	23.8	28.4	23.7	25.3	15.4	14.4	15.9	15.7	15.3	-35.6%
Estonia	..	..	..	..	24.1	11.3	10.5	12.0	12.9	10.6	14.2	-41.1%
Finland	8.4	9.3	19.6	19.8	21.1	23.2	20.9	20.0	22.1	21.5	27.7	31.2%
France	135.3	104.2	121.2	91.3	73.6	57.5	57.5	53.8	51.1	43.2	45.3	-38.5%
Germany	554.1	494.5	552.2	580.7	504.6	370.1	337.2	332.3	328.3	290.3	306.2	-39.3%
Greece	6.8	11.0	13.4	24.9	33.4	36.4	37.6	37.8	35.4	35.1	32.9	-1.3%
Hungary	34.9	32.9	36.3	34.5	23.8	17.0	15.2	12.2	11.6	9.9	10.4	-56.1%
Iceland	0.0	-	0.1	0.3	0.3	0.2	0.4	0.4	0.4	0.3	0.4	39.5%
Ireland	8.8	7.1	8.0	10.5	13.7	11.6	10.3	10.5	9.1	8.0	7.9	-42.6%
Italy	31.7	30.2	43.0	58.1	55.1	44.9	43.3	62.8	58.9	46.8	51.8	-5.9%
Luxembourg	11.3	7.5	7.9	6.3	5.0	2.1	0.5	0.3	0.3	0.3	0.3	-94.1%
Netherlands	14.4	11.5	13.8	23.1	31.8	33.1	29.1	30.3	29.8	27.6	28.2	-11.4%
Norway	3.7	3.9	3.9	4.4	3.4	4.1	4.2	3.0	3.0	2.2	2.8	-19.8%
Poland	252.5	289.7	350.9	359.8	285.6	268.1	216.8	206.6	205.4	193.9	207.2	-27.4%
Portugal	2.4	1.6	1.6	2.9	10.6	13.9	14.7	13.1	9.8	11.1	6.4	-39.6%
Slovak Republic	23.5	23.7	32.0	33.3	30.7	21.1	16.0	15.6	15.1	14.4	14.1	-54.0%
Slovenia	..	..	..	..	5.7	4.9	5.5	6.3	6.2	5.8	5.9	4.5%
Spain	36.8	37.4	47.7	69.1	73.5	71.3	81.5	80.0	52.9	40.2	31.4	-57.3%
Sweden	5.4	6.9	5.4	10.6	10.4	9.4	8.1	9.8	8.9	6.1	9.4	-10.0%
Switzerland	2.0	1.0	1.4	2.0	1.4	0.8	0.6	0.6	0.6	0.6	0.6	-57.0%
Turkey	16.0	20.7	26.8	45.1	57.9	60.7	88.9	86.3	115.4	112.3	119.7	106.9%
United Kingdom	348.4	274.2	266.1	236.8	238.2	174.1	138.6	145.5	136.7	114.0	117.0	-50.9%
OECD Europe ***	**1 690.0**	**1 547.5**	**1 758.4**	**1 832.7**	**1 703.3**	**1 396.8**	**1 279.9**	**1 264.9**	**1 237.8**	**1 102.4**	**1 154.4**	**-32.2%**
European Union - 27	*..*	*..*	*..*	*..*	*1 733.6*	*1 403.5*	*1 241.1*	*1 238.7*	*1 187.9*	*1 044.8*	*1 089.0*	*-37.2%*

* Total world includes non-OECD total, OECD total as well as international marine bunkers and international aviation bunkers.
** Includes Estonia and Slovenia prior to 1990.
*** Excludes Estonia and Slovenia prior to 1990.

CO_2 emissions: Sectoral Approach - Coal/peat

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**2 047.5**	**2 462.4**	**2 950.7**	**3 335.5**	**4 147.8**	**4 514.2**	**4 500.1**	**6 582.8**	**8 252.8**	**8 495.3**	**8 884.4**	**114.2%**
Albania	1.2	1.6	2.5	3.7	2.4	0.1	0.1	0.1	0.1	0.2	0.2	-89.8%
Armenia	..	..	..	..	1.0	0.0	-	-	-	-	-	..
Azerbaijan	..	..	..	..	0.3	0.0	-	-	-	-	-	..
Belarus	..	..	..	..	9.2	5.2	3.5	2.3	1.9	1.9	2.0	-77.8%
Bosnia and Herzegovina	..	..	..	..	17.3	1.4	9.9	11.7	15.0	14.9	15.2	-12.4%
Bulgaria	33.2	35.0	37.8	42.2	36.8	29.6	25.4	27.7	30.8	26.1	27.9	-24.2%
Croatia	..	..	..	..	3.4	0.7	1.7	2.7	2.8	2.0	2.7	-21.1%
Cyprus	-	-	-	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	-69.9%
Georgia	..	..	..	..	3.4	0.1	0.0	0.0	0.3	0.5	0.1	-95.8%
Gibraltar	-	-	-	-	-	-	-	-	-	-	-	-
Kazakhstan	..	..	..	..	153.3	111.6	75.6	102.8	142.0	123.3	131.8	-14.0%
Kosovo **	..	..	..	..	..	..	4.0	5.1	5.8	6.6	6.9	..
Kyrgyzstan	..	..	..	..	10.0	1.3	1.9	2.2	2.2	2.4	2.4	-75.7%
Latvia	..	..	..	..	2.7	1.1	0.5	0.3	0.4	0.3	0.4	-84.7%
Lithuania	..	..	..	..	3.1	1.0	0.4	0.8	0.9	0.6	0.8	-74.5%
FYR of Macedonia	..	..	..	..	5.5	5.9	5.5	6.0	6.2	5.5	5.4	-2.1%
Malta	-	-	-	0.5	0.7	0.1	-	-	-	-	-	..
Republic of Moldova	..	..	..	..	7.8	2.3	0.4	0.3	0.3	0.3	0.3	-95.6%
Montenegro **	..	..	..	..	..	..	..	1.2	1.6	0.9	1.7	..
Romania	31.2	38.0	48.9	57.6	49.7	40.5	28.7	35.2	37.5	30.7	28.9	-41.9%
Russian Federation	..	..	..	..	687.1	483.9	441.4	407.3	421.7	404.9	396.7	-42.3%
Serbia **	..	..	..	..	41.3	36.2	35.0	33.3	34.6	32.7	31.7	-23.3%
Tajikistan	..	..	..	..	2.5	0.1	0.0	0.2	0.4	0.4	0.4	-85.2%
Turkmenistan	..	..	..	..	1.2	-	-	-	-	-	-	..
Ukraine	..	..	..	..	283.0	161.2	116.3	123.4	144.7	119.8	127.3	-55.0%
Uzbekistan	..	..	..	..	13.7	4.4	5.1	4.6	5.1	5.5	4.9	-64.0%
Former Soviet Union ***	875.2	1 028.9	1 141.8	982.9	..	..	..	..	..	..	..	..
Former Yugoslavia ***	35.8	40.5	42.6	72.4	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**976.6**	**1 143.9**	**1 273.5**	**1 159.5**	**1 335.6**	**886.8**	**755.8**	**767.3**	**854.3**	**779.5**	**788.1**	**-41.0%**
Algeria	0.4	0.3	0.2	1.0	1.3	1.4	0.7	1.0	1.2	0.7	0.7	-46.9%
Angola	-	-	-	-	-	-	-	-	-	-	-	-
Benin	-	-	-	-	-	-	-	-	-	-	-	-
Botswana	..	..	..	1.1	1.9	2.2	2.5	2.4	1.9	1.8	1.9	-0.5%
Cameroon	-	-	-	-	-	-	-	-	-	-	-	-
Congo	-	-	-	-	-	-	-	-	-	-	-	-
Dem. Rep. of Congo	1.0	0.8	0.8	0.8	0.9	1.0	0.8	1.0	1.1	1.2	1.2	42.9%
Côte d'Ivoire	-	-	-	-	-	-	-	-	-	-	-	-
Egypt	1.3	2.2	2.1	2.7	2.7	3.0	3.0	3.2	3.0	2.9	2.8	5.0%
Eritrea	..	..	..	..	..	-	-	-	-	-	-	..
Ethiopia	-	-	-	-	-	-	-	-	-	-	-	-
Gabon	-	-	-	-	-	-	-	-	-	-	-	-
Ghana	-	-	-	-	-	-	-	-	-	-	-	-
Kenya	0.2	0.1	0.0	0.2	0.4	0.2	0.2	0.2	0.3	0.2	0.4	9.3%
Libya	-	-	-	-	-	-	-	-	-	-	-	-
Morocco	1.2	1.7	1.6	2.7	4.1	6.7	10.3	12.7	11.4	10.5	10.8	162.0%
Mozambique	1.5	1.2	0.7	0.2	0.1	0.1	-	-	0.0	0.0	0.0	-82.8%
Namibia	..	..	..	..	..	0.0	0.0	0.0	0.9	0.4	0.3	..
Nigeria	0.5	0.6	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	-89.5%
Senegal	-	-	-	-	-	-	-	0.4	0.5	0.6	0.6	x
South Africa	129.2	167.4	173.7	189.2	207.2	225.7	247.6	270.1	312.5	296.4	291.0	40.4%
Sudan	-	-	0.0	-	-	-	-	-	-	-	-	-
United Rep. of Tanzania	-	-	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.3	+
Togo	-	-	-	-	-	-	-	-	-	-	-	-
Tunisia	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-	-	-	-	..
Zambia	2.0	1.9	1.4	1.1	0.9	0.3	0.3	0.3	0.0	0.0	0.0	-99.5%
Zimbabwe	5.6	5.0	6.1	7.5	13.4	11.2	9.7	8.3	6.2	6.6	7.1	-46.6%
Other Africa	0.5	0.7	0.6	0.7	1.0	0.7	1.6	1.8	2.5	2.3	2.4	144.2%
Africa	**143.6**	**182.3**	**187.9**	**207.9**	**234.4**	**253.0**	**277.0**	**301.6**	**341.7**	**323.9**	**319.7**	**36.4%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

CO_2 emissions: Sectoral Approach - Coal/peat

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	0.4	0.5	0.5	0.2	1.1	1.2	1.3	1.4	2.4	2.4	2.4	123.3%
Brunei Darussalam	-	-	-	-	-	-	-	-	-	-	-	-
Cambodia	..	..	..	..	..	-	-	-	-	0.0	0.0	..
Chinese Taipei	10.0	8.4	14.6	26.0	42.3	63.7	109.6	145.3	150.7	144.5	154.8	265.9%
India	142.6	176.1	195.4	283.7	395.9	517.3	623.6	786.5	985.0	1 073.9	1 096.8	177.0%
Indonesia	0.5	0.5	0.5	4.5	17.6	26.0	51.4	85.8	113.1	111.5	124.5	608.8%
DPR of Korea	64.9	72.5	97.5	119.0	106.1	70.9	65.4	71.0	66.3	63.8	61.0	-42.5%
Malaysia	0.0	0.0	0.2	1.4	5.1	6.5	9.6	26.7	38.0	41.0	58.0	+
Mongolia	..	..	..	9.4	10.2	9.0	7.5	7.8	8.7	9.4	9.4	-8.1%
Myanmar	0.6	0.6	0.6	0.6	0.3	0.1	1.3	1.3	1.5	1.4	1.6	511.4%
Nepal	0.0	0.1	0.2	0.0	0.2	0.3	1.0	1.0	0.7	0.7	0.8	381.4%
Pakistan	2.5	2.2	2.6	4.8	7.1	7.8	6.7	13.7	16.8	16.5	15.7	121.7%
Philippines	0.1	0.2	1.5	5.4	5.2	7.0	19.5	22.3	26.7	25.6	29.5	466.3%
Singapore	0.0	0.0	0.0	0.1	0.1	0.1	-	0.0	0.0	0.0	0.0	-65.4%
Sri Lanka	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.3	0.3	+
Thailand	0.5	0.6	1.9	6.5	16.1	29.4	31.4	46.9	60.4	58.6	64.2	299.5%
Vietnam	5.6	10.0	9.2	11.3	9.0	13.4	17.6	33.3	47.3	50.8	59.0	558.5%
Other Asia	4.1	4.3	7.7	0.9	0.8	0.6	1.3	1.6	2.9	3.0	3.2	284.3%
Asia	**231.8**	**276.1**	**332.4**	**473.9**	**617.0**	**753.3**	**947.3**	**1 244.9**	**1 520.7**	**1 603.4**	**1 681.2**	**172.5%**
People's Rep. of China	677.9	837.9	1 125.0	1 435.4	1 889.3	2 538.9	2 433.1	4 169.6	5 431.9	5 689.1	5 988.0	216.9%
Hong Kong, China	0.1	0.1	0.2	12.8	24.4	24.4	17.7	27.2	28.5	30.8	26.1	6.8%
China	**678.0**	**838.1**	**1 125.2**	**1 448.1**	**1 913.7**	**2 563.2**	**2 450.9**	**4 196.8**	**5 460.4**	**5 720.0**	**6 014.0**	**214.3%**
Argentina	3.2	3.3	3.0	3.4	3.4	4.7	4.5	4.8	4.8	4.8	5.2	53.1%
Bolivia	-	-	-	0.2	-	-	-	-	-	-	-	-
Brazil	6.8	8.3	17.3	29.4	28.5	36.4	45.1	44.4	47.3	38.5	51.9	81.8%
Colombia	5.6	6.6	7.5	8.8	10.7	12.4	11.4	9.7	9.7	11.3	8.5	-20.3%
Costa Rica	0.0	0.0	0.0	0.0	-	-	0.0	0.1	0.3	0.3	0.3	x
Cuba	0.2	0.1	0.4	0.5	0.6	0.3	0.1	0.1	0.1	0.1	0.1	-89.0%
Dominican Republic	-	-	-	0.5	0.0	0.2	0.2	1.1	2.2	2.2	2.1	+
Ecuador	-	-	-	-	-	-	-	-	-	-	-	-
El Salvador	-	-	0.0	-	-	0.0	0.0	0.0	-	-	-	-
Guatemala	-	-	0.1	-	-	-	0.5	1.0	1.1	0.7	1.2	x
Haiti	-	-	-	0.1	0.0	-	-	-	-	-	-	..
Honduras	-	-	-	-	0.0	0.0	0.3	0.4	0.5	0.5	0.5	+
Jamaica	-	-	-	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	3.8%
Netherlands Antilles	-	-	-	-	-	-	-	-	-	-	-	-
Nicaragua	-	-	-	-	-	-	-	-	-	-	-	-
Panama	0.0	0.0	-	0.1	0.1	0.1	0.1	1.0	0.1	0.2	0.3	317.9%
Paraguay	-	-	-	-	-	-	-	-	-	-	-	-
Peru	0.5	0.6	0.6	0.7	0.6	1.4	2.4	3.5	3.7	3.3	3.6	533.1%
Trinidad and Tobago	-	-	-	-	-	-	-	-	-	-	-	-
Uruguay	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-60.7%
Venezuela	0.6	1.0	0.6	0.7	1.8	0.0	0.5	0.1	0.5	0.9	0.8	-57.2%
Other Non-OECD Americas	0.1	0.1	0.1	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	299.9%
Non-OECD Americas	**17.0**	**20.0**	**29.6**	**44.5**	**45.9**	**55.6**	**65.4**	**66.5**	**70.3**	**62.9**	**74.6**	**62.6%**
Bahrain	-	-	-	-	-	-	-	-	-	-	-	-
Islamic Republic of Iran	0.4	2.1	1.9	1.6	1.2	1.8	3.2	4.5	3.4	3.2	3.2	173.5%
Iraq	-	-	-	-	-	-	-	-	-	-	-	-
Jordan	-	-	-	-	-	-	-	-	-	-	-	-
Kuwait	-	-	-	-	-	-	-	-	-	-	-	-
Lebanon	0.0	0.0	0.0	-	-	0.5	0.5	0.5	0.5	0.3	0.9	x
Oman	-	-	-	-	-	-	-	-	-	-	-	-
Qatar	-	-	-	-	-	-	-	-	-	-	-	-
Saudi Arabia	-	-	-	-	-	-	-	-	-	-	-	-
Syrian Arab Republic	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0	x
United Arab Emirates	-	-	-	-	-	-	-	0.6	1.3	2.1	2.8	x
Yemen	-	-	-	-	-	-	-	-	-	-	-	-
Middle East	**0.4**	**2.1**	**2.0**	**1.6**	**1.2**	**2.3**	**3.7**	**5.6**	**5.3**	**5.6**	**6.9**	**483.5%**

CO_2 emissions: Sectoral Approach - Oil

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World *	**6 824.1**	**7 785.9**	**8 719.7**	**8 085.6**	**8 824.5**	**9 122.4**	**9 893.8**	**10 725.0**	**10 843.8**	**10 606.6**	**10 890.5**	**23.4%**
Annex I Parties	*..*	*..*	*..*	*..*	*5 686.4*	*5 332.7*	*5 489.0*	*5 654.7*	*5 304.9*	*5 018.0*	*5 026.0*	*-11.6%*
Annex II Parties	*4 522.9*	*4 773.7*	*4 914.7*	*4 232.8*	*4 485.3*	*4 624.8*	*4 852.1*	*5 022.4*	*4 635.5*	*4 376.6*	*4 397.1*	*-2.0%*
North America	*2 232.9*	*2 341.6*	*2 427.9*	*2 164.8*	*2 251.2*	*2 265.8*	*2 517.9*	*2 705.0*	*2 478.9*	*2 344.4*	*2 378.2*	*5.6%*
Europe	*1 657.7*	*1 700.3*	*1 750.2*	*1 431.1*	*1 477.4*	*1 560.7*	*1 566.6*	*1 573.7*	*1 489.3*	*1 404.5*	*1 386.8*	*-6.1%*
Asia Oceania	*632.3*	*731.8*	*736.6*	*636.9*	*756.7*	*798.4*	*767.7*	*743.7*	*667.3*	*627.6*	*632.1*	*-16.5%*
Annex I EIT	*..*	*..*	*..*	*..*	*1 137.0*	*626.8*	*552.0*	*552.5*	*589.0*	*562.5*	*553.6*	*-51.3%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*2 520.3*	*3 083.3*	*3 565.9*	*4 090.7*	*4 471.6*	*4 559.2*	*4 765.5*	*89.1%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*3 492.7*	*3 167.4*	*3 101.1*	*3 121.2*	*2 987.6*	*2 822.1*	*2 813.1*	*-19.5%*
Intl. marine bunkers	**344.2**	**331.7**	**347.9**	**297.7**	**362.5**	**419.5**	**488.8**	**565.8**	**620.2**	**601.8**	**643.7**	**77.6%**
Intl. aviation bunkers	**167.3**	**171.8**	**199.7**	**222.0**	**255.3**	**286.8**	**350.1**	**413.8**	**447.1**	**427.6**	**455.3**	**78.3%**
Non-OECD Total **	**1 560.0**	**2 184.3**	**2 819.6**	**2 885.4**	**3 172.7**	**3 106.5**	**3 478.6**	**4 002.9**	**4 415.7**	**4 492.7**	**4 683.2**	**47.6%**
OECD Total ***	**4 752.7**	**5 098.0**	**5 352.4**	**4 680.4**	**5 034.0**	**5 309.5**	**5 576.3**	**5 742.5**	**5 360.8**	**5 084.5**	**5 108.2**	**1.5%**
Canada	209.8	233.2	246.7	188.8	209.4	212.2	237.1	272.2	263.3	253.6	261.5	24.9%
Chile	14.5	12.4	15.1	13.0	19.1	27.8	30.4	34.1	47.3	44.8	42.7	123.1%
Mexico	71.7	106.5	161.6	186.5	198.6	215.3	256.1	259.3	264.2	254.3	254.6	28.2%
United States	2 023.0	2 108.4	2 181.2	1 976.0	2 041.8	2 053.5	2 280.8	2 432.8	2 215.6	2 090.8	2 116.7	3.7%
OECD Americas	**2 319.1**	**2 460.5**	**2 604.6**	**2 364.3**	**2 468.9**	**2 508.9**	**2 804.4**	**2 998.5**	**2 790.4**	**2 643.4**	**2 675.5**	**8.4%**
Australia	66.8	80.8	87.3	79.9	89.3	94.6	104.7	112.8	118.4	115.5	117.2	31.2%
Israel	14.2	17.0	19.4	17.3	24.2	30.1	30.1	26.6	27.8	26.5	29.1	20.3%
Japan	556.2	639.4	638.6	547.4	655.4	689.5	647.1	613.0	530.4	494.5	497.4	-24.1%
Korea	30.9	46.2	76.2	73.1	135.3	234.1	219.6	203.8	181.1	182.1	186.6	37.9%
New Zealand	9.3	11.6	10.7	9.6	12.0	14.3	15.8	17.9	18.4	17.5	17.6	46.6%
OECD Asia Oceania	**677.4**	**795.0**	**832.3**	**727.2**	**916.3**	**1 062.5**	**1 017.4**	**974.1**	**876.1**	**836.2**	**847.9**	**-7.5%**
Austria	27.2	29.2	33.0	26.9	27.7	29.9	31.2	37.9	34.2	32.2	33.0	19.3%
Belgium	63.3	60.4	65.0	46.7	48.7	55.4	56.9	57.9	57.0	52.2	52.8	8.3%
Czech Republic	19.9	27.9	30.6	27.9	23.0	20.5	20.2	24.9	24.9	23.8	22.8	-0.6%
Denmark	49.0	44.2	38.5	30.2	22.0	24.4	23.5	21.7	21.1	20.1	19.7	-10.7%
Estonia	..	..	..	..	9.3	3.5	2.7	3.1	3.1	2.8	3.0	-68.0%
Finland	31.4	33.6	33.9	26.9	28.2	26.2	25.9	26.4	25.6	24.9	25.8	-8.4%
France	277.3	293.5	292.8	214.5	220.1	227.3	234.0	237.0	223.8	216.3	211.4	-3.9%
Germany	385.7	392.4	385.9	326.6	322.3	344.2	321.9	292.9	279.3	267.7	266.1	-17.5%
Greece	18.4	23.5	32.0	29.6	36.5	39.1	45.7	51.7	50.7	48.5	44.0	20.5%
Hungary	18.6	27.2	29.8	27.0	22.7	19.8	17.3	16.8	17.2	17.2	15.9	-29.9%
Iceland	1.4	1.6	1.7	1.4	1.6	1.7	1.7	1.8	1.7	1.7	1.6	-3.7%
Ireland	12.9	14.0	16.2	11.4	12.1	15.7	22.9	24.9	24.3	21.1	19.9	64.2%
Italy	237.3	248.6	267.5	229.6	252.3	261.1	248.0	231.8	211.6	191.2	184.9	-26.7%
Luxembourg	4.1	3.8	3.0	2.9	4.4	4.7	5.9	8.2	7.5	7.0	7.4	66.0%
Netherlands	68.1	56.8	83.5	55.6	52.7	57.8	60.7	68.5	69.9	64.7	65.4	24.1%
Norway	19.8	19.8	22.0	19.8	20.0	20.4	21.0	22.8	22.9	23.0	24.0	19.9%
Poland	21.9	33.5	42.8	39.2	34.5	40.9	51.5	57.9	63.8	63.8	66.6	93.1%
Portugal	12.0	16.5	22.2	21.8	28.7	34.4	39.8	40.4	33.3	31.8	30.6	6.9%
Slovak Republic	12.6	15.2	18.1	14.3	14.4	7.1	6.8	9.1	9.7	8.8	9.6	-33.2%
Slovenia	..	..	..	..	5.0	6.7	6.7	7.2	8.5	7.4	7.3	45.6%
Spain	82.4	117.3	136.9	101.6	120.9	143.1	166.8	191.4	181.8	168.5	163.7	35.4%
Sweden	77.1	72.5	67.6	47.3	40.1	45.4	41.5	36.6	31.9	31.0	32.8	-18.3%
Switzerland	36.9	34.8	36.0	35.8	34.2	33.5	33.2	34.2	33.1	32.1	32.7	-4.3%
Turkey	25.4	38.5	44.1	49.4	62.5	78.9	82.7	77.1	77.8	76.5	72.8	16.4%
United Kingdom	253.5	238.0	212.7	202.5	204.7	196.4	185.8	187.6	179.7	170.6	171.1	-16.4%
OECD Europe ***	**1 756.2**	**1 842.6**	**1 915.6**	**1 588.9**	**1 648.8**	**1 738.1**	**1 754.5**	**1 769.9**	**1 694.3**	**1 604.9**	**1 584.9**	**-3.9%**
European Union - 27	*..*	*..*	*..*	*..*	*1 641.6*	*1 670.8*	*1 671.1*	*1 695.1*	*1 620.4*	*1 528.5*	*1 508.3*	*-8.1%*

* Total world includes non-OECD total, OECD total as well as international marine bunkers and international aviation bunkers.
** Includes Estonia and Slovenia prior to 1990.
*** Excludes Estonia and Slovenia prior to 1990.

CO_2 emissions: Sectoral Approach - Oil

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**1 560.0**	**2 184.3**	**2 819.6**	**2 885.4**	**3 172.7**	**3 106.5**	**3 478.6**	**4 002.9**	**4 415.7**	**4 492.7**	**4 683.2**	**47.6%**
Albania	2.5	2.3	4.4	2.8	3.4	1.7	3.0	4.0	3.8	3.3	3.5	2.4%
Armenia	..	..	..	..	11.2	0.7	0.8	1.0	1.0	1.0	1.0	-90.8%
Azerbaijan	..	..	..	..	33.1	19.5	19.0	15.2	10.0	8.0	8.6	-74.1%
Belarus	..	..	..	..	87.8	30.6	22.3	20.9	21.3	26.1	20.9	-76.2%
Bosnia and Herzegovina	..	..	..	..	5.4	1.5	3.2	3.2	4.1	4.0	4.3	-20.9%
Bulgaria	29.1	34.9	38.6	28.0	26.0	13.7	10.3	12.0	11.7	11.3	10.8	-58.3%
Croatia	..	..	..	..	13.5	11.0	11.3	12.9	12.6	12.5	10.6	-21.1%
Cyprus	1.8	1.7	2.6	2.6	3.6	5.0	6.1	6.8	7.4	7.4	7.1	97.3%
Georgia	..	..	..	..	19.2	5.8	2.3	2.1	2.2	2.5	2.6	-86.4%
Gibraltar	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.5	0.5	0.5	193.9%
Kazakhstan	..	..	..	..	58.3	32.5	22.1	25.8	38.2	28.3	46.7	-19.9%
Kosovo **	..	..	..	..	..	..	1.0	1.3	1.6	1.6	1.5	..
Kyrgyzstan	..	..	..	..	8.9	1.4	1.2	1.4	2.2	3.5	3.6	-59.0%
Latvia	..	..	..	..	10.4	5.5	3.8	4.1	4.4	4.0	4.1	-60.3%
Lithuania	..	..	..	..	19.7	8.9	6.5	7.5	8.1	7.2	7.2	-63.6%
FYR of Macedonia	..	..	..	..	3.0	2.3	2.7	2.6	2.6	2.7	2.6	-13.7%
Malta	0.6	0.6	1.0	0.7	1.6	2.2	2.1	2.7	2.6	2.5	2.5	57.8%
Republic of Moldova	..	..	..	..	14.8	3.1	1.2	1.9	2.2	2.0	2.2	-84.9%
Montenegro **	..	..	..	..	..	..	..	0.2	0.3	0.4	0.4	..
Romania	31.5	40.0	51.6	41.1	49.9	31.9	26.5	28.0	27.2	24.7	22.7	-54.5%
Russian Federation	..	..	..	..	625.4	351.2	332.4	309.9	336.2	314.9	314.8	-49.7%
Serbia **	..	..	..	..	14.1	4.8	4.1	11.5	10.8	10.5	10.2	-27.7%
Tajikistan	..	..	..	..	5.2	1.2	0.7	0.9	1.6	1.6	1.7	-67.7%
Turkmenistan	..	..	..	..	16.0	7.7	9.9	11.8	13.8	12.8	12.2	-23.9%
Ukraine	..	..	..	..	195.5	75.4	33.7	38.2	40.2	38.0	37.2	-81.0%
Uzbekistan	..	..	..	..	30.6	19.8	19.1	13.7	11.8	11.9	10.3	-66.4%
Former Soviet Union ***	688.9	1 018.6	1 210.0	1 193.3	..	..	..	..	..	..	..	..
Former Yugoslavia ***	25.5	31.8	39.2	38.3	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**780.0**	**1 130.0**	**1 347.5**	**1 307.0**	**1 256.6**	**637.9**	**545.9**	**540.1**	**578.5**	**543.0**	**549.8**	**-56.2%**
Algeria	6.2	9.1	14.8	20.5	24.0	23.0	25.3	31.7	37.8	43.2	44.0	83.2%
Angola	1.6	1.9	2.5	2.7	3.0	2.9	4.0	6.0	11.5	12.8	15.2	411.0%
Benin	0.3	0.5	0.4	0.5	0.3	0.2	1.4	2.7	3.8	4.2	4.5	+
Botswana	..	..	..	0.5	1.0	1.2	1.7	2.0	2.6	2.5	2.7	170.0%
Cameroon	0.7	1.0	1.7	2.4	2.7	2.5	2.8	2.9	3.7	4.3	4.5	70.0%
Congo	0.6	0.6	0.7	0.8	0.6	0.5	0.5	0.8	1.3	1.4	1.6	157.6%
Dem. Rep. of Congo	1.5	1.8	2.3	2.4	2.1	1.1	0.8	1.3	1.7	1.7	1.8	-13.5%
Côte d'Ivoire	2.4	3.0	3.4	3.0	2.6	3.1	3.2	2.9	3.4	3.2	2.7	2.1%
Egypt	18.8	23.4	36.4	54.1	60.8	57.2	65.9	81.9	90.8	90.1	89.5	47.3%
Eritrea	..	..	..	..	..	0.8	0.6	0.6	0.5	0.5	0.5	..
Ethiopia	1.3	1.2	1.4	1.4	2.2	2.4	3.2	4.5	5.7	5.7	5.4	142.8%
Gabon	0.5	0.7	1.3	1.6	0.7	1.1	1.1	1.9	2.0	2.1	2.3	228.8%
Ghana	1.9	2.3	2.3	2.2	2.7	3.3	5.1	6.4	7.4	9.1	9.5	250.1%
Kenya	3.0	3.4	4.4	4.4	5.1	5.4	6.6	7.0	8.3	10.0	10.5	103.9%
Libya	1.6	6.7	13.1	15.5	18.3	26.6	30.9	32.1	35.2	38.0	39.3	114.2%
Morocco	5.6	8.1	12.3	13.6	15.4	19.2	19.0	26.6	31.0	31.0	33.8	119.3%
Mozambique	1.4	1.1	1.6	1.2	0.9	1.0	1.3	1.5	1.8	2.0	2.2	129.6%
Namibia	..	..	..	..	..	1.7	1.8	2.4	2.7	2.9	3.0	..
Nigeria	5.0	10.1	23.4	25.2	22.1	21.9	30.0	38.5	31.5	29.8	30.0	35.7%
Senegal	1.2	1.6	2.0	2.1	2.1	2.4	3.6	4.3	4.5	4.6	4.8	127.3%
South Africa	27.5	34.1	35.1	39.6	46.4	48.8	49.1	59.0	74.6	72.3	55.8	20.3%
Sudan	3.3	3.3	3.7	4.2	5.5	4.6	5.5	9.2	12.4	13.5	13.7	148.8%
United Rep. of Tanzania	1.5	1.5	1.6	1.5	1.7	2.4	2.4	4.2	4.5	4.1	4.2	149.5%
Togo	0.3	0.3	0.4	0.3	0.6	0.6	1.0	1.0	1.1	1.1	1.2	106.2%
Tunisia	3.4	4.0	6.7	7.1	9.0	9.4	11.3	12.5	12.4	12.0	11.9	33.0%
Zambia	1.5	2.5	1.9	1.7	1.7	1.7	1.4	1.8	1.6	1.7	1.9	10.9%
Zimbabwe	1.6	2.1	1.8	2.0	2.6	3.6	3.0	2.1	1.7	1.8	1.9	-26.4%
Other Africa	7.1	8.5	12.4	10.9	13.4	16.0	17.6	21.4	24.4	24.6	25.5	89.3%
Africa	**99.9**	**132.9**	**187.7**	**221.5**	**247.7**	**264.4**	**300.3**	**368.9**	**419.6**	**430.2**	**423.9**	**71.2%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

CO_2 emissions: Sectoral Approach - Oil

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	2.2	3.3	4.6	4.6	5.2	8.4	9.5	12.9	13.4	14.3	15.4	197.9%
Brunei Darussalam	0.2	0.2	0.5	0.6	0.9	1.3	1.4	1.6	2.0	2.0	2.0	136.0%
Cambodia	..	..	..	..	..	1.5	2.0	2.6	3.5	3.6	3.7	..
Chinese Taipei	19.0	31.3	54.9	43.5	68.8	86.6	95.0	94.3	84.7	79.8	82.6	20.1%
India	56.3	63.3	85.3	119.3	165.8	223.9	301.8	309.9	377.3	385.4	415.8	150.7%
Indonesia	24.4	36.4	61.0	70.0	97.9	134.3	166.4	189.2	190.4	194.9	209.5	113.9%
DPR of Korea	2.6	4.2	8.0	7.4	7.9	3.9	3.1	2.8	2.7	2.0	1.9	-75.3%
Malaysia	12.6	16.0	23.9	27.9	37.6	53.2	57.5	64.8	69.8	67.7	67.2	78.9%
Mongolia	..	..	..	2.2	2.4	1.0	1.3	1.7	2.5	2.3	2.5	2.1%
Myanmar	3.9	3.0	3.9	3.5	2.1	4.0	5.4	6.2	3.2	3.3	3.3	58.5%
Nepal	0.2	0.2	0.3	0.5	0.7	1.5	2.1	2.1	2.1	2.7	2.9	297.7%
Pakistan	8.8	11.0	13.2	20.9	30.6	43.7	56.1	47.2	57.5	61.2	61.8	101.7%
Philippines	23.0	28.9	31.8	23.0	33.0	50.1	48.0	41.8	36.5	37.7	39.8	20.5%
Singapore	6.1	8.4	12.6	16.1	29.0	38.1	44.5	35.9	37.6	39.1	45.2	55.6%
Sri Lanka	2.8	2.7	3.7	3.6	3.7	5.5	10.6	13.2	12.0	11.8	13.1	251.3%
Thailand	15.8	20.6	31.8	28.5	52.7	90.8	86.1	109.2	97.7	103.2	108.2	105.1%
Vietnam	10.6	6.7	5.6	5.8	8.2	13.9	23.8	35.5	39.7	46.4	52.5	537.4%
Other Asia	3.8	5.4	8.6	8.0	8.8	8.2	9.4	13.3	13.8	15.9	17.0	91.9%
Asia	**192.1**	**241.6**	**349.9**	**385.3**	**555.5**	**770.1**	**923.9**	**984.0**	**1 046.5**	**1 073.3**	**1 144.3**	**106.0%**
People's Rep. of China	115.2	195.9	252.4	247.6	296.1	415.5	560.7	809.9	926.5	947.9	1 017.2	243.5%
Hong Kong, China	9.0	10.7	14.3	9.2	8.4	11.6	16.4	8.4	8.3	9.7	8.9	5.3%
China	**124.2**	**206.6**	**266.8**	**256.9**	**304.6**	**427.1**	**577.1**	**818.3**	**934.9**	**957.6**	**1 026.1**	**236.9%**
Argentina	67.3	65.1	70.9	54.4	53.1	62.1	66.0	67.7	78.7	73.8	79.5	49.8%
Bolivia	2.0	2.9	3.6	3.3	3.7	4.6	4.7	5.7	7.2	7.4	8.0	116.6%
Brazil	83.9	127.8	160.9	133.6	158.8	195.3	241.1	240.0	265.6	260.6	284.0	78.9%
Colombia	18.1	18.6	20.7	22.3	26.8	36.4	34.6	33.5	34.4	32.7	34.0	27.0%
Costa Rica	1.3	1.7	2.2	2.0	2.6	4.4	4.5	5.6	6.3	6.0	6.3	141.3%
Cuba	20.1	23.4	29.7	31.2	33.1	21.8	25.9	23.6	22.6	29.4	27.9	-15.5%
Dominican Republic	3.4	5.2	6.3	5.6	7.6	11.2	17.2	15.9	16.1	14.9	14.8	94.6%
Ecuador	3.5	5.9	10.5	11.7	12.7	15.6	17.5	23.3	25.6	28.2	29.0	128.6%
El Salvador	1.4	2.0	1.7	1.8	2.2	4.6	5.2	6.1	6.2	6.2	5.9	162.8%
Guatemala	2.3	3.0	4.2	3.2	3.2	5.8	7.9	9.5	9.1	10.4	9.1	184.6%
Haiti	0.4	0.4	0.6	0.6	0.9	0.9	1.4	2.0	2.3	2.4	2.1	132.2%
Honduras	1.1	1.3	1.7	1.7	2.2	3.5	4.1	6.5	7.3	6.9	6.8	216.8%
Jamaica	5.5	7.4	6.5	4.6	7.1	8.2	9.6	10.3	11.7	8.1	7.8	10.9%
Netherlands Antilles	14.4	10.2	8.7	4.6	2.7	2.8	4.1	4.2	4.3	5.0	3.8	39.1%
Nicaragua	1.5	1.8	1.8	1.8	1.8	2.5	3.5	4.0	4.1	4.1	4.5	143.6%
Panama	2.5	3.1	2.9	2.6	2.5	4.0	4.8	5.8	6.5	7.6	8.1	225.9%
Paraguay	0.6	0.7	1.4	1.4	1.9	3.4	3.3	3.4	3.8	4.1	4.7	145.2%
Peru	14.4	17.0	18.9	16.2	17.6	21.8	23.0	21.5	24.4	25.4	25.5	44.7%
Trinidad and Tobago	2.7	3.0	2.8	2.5	2.1	2.2	2.6	4.0	4.2	4.3	4.7	126.4%
Uruguay	5.1	5.4	5.5	3.1	3.7	4.5	5.2	5.1	7.5	7.6	6.3	68.8%
Venezuela	30.7	37.5	59.1	56.0	57.0	59.9	64.6	84.1	95.5	99.2	109.7	92.7%
Other Non-OECD Americas	7.7	10.7	10.1	9.1	12.4	13.4	14.4	15.3	16.1	16.5	16.9	36.2%
Non-OECD Americas	**290.1**	**354.3**	**430.8**	**373.4**	**415.6**	**489.1**	**565.0**	**597.1**	**659.6**	**660.7**	**699.5**	**68.3%**
Bahrain	1.2	1.2	1.7	1.8	2.1	2.4	2.5	3.6	4.1	4.4	4.7	126.9%
Islamic Republic of Iran	35.8	61.4	79.7	128.0	140.5	169.5	190.7	223.6	241.1	245.2	226.1	60.9%
Iraq	8.6	12.4	24.5	35.2	49.6	91.4	64.3	71.4	67.0	82.9	94.7	90.8%
Jordan	1.3	2.1	4.3	7.4	9.0	11.7	13.9	14.8	12.1	12.1	13.3	47.4%
Kuwait	4.1	5.2	13.4	27.4	17.2	18.4	30.8	46.7	49.6	57.1	59.4	245.0%
Lebanon	4.5	5.6	6.6	6.5	5.5	12.4	13.6	14.0	15.3	18.7	17.3	216.1%
Oman	0.3	0.7	1.5	3.6	5.3	8.0	8.8	12.2	17.4	19.1	19.0	256.6%
Qatar	0.3	0.7	1.4	1.6	1.9	2.4	2.8	7.8	9.9	11.5	11.6	510.1%
Saudi Arabia	10.0	17.1	77.9	88.5	111.5	143.4	175.1	209.5	254.9	278.4	300.2	169.3%
Syrian Arab Republic	6.0	9.0	13.0	20.8	25.0	28.0	29.4	44.1	52.0	44.3	40.3	61.4%
United Arab Emirates	0.4	1.6	9.5	15.8	18.8	21.1	21.4	28.1	32.0	32.6	33.2	77.0%
Yemen	1.2	1.7	3.4	4.8	6.4	9.3	13.2	18.8	21.1	21.4	19.9	210.1%
Middle East	**73.8**	**118.9**	**237.0**	**341.4**	**392.8**	**518.0**	**566.4**	**694.6**	**776.6**	**827.8**	**839.6**	**113.8%**

CO_2 emissions: Sectoral Approach - Natural gas

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World *	**2 058.7**	**2 281.8**	**2 768.0**	**3 163.5**	**3 806.3**	**4 107.5**	**4 688.6**	**5 370.3**	**5 914.7**	**5 768.4**	**6 179.1**	**62.3%**
Annex I Parties	*..*	*..*	*..*	*..*	*3 070.2*	*3 178.2*	*3 471.3*	*3 646.7*	*3 809.2*	*3 633.8*	*3 854.5*	*25.5%*
Annex II Parties	*1 438.5*	*1 503.1*	*1 663.5*	*1 616.2*	*1 794.6*	*2 123.1*	*2 426.3*	*2 490.4*	*2 622.4*	*2 542.2*	*2 661.1*	*48.3%*
North America	*1 257.4*	*1 143.4*	*1 179.4*	*1 058.1*	*1 135.1*	*1 309.4*	*1 423.0*	*1 359.9*	*1 439.8*	*1 410.1*	*1 460.7*	*28.7%*
Europe	*168.1*	*331.0*	*414.3*	*446.1*	*505.1*	*631.3*	*783.8*	*894.7*	*907.4*	*856.8*	*910.8*	*80.3%*
Asia Oceania	*12.9*	*28.7*	*69.8*	*112.0*	*154.4*	*182.4*	*219.5*	*235.8*	*275.2*	*275.3*	*289.5*	*87.5%*
Annex I EIT	*..*	*..*	*..*	*..*	*1 269.1*	*1 042.1*	*1 016.2*	*1 103.5*	*1 116.6*	*1 024.1*	*1 120.2*	*-11.7%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*736.1*	*929.3*	*1 217.2*	*1 723.6*	*2 105.4*	*2 134.6*	*2 324.6*	*215.8%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*2 024.8*	*1 979.4*	*2 155.3*	*2 365.9*	*2 439.1*	*2 298.7*	*2 458.0*	*21.4%*
Intl. marine bunkers	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Intl. aviation bunkers	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Non-OECD Total **	**575.6**	**719.7**	**1 013.7**	**1 438.8**	**1 878.7**	**1 826.2**	**2 041.0**	**2 569.7**	**2 941.2**	**2 885.9**	**3 128.9**	**66.5%**
OECD Total ***	**1 483.1**	**1 562.1**	**1 754.3**	**1 724.7**	**1 927.6**	**2 281.4**	**2 647.6**	**2 800.6**	**2 973.5**	**2 882.4**	**3 050.2**	**58.2%**
Canada	67.9	87.3	99.7	113.9	123.8	149.1	168.1	170.2	180.0	175.6	178.5	44.2%
Chile	1.3	1.1	1.4	1.6	2.1	2.1	10.3	14.0	4.7	5.8	9.8	368.2%
Mexico	20.2	25.6	43.2	53.6	52.1	55.9	66.6	88.3	112.5	111.7	123.8	137.8%
United States	1 189.5	1 056.1	1 079.7	944.2	1 011.3	1 160.2	1 254.9	1 189.7	1 259.8	1 234.5	1 282.2	26.8%
OECD Americas	**1 278.9**	**1 170.1**	**1 224.0**	**1 113.3**	**1 189.3**	**1 367.4**	**1 499.9**	**1 462.2**	**1 556.9**	**1 527.6**	**1 594.4**	**34.1%**
Australia	4.1	8.9	16.7	24.4	32.8	37.7	43.9	54.8	62.8	63.7	66.5	102.8%
Israel	0.2	0.1	0.2	0.1	0.0	0.0	0.0	3.1	6.9	8.4	10.1	+
Japan	8.5	19.2	51.2	81.5	114.6	137.1	164.8	173.7	204.9	204.2	215.0	87.6%
Korea	-	-	-	-	6.4	19.4	39.9	63.8	74.9	72.0	90.2	+
New Zealand	0.2	0.6	1.8	6.1	7.0	7.6	10.8	7.3	7.5	7.5	8.0	14.0%
OECD Asia Oceania	**13.1**	**28.8**	**70.0**	**112.0**	**160.8**	**201.8**	**259.4**	**302.8**	**357.0**	**355.8**	**389.9**	**142.5%**
Austria	5.6	7.5	9.0	10.1	11.8	14.7	15.0	18.8	17.6	17.2	18.9	59.9%
Belgium	11.3	18.2	20.5	16.9	18.9	24.5	30.7	33.3	34.3	34.6	38.8	105.4%
Czech Republic	1.9	3.1	5.6	9.1	11.5	14.5	17.0	17.8	16.3	15.2	17.4	51.8%
Denmark	-	0.0	0.0	1.5	4.2	7.3	10.3	10.4	9.6	9.2	10.4	150.1%
Estonia	..	..	..	..	2.7	1.3	1.5	1.8	1.7	1.2	1.3	-51.6%
Finland	-	1.5	1.7	1.9	5.1	6.6	7.9	8.4	8.8	7.9	8.7	72.3%
France	19.2	33.0	47.4	54.5	56.1	65.8	81.1	92.5	90.4	86.8	95.6	70.5%
Germany	38.8	86.4	114.9	105.3	118.1	147.0	158.4	179.9	181.0	173.0	171.8	45.4%
Greece	-	-	-	0.1	0.2	0.1	3.9	5.4	8.1	6.6	7.2	+
Hungary	6.8	10.7	17.6	19.2	19.8	20.3	21.6	27.0	23.9	20.7	22.2	11.9%
Iceland	-	-	-	-	-	-	-	-	-	-	-	-
Ireland	-	-	1.7	4.5	4.0	5.0	7.7	8.2	10.2	9.9	10.8	172.9%
Italy	23.9	40.8	49.3	59.8	89.2	102.8	134.0	163.2	161.1	148.0	157.4	76.4%
Luxembourg	0.0	0.8	1.0	0.7	1.0	1.3	1.6	2.7	2.6	2.6	2.8	178.6%
Netherlands	47.0	72.5	69.4	75.3	70.2	78.6	79.7	80.7	79.7	80.5	90.1	28.2%
Norway	-	0.4	2.0	2.8	4.6	8.1	8.0	10.0	11.1	11.3	11.8	155.3%
Poland	11.4	13.5	17.6	18.2	18.5	18.3	20.6	26.2	26.8	26.1	27.9	51.2%
Portugal	-	-	-	-	-	-	4.6	8.6	9.5	9.6	10.5	x
Slovak Republic	2.9	4.9	5.1	6.7	11.7	11.7	13.1	13.2	11.2	9.8	11.2	-4.4%
Slovenia	..	..	..	..	1.8	1.7	1.8	2.1	2.0	1.9	2.0	9.1%
Spain	0.7	1.8	3.1	4.5	10.5	17.4	34.7	67.2	80.9	72.3	72.2	585.4%
Sweden	-	-	-	0.2	1.2	1.6	1.6	1.7	1.6	2.3	3.1	147.8%
Switzerland	0.0	1.0	1.9	2.9	3.8	5.1	5.6	6.5	6.5	6.3	7.0	85.7%
Turkey	-	-	-	0.1	6.5	13.0	28.9	52.8	70.2	67.4	73.2	+
United Kingdom	21.6	67.2	92.3	105.2	106.0	145.4	199.0	197.2	194.3	178.8	193.6	82.6%
OECD Europe ***	**191.1**	**363.2**	**460.3**	**499.4**	**577.5**	**712.2**	**888.3**	**1 035.6**	**1 059.5**	**999.1**	**1 065.9**	**84.6%**
European Union - 27	*..*	*..*	*..*	*..*	*657.9*	*745.6*	*889.4*	*1 010.9*	*1 014.1*	*949.7*	*1 011.6*	*53.8%*

* Total world includes non-OECD total, OECD total as well as international marine bunkers and international aviation bunkers.
** Includes Estonia and Slovenia prior to 1990.
*** Excludes Estonia and Slovenia prior to 1990.

CO_2 emissions: Sectoral Approach - Natural gas

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**575.6**	**719.7**	**1 013.7**	**1 438.8**	**1 878.7**	**1 826.2**	**2 041.0**	**2 569.7**	**2 941.2**	**2 885.9**	**3 128.9**	**66.5%**
Albania	0.2	0.6	0.8	0.8	0.5	0.1	0.0	0.0	0.0	0.0	0.0	-94.3%
Armenia	..	..	..	..	8.3	2.7	2.6	3.1	4.2	3.3	3.0	-63.8%
Azerbaijan	..	..	..	..	31.5	12.7	10.8	17.7	19.6	16.7	16.1	-48.9%
Belarus	..	..	..	..	27.5	25.6	32.2	38.3	40.2	33.1	41.2	49.7%
Bosnia and Herzegovina	..	..	..	..	0.9	0.3	0.5	0.7	0.8	0.4	0.5	-49.9%
Bulgaria	0.6	2.3	7.4	10.8	12.0	10.0	6.2	5.9	6.1	4.7	5.0	-58.2%
Croatia	..	..	..	..	4.7	4.1	4.7	5.1	5.6	5.2	5.7	20.2%
Cyprus	-	-	-	-	-	-	-	-	-	-	-	-
Georgia	..	..	..	..	10.6	2.2	2.2	2.2	2.3	2.3	2.2	-79.4%
Gibraltar	-	-	-	-	-	-	-	-	-	-	-	-
Kazakhstan	..	..	..	..	24.8	23.5	15.2	28.5	47.7	46.2	53.5	115.8%
Kosovo **	..	..	..	..	..	..	-	-	-	-	-	..
Kyrgyzstan	..	..	..	..	3.6	1.7	1.3	1.4	1.4	1.3	0.9	-74.5%
Latvia	..	..	..	..	5.6	2.3	2.5	3.2	3.1	2.8	3.4	-38.8%
Lithuania	..	..	..	..	10.3	4.3	4.3	5.3	5.3	4.6	5.4	-47.7%
FYR of Macedonia	..	..	..	..	-	-	0.1	0.1	0.2	0.1	0.2	x
Malta	-	-	-	-	-	-	-	-	-	-	-	-
Republic of Moldova	..	..	..	..	7.6	5.5	4.0	4.6	3.8	3.4	3.5	-54.3%
Montenegro **	..	..	..	..	..	..	..	-	-	-	-	..
Romania	52.1	62.6	75.7	74.6	67.4	43.1	30.6	30.2	27.9	23.4	23.8	-64.6%
Russian Federation	..	..	..	..	866.3	728.8	718.1	783.4	821.5	784.8	851.7	-1.7%
Serbia **	..	..	..	..	6.0	3.0	3.4	4.3	4.5	3.2	4.1	-31.8%
Tajikistan	..	..	..	..	3.2	1.2	1.5	1.3	1.0	0.8	0.7	-78.6%
Turkmenistan	..	..	..	..	28.6	26.2	25.5	33.3	40.9	35.2	40.5	41.5%
Ukraine	..	..	..	..	209.4	156.1	141.9	144.0	125.1	90.5	102.1	-51.3%
Uzbekistan	..	..	..	..	75.5	77.4	93.4	89.4	97.9	86.2	85.0	12.5%
Former Soviet Union ***	431.8	520.4	704.2	1 021.2	..	..	..	..	..	..	..	..
Former Yugoslavia ***	1.9	2.9	5.8	11.0	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**486.6**	**588.8**	**793.9**	**1 118.3**	**1 404.5**	**1 130.7**	**1 101.1**	**1 202.1**	**1 259.1**	**1 148.5**	**1 248.6**	**-11.1%**
Algeria	2.4	4.6	13.4	21.7	27.4	32.4	37.6	46.9	50.8	55.2	53.9	96.4%
Angola	0.1	0.1	0.2	0.2	1.0	1.1	1.1	1.2	1.3	1.3	1.4	35.2%
Benin	-	-	-	-	-	-	-	-	-	-	-	-
Botswana	..	..	..	-	-	-	-	-	-	-	-	-
Cameroon	-	-	-	-	-	-	-	-	0.6	0.5	0.5	x
Congo	0.0	0.0	-	0.0	-	-	-	0.0	0.0	0.1	0.1	x
Dem. Rep. of Congo	-	-	-	-	-	-	-	-	0.0	0.0	0.0	x
Côte d'Ivoire	-	-	-	-	-	0.1	3.0	2.9	3.1	2.8	3.1	x
Egypt	0.2	0.1	3.4	7.9	14.9	22.9	32.4	67.6	81.5	79.7	85.3	471.1%
Eritrea	..	..	..	..	..	-	-	-	-	-	-	..
Ethiopia	-	-	-	-	-	-	-	-	-	-	-	-
Gabon	-	-	0.0	0.1	0.2	0.3	0.2	0.3	0.4	0.3	0.4	77.7%
Ghana	-	-	-	-	-	-	-	-	-	-	-	-
Kenya	-	-	-	-	-	-	-	-	-	-	-	-
Libya	2.1	2.5	5.5	7.0	9.0	8.5	8.8	10.4	11.8	11.8	12.3	36.7%
Morocco	0.1	0.1	0.1	0.2	0.1	0.0	0.1	0.9	1.1	1.2	1.3	+
Mozambique	-	-	-	-	-	0.0	0.0	0.0	0.2	0.2	0.3	x
Namibia	..	..	..	..	..	-	-	-	-	-	-	..
Nigeria	0.4	1.0	2.9	6.9	6.9	9.2	12.0	16.7	18.2	12.5	15.9	131.2%
Senegal	-	-	-	-	0.0	0.1	0.0	0.0	0.0	0.0	0.0	172.2%
South Africa	-	-	-	-	-	-	-	-	-	-	-	-
Sudan	-	-	-	-	-	-	-	-	-	-	-	-
United Rep. of Tanzania	-	-	-	-	-	-	-	0.8	1.1	1.3	1.5	x
Togo	-	-	-	-	-	-	-	-	-	-	-	-
Tunisia	0.0	0.5	0.8	2.2	2.8	4.6	6.4	7.7	9.2	9.3	10.0	258.2%
Zambia	-	-	-	-	-	-	-	-	-	-	-	-
Zimbabwe	-	-	-	-	-	-	-	-	-	-	-	-
Other Africa	-	-	-	-	-	-	0.0	0.1	0.1	0.1	0.1	x
Africa	**5.2**	**9.0**	**26.3**	**46.2**	**62.4**	**79.2**	**101.5**	**155.5**	**179.3**	**176.5**	**186.1**	**198.2%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

CO_2 emissions: Sectoral Approach - Natural gas

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	0.6	0.9	2.1	4.0	7.3	10.9	14.6	22.2	30.6	33.9	35.1	381.3%
Brunei Darussalam	0.2	1.2	2.1	2.3	2.5	3.4	3.2	3.5	5.5	6.1	6.2	147.0%
Cambodia	..	..	..	..	..	-	-	-	-	-	-	..
Chinese Taipei	1.9	2.7	3.3	1.9	3.3	7.8	12.9	20.7	25.1	24.0	30.4	828.9%
India	1.3	1.9	2.5	8.0	20.6	35.3	47.1	68.5	76.3	104.7	113.2	449.0%
Indonesia	0.3	1.0	7.3	13.6	30.6	54.1	55.0	60.7	61.1	75.0	77.0	151.8%
DPR of Korea	-	-	-	-	-	-	-	-	-	-	-	-
Malaysia	0.0	0.1	0.1	4.4	6.9	23.1	45.5	60.6	76.2	60.7	59.8	764.2%
Mongolia	..	..	..	-	-	-	-	-	-	-	-	-
Myanmar	0.1	0.3	0.6	1.8	1.7	2.8	2.7	3.0	2.8	2.3	3.1	81.6%
Nepal	-	-	-	-	-	-	-	-	-	-	-	-
Pakistan	5.3	7.7	10.3	13.4	20.9	28.0	34.5	56.9	59.1	59.3	57.2	173.6%
Philippines	-	-	-	-	-	0.0	0.0	6.7	7.2	7.5	7.1	x
Singapore	0.0	0.1	0.1	0.1	0.1	3.1	2.9	14.0	16.7	15.7	16.8	+
Sri Lanka	-	-	-	-	-	-	-	-	-	-	-	-
Thailand	-	-	-	6.8	11.7	20.4	40.6	60.6	72.3	66.7	76.1	552.1%
Vietnam	-	-	-	0.1	0.0	0.4	2.6	11.0	14.9	16.6	19.0	+
Other Asia	0.5	0.5	0.2	1.2	0.6	0.5	0.5	0.5	0.7	0.7	0.8	35.1%
Asia	**10.2**	**16.3**	**28.8**	**57.7**	**106.2**	**189.9**	**262.1**	**388.7**	**448.5**	**473.2**	**501.8**	**372.5%**
People's Rep. of China	7.3	17.3	27.8	21.9	25.8	31.7	43.4	82.9	148.3	163.7	194.7	654.5%
Hong Kong, China	-	-	-	-	-	0.1	5.7	5.1	5.4	5.1	6.5	x
China	**7.3**	**17.3**	**27.8**	**21.9**	**25.8**	**31.8**	**49.2**	**88.0**	**153.8**	**168.8**	**201.3**	**679.8%**
Argentina	12.3	17.1	21.7	30.5	43.4	51.2	68.5	78.4	88.2	87.1	85.5	97.2%
Bolivia	0.1	0.3	0.6	0.8	1.4	2.3	2.4	3.7	4.9	5.4	6.0	318.0%
Brazil	0.5	1.1	2.2	5.0	7.0	8.8	17.4	38.0	49.0	39.1	51.8	642.6%
Colombia	2.6	3.2	5.7	7.3	7.5	8.3	12.8	14.3	15.2	17.4	18.2	141.7%
Costa Rica	-	-	-	-	-	-	-	-	-	-	-	-
Cuba	0.1	0.2	0.1	0.1	0.1	0.2	1.1	1.5	2.2	2.2	2.0	+
Dominican Republic	-	-	-	-	-	-	-	0.5	0.9	1.0	1.6	x
Ecuador	0.1	0.3	0.1	0.4	0.5	0.6	0.7	0.9	1.0	1.0	1.1	116.3%
El Salvador	-	-	-	-	-	-	-	-	-	-	-	-
Guatemala	-	-	-	-	-	-	-	-	-	-	-	-
Haiti	-	-	-	-	-	-	-	-	-	-	-	-
Honduras	-	-	-	-	-	-	-	-	-	-	-	-
Jamaica	-	-	-	-	-	-	-	-	-	-	-	-
Netherlands Antilles	-	-	-	-	-	-	-	-	-	-	-	-
Nicaragua	-	-	-	-	-	-	-	-	-	-	-	-
Panama	-	-	-	-	-	-	-	-	-	-	-	-
Paraguay	-	-	-	-	-	-	-	-	-	-	-	-
Peru	0.6	0.8	1.0	1.3	1.0	0.6	1.1	3.9	7.6	9.6	12.8	+
Trinidad and Tobago	3.4	2.8	5.1	7.1	9.3	10.0	18.4	29.9	35.0	35.9	38.0	310.3%
Uruguay	-	-	-	-	-	-	0.1	0.2	0.2	0.1	0.1	x
Venezuela	20.8	24.3	32.6	38.5	46.3	58.4	61.7	64.0	72.2	68.3	72.5	56.6%
Other Non-OECD Americas	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.4	1.6	1.5	1.5	+
Non-OECD Americas	**40.7**	**50.2**	**69.2**	**91.0**	**116.6**	**140.4**	**184.9**	**236.6**	**278.0**	**268.6**	**291.4**	**149.8%**
Bahrain	1.8	4.1	5.7	8.6	9.6	9.3	11.6	14.6	18.2	18.4	18.9	96.4%
Islamic Republic of Iran	5.5	8.1	8.5	16.8	37.0	80.0	121.1	193.5	253.1	265.5	279.7	656.1%
Iraq	1.8	3.1	2.4	1.6	3.8	6.0	6.0	3.5	6.3	9.0	9.8	159.0%
Jordan	-	-	-	-	0.2	0.5	0.5	3.2	6.4	7.2	5.3	+
Kuwait	9.9	9.9	13.2	9.7	11.5	17.7	18.3	23.5	24.2	23.6	28.0	143.5%
Lebanon	-	-	-	-	-	-	-	-	-	0.1	0.5	x
Oman	-	-	0.7	2.1	4.9	6.7	11.4	16.0	19.1	20.8	21.3	333.3%
Qatar	1.9	4.2	6.3	10.5	12.2	16.2	20.9	29.7	39.9	44.9	53.3	338.5%
Saudi Arabia	2.7	5.4	21.2	34.1	47.6	64.4	77.7	124.3	132.3	133.0	145.7	206.1%
Syrian Arab Republic	-	-	0.1	0.3	3.2	4.8	10.4	10.8	10.7	13.0	17.5	446.1%
United Arab Emirates	2.0	3.3	9.6	19.8	33.1	48.5	64.2	79.7	112.3	114.7	118.0	256.3%
Yemen	-	-	-	-	-	-	-	-	-	0.2	1.7	x
Middle East	**25.6**	**38.0**	**67.7**	**103.6**	**163.1**	**254.2**	**342.1**	**498.7**	**622.5**	**650.4**	**699.8**	**328.9%**

CO_2 emissions: Reference Approach

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World *	**14 612.0**	**16 155.0**	**18 630.4**	**19 282.4**	**21 532.3**	**22 124.5**	**23 728.9**	**27 688.1**	**29 937.2**	**29 627.8**	**31 102.3**	**44.4%**
Annex I Parties	*..*	*..*	*..*	*..*	*14 167.6*	*13 311.2*	*13 864.4*	*14 320.5*	*14 123.4*	*13 120.9*	*13 594.0*	*-4.0%*
Annex II Parties	*8 638.2*	*8 951.2*	*9 721.9*	*9 303.2*	*9 843.2*	*10 213.3*	*11 019.1*	*11 380.2*	*11 055.9*	*10 329.1*	*10 581.8*	*7.5%*
North America	*4 612.3*	*4 775.0*	*5 191.6*	*5 009.8*	*5 283.9*	*5 571.2*	*6 194.9*	*6 389.2*	*6 193.1*	*5 786.2*	*5 902.6*	*11.7%*
Europe	*3 098.9*	*3 118.8*	*3 387.8*	*3 151.9*	*3 200.9*	*3 170.6*	*3 254.0*	*3 374.5*	*3 254.8*	*3 035.3*	*3 100.1*	*-3.1%*
Asia Oceania	*927.0*	*1 057.4*	*1 142.4*	*1 141.5*	*1 358.5*	*1 471.5*	*1 570.2*	*1 616.5*	*1 608.0*	*1 507.6*	*1 579.0*	*16.2%*
Annex I EIT	*..*	*..*	*..*	*..*	*4 184.0*	*2 938.4*	*2 639.7*	*2 718.0*	*2 802.0*	*2 533.1*	*2 735.8*	*-34.6%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*6 746.8*	*8 106.9*	*9 025.6*	*12 388.0*	*14 746.4*	*15 477.5*	*16 409.3*	*143.2%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*9 039.4*	*7 970.2*	*7 922.7*	*8 190.4*	*8 123.1*	*7 500.4*	*7 837.8*	*-13.3%*
Intl. marine bunkers	**344.2**	**331.7**	**347.9**	**297.7**	**362.5**	**419.5**	**488.8**	**565.8**	**620.2**	**601.8**	**643.7**	**77.6%**
Intl. aviation bunkers	**167.3**	**171.8**	**199.7**	**222.0**	**255.3**	**286.8**	**350.1**	**413.8**	**447.1**	**427.6**	**455.3**	**78.3%**
Non-OECD Total **	**4 639.0**	**5 727.6**	**7 112.9**	**8 135.2**	**9 640.0**	**9 705.1**	**10 230.5**	**13 557.4**	**15 907.3**	**16 424.5**	**17 443.8**	**81.0%**
OECD Total ***	**9 461.5**	**9 923.9**	**10 969.9**	**10 627.5**	**11 274.5**	**11 713.1**	**12 659.5**	**13 151.2**	**12 962.6**	**12 173.9**	**12 559.5**	**11.4%**
Canada	337.2	392.3	428.7	400.0	423.5	452.7	518.8	545.3	524.5	488.4	487.7	15.2%
Chile	21.5	17.5	21.7	19.8	31.2	39.3	53.7	59.8	70.5	65.7	72.7	132.8%
Mexico	100.8	145.1	242.2	265.7	289.8	298.8	344.4	414.5	435.8	422.5	432.5	49.2%
United States	4 275.1	4 382.7	4 763.0	4 609.9	4 860.4	5 118.5	5 676.2	5 843.9	5 668.6	5 297.8	5 415.0	11.4%
OECD Americas	**4 734.6**	**4 937.7**	**5 455.5**	**5 295.3**	**5 604.8**	**5 909.4**	**6 593.0**	**6 863.5**	**6 699.5**	**6 274.5**	**6 407.8**	**14.3%**
Australia	156.9	182.7	212.1	220.0	260.9	278.6	330.4	353.9	378.4	383.6	379.9	45.6%
Israel	17.2	21.0	23.1	23.5	34.9	48.1	55.3	56.2	67.3	63.2	66.5	90.6%
Japan	755.6	857.1	913.0	899.8	1 074.1	1 165.5	1 208.4	1 229.3	1 196.1	1 092.6	1 168.5	8.8%
Korea	54.8	77.9	125.7	157.7	238.6	355.3	441.0	464.6	512.8	518.1	579.7	143.0%
New Zealand	14.4	17.7	17.3	21.7	23.4	27.4	31.3	33.3	33.4	31.4	30.7	31.0%
OECD Asia Oceania	**999.0**	**1 156.3**	**1 291.2**	**1 322.6**	**1 631.9**	**1 874.9**	**2 066.4**	**2 137.4**	**2 188.1**	**2 088.9**	**2 225.2**	**36.4%**
Austria	51.2	52.3	58.3	55.9	57.2	60.2	62.6	75.3	70.1	63.6	69.3	21.2%
Belgium	120.0	119.5	129.8	103.9	109.4	116.3	121.4	114.8	111.3	108.0	115.0	5.0%
Czech Republic	168.5	158.9	170.1	174.5	160.7	126.8	125.3	124.9	121.2	111.5	116.1	-27.8%
Denmark	56.2	52.6	61.0	61.0	50.8	58.0	51.2	48.4	48.7	46.4	47.0	-7.4%
Estonia	..	..	..	..	38.5	18.3	16.3	17.8	18.6	15.8	20.0	-48.1%
Finland	39.9	45.5	57.4	50.5	52.1	54.0	54.0	56.7	58.0	55.3	63.6	22.3%
France	434.6	431.8	473.0	374.3	367.3	348.7	360.6	389.9	369.3	355.2	360.9	-1.8%
Germany	993.1	976.5	1 076.4	1 022.5	970.9	875.8	841.8	818.8	800.6	751.3	770.0	-20.7%
Greece	25.3	35.4	45.4	55.9	69.2	72.6	85.3	93.1	91.2	88.2	81.1	17.2%
Hungary	58.2	67.4	80.7	78.8	68.1	59.4	55.0	57.3	53.5	48.0	49.3	-27.6%
Iceland	1.4	1.6	1.8	1.6	2.0	1.9	2.1	2.2	2.1	2.0	1.9	-2.3%
Ireland	22.5	21.8	26.3	27.2	31.4	32.7	40.7	41.9	42.1	40.4	39.6	26.2%
Italy	280.3	311.2	349.0	339.6	384.0	413.0	433.6	458.8	432.5	391.0	396.6	3.3%
Luxembourg	15.2	13.1	12.0	10.0	10.4	8.3	8.1	11.5	10.6	10.0	10.6	1.8%
Netherlands	130.4	138.0	155.7	147.2	158.5	172.3	174.5	182.6	182.9	178.9	190.7	20.3%
Norway	23.4	24.0	28.6	27.1	28.5	31.8	37.0	37.6	44.8	42.1	51.7	81.4%
Poland	310.3	367.5	450.4	445.3	363.3	340.0	294.6	301.6	310.1	294.8	316.0	-13.0%
Portugal	14.9	18.9	24.6	25.5	38.5	49.4	59.9	63.4	54.0	53.7	48.7	26.4%
Slovak Republic	48.3	55.0	60.9	59.4	54.5	42.3	37.4	38.9	36.9	33.7	36.0	-33.9%
Slovenia	..	..	..	..	13.5	14.2	13.9	15.7	16.8	15.2	15.3	13.0%
Spain	121.5	162.0	192.0	187.5	212.1	239.0	286.8	342.2	322.4	285.2	267.5	26.1%
Sweden	84.5	80.9	72.0	61.8	51.8	54.7	49.5	51.3	48.4	43.0	51.6	-0.3%
Switzerland	39.7	37.4	39.8	39.5	42.7	40.1	40.9	43.6	42.9	43.8	41.0	-4.0%
Turkey	43.7	62.4	73.3	99.7	138.2	157.3	203.5	219.7	262.9	256.2	273.8	98.1%
United Kingdom	644.9	596.3	584.7	560.8	564.0	541.7	544.2	542.5	522.9	477.2	493.2	-12.6%
OECD Europe ***	**3 727.9**	**3 830.0**	**4 223.1**	**4 009.6**	**4 037.7**	**3 928.8**	**4 000.0**	**4 150.2**	**4 074.9**	**3 810.5**	**3 926.5**	**-2.8%**
European Union - 27	*..*	*..*	*..*	*..*	*4 132.8*	*3 914.4*	*3 873.4*	*4 018.3*	*3 896.5*	*3 616.4*	*3 710.2*	*-10.2%*

* Total world includes non-OECD total, OECD total as well as international marine bunkers and international aviation bunkers.
** Includes Estonia and Slovenia prior to 1990.
*** Excludes Estonia and Slovenia prior to 1990.

CO_2 emissions: Reference Approach

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**4 639.0**	**5 727.6**	**7 112.9**	**8 135.2**	**9 640.0**	**9 705.1**	**10 230.5**	**13 557.4**	**15 907.3**	**16 424.5**	**17 443.8**	**81.0%**
Albania	4.1	4.8	8.0	7.5	6.5	1.9	3.1	4.3	3.8	3.4	3.7	-43.0%
Armenia	..	..	..	..	20.5	3.4	3.4	4.1	5.3	4.3	4.0	-80.3%
Azerbaijan	..	..	..	..	67.8	33.9	30.5	34.5	30.8	26.8	26.9	-60.3%
Belarus	..	..	..	..	127.4	63.0	60.0	63.9	66.2	64.0	64.8	-49.1%
Bosnia and Herzegovina	..	..	..	..	24.0	3.4	13.7	15.8	19.4	19.8	20.5	-14.4%
Bulgaria	63.8	73.0	84.2	85.1	76.1	57.7	43.4	47.9	49.9	43.0	45.1	-40.8%
Croatia	..	..	..	..	21.6	15.9	17.9	21.0	21.3	20.0	19.3	-10.4%
Cyprus	1.8	1.7	2.6	2.8	4.1	5.2	6.3	6.6	7.7	7.5	7.1	72.8%
Georgia	..	..	..	..	30.3	7.2	4.4	4.4	5.0	5.5	5.1	-83.1%
Gibraltar	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.5	0.5	0.5	193.9%
Kazakhstan	..	..	..	..	240.9	171.2	116.3	166.0	223.4	202.0	237.0	-1.6%
Kosovo **	..	..	..	..	..	..	4.8	6.2	7.0	8.0	8.3	..
Kyrgyzstan	..	..	..	..	22.5	4.4	4.5	5.0	5.4	6.5	6.4	-71.7%
Latvia	..	..	..	..	18.8	9.1	6.4	6.9	7.6	6.6	7.3	-60.9%
Lithuania	..	..	..	..	33.5	14.5	10.8	13.9	14.5	12.5	13.5	-59.8%
FYR of Macedonia	..	..	..	..	8.6	8.2	8.5	9.1	9.2	8.6	8.4	-2.2%
Malta	0.6	0.6	1.0	1.1	2.3	2.2	2.1	2.7	2.6	2.5	2.6	13.6%
Republic of Moldova	..	..	..	..	30.2	11.4	5.7	6.9	6.4	5.8	6.2	-79.5%
Montenegro **	..	..	..	..	..	..	..	1.4	1.9	1.2	2.1	..
Romania	111.6	138.9	177.8	178.9	171.7	128.0	87.8	93.0	92.0	77.8	76.5	-55.4%
Russian Federation	..	..	..	..	2 337.2	1 620.4	1 545.2	1 579.8	1 669.5	1 528.6	1 676.4	-28.3%
Serbia **	..	..	..	..	61.6	44.4	41.9	50.8	52.8	47.3	47.0	-23.6%
Tajikistan	..	..	..	..	11.2	2.4	2.2	2.3	3.0	2.8	2.7	-75.5%
Turkmenistan	..	..	..	..	46.2	34.2	35.5	45.2	54.8	48.2	52.8	14.5%
Ukraine	..	..	..	..	699.1	428.8	325.7	335.4	323.8	261.5	280.3	-59.9%
Uzbekistan	..	..	..	..	120.6	103.8	122.4	112.8	120.2	107.7	104.2	-13.6%
Former Soviet Union ***	2 368.9	2 842.6	3 242.5	3 448.3	..	..	..	..	..	..	..	..
Former Yugoslavia ***	65.5	77.1	101.5	127.2	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**2 616.4**	**3 138.8**	**3 617.7**	**3 851.1**	**4 182.8**	**2 775.1**	**2 502.9**	**2 640.5**	**2 804.0**	**2 522.3**	**2 728.9**	**-34.8%**
Algeria	9.8	15.0	29.0	46.4	54.7	59.8	66.0	80.1	93.0	100.9	99.5	81.9%
Angola	1.7	2.1	2.7	2.9	4.1	3.9	5.1	7.2	12.5	14.0	16.5	299.3%
Benin	0.3	0.5	0.4	0.5	0.2	0.2	1.5	2.3	3.8	4.1	4.5	+
Botswana	..	..	..	1.6	2.9	3.3	4.2	4.4	4.8	4.3	5.0	72.2%
Cameroon	0.7	1.0	1.7	2.5	2.7	2.6	3.0	3.2	5.1	6.2	6.8	148.3%
Congo	0.6	0.6	0.7	0.9	0.7	0.6	0.5	1.0	1.3	1.7	1.8	151.7%
Dem. Rep. of Congo	2.7	2.9	2.9	3.4	4.1	3.0	1.7	2.3	2.8	2.7	3.1	-25.8%
Côte d'Ivoire	2.4	3.1	3.4	2.5	2.9	3.7	6.6	6.5	6.7	5.7	5.7	99.7%
Egypt	20.1	25.6	38.5	67.1	83.5	87.5	98.5	152.0	173.0	171.4	175.9	110.6%
Eritrea	..	..	..	..	..	0.8	0.6	0.8	0.4	0.5	0.5	..
Ethiopia	1.4	1.2	1.4	1.4	2.4	2.6	3.2	4.4	5.7	5.7	5.4	122.9%
Gabon	1.7	2.1	2.2	1.9	1.1	1.2	1.3	2.1	2.3	2.5	2.7	151.1%
Ghana	1.9	2.5	2.2	2.5	2.8	3.6	5.4	6.3	7.8	7.0	8.5	198.2%
Kenya	3.2	3.4	4.3	4.6	5.7	5.5	6.7	7.1	8.8	10.5	11.1	95.5%
Libya	3.8	9.9	17.2	24.7	28.0	40.6	42.6	45.1	49.8	58.0	49.0	75.2%
Morocco	6.8	9.9	13.9	16.4	20.2	25.2	30.0	39.5	43.8	42.9	47.6	135.9%
Mozambique	3.0	2.4	2.4	1.5	1.0	1.1	1.5	1.5	2.0	2.2	2.5	149.4%
Namibia	..	..	..	..	..	1.7	1.8	2.5	3.6	3.3	3.3	..
Nigeria	5.9	11.8	26.9	33.2	38.2	34.1	43.5	59.9	54.3	44.2	47.5	24.3%
Senegal	1.2	1.6	2.0	1.9	2.2	2.5	3.7	4.7	5.1	5.3	5.5	152.6%
South Africa	149.7	176.2	215.3	288.5	291.6	334.1	345.9	410.7	477.7	465.4	441.3	51.3%
Sudan	4.1	3.9	3.9	4.3	5.6	4.7	7.1	11.1	13.2	14.5	14.4	158.7%
United Rep. of Tanzania	2.1	1.9	2.2	2.0	2.0	3.0	2.3	5.1	5.8	5.6	6.0	193.2%
Togo	0.3	0.3	0.4	0.3	0.6	0.6	1.0	1.0	1.1	1.1	1.2	106.2%
Tunisia	3.7	5.0	8.0	10.1	12.3	14.0	17.4	19.6	22.0	21.1	22.2	80.0%
Zambia	3.4	3.3	3.4	2.9	2.7	2.1	1.7	2.2	1.7	1.8	2.1	-24.6%
Zimbabwe	7.9	7.7	8.0	9.6	15.4	15.3	12.8	10.6	8.0	8.5	9.2	-40.6%
Other Africa	7.3	8.7	11.3	12.1	14.6	17.2	19.5	23.8	28.4	29.6	30.7	110.2%
Africa	**245.9**	**302.9**	**404.4**	**545.6**	**602.5**	**674.7**	**734.8**	**917.0**	**1 044.6**	**1 040.8**	**1 029.4**	**70.9%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

CO_2 emissions: Reference Approach

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	3.4	4.7	7.2	9.3	14.1	21.3	26.7	38.1	47.4	51.2	55.3	290.7%
Brunei Darussalam	0.4	1.7	3.2	4.3	4.1	5.5	6.0	5.6	8.9	7.7	8.1	95.8%
Cambodia	..	..	..	..	..	1.5	2.1	2.9	3.7	3.8	3.9	..
Chinese Taipei	31.2	43.2	75.1	74.8	118.5	162.7	229.1	269.0	269.2	253.3	273.0	130.3%
India	198.5	238.4	283.5	419.2	590.8	791.0	973.6	1 200.4	1 467.9	1 620.8	1 665.4	181.9%
Indonesia	25.5	39.3	71.8	88.1	145.4	220.1	277.2	345.5	352.4	381.2	400.9	175.8%
DPR of Korea	69.4	79.6	108.6	129.8	117.6	75.8	68.7	73.9	69.1	65.9	63.1	-46.4%
Malaysia	13.8	16.9	28.9	37.5	53.6	85.4	117.4	166.8	188.6	177.1	191.7	257.8%
Mongolia	..	..	..	11.6	12.7	10.1	8.8	9.5	11.2	11.8	11.9	-5.9%
Myanmar	4.7	4.2	5.3	6.1	4.2	6.8	10.0	12.0	11.6	9.2	8.5	104.2%
Nepal	0.2	0.3	0.5	0.5	0.9	1.8	3.1	3.0	2.9	3.4	3.7	300.2%
Pakistan	17.1	21.2	26.8	40.0	60.7	82.5	102.0	121.2	137.7	141.9	140.9	132.0%
Philippines	23.5	28.7	33.3	26.2	38.5	57.7	67.4	70.4	72.9	67.2	77.9	102.2%
Singapore	7.0	9.7	14.1	16.2	29.4	50.7	50.7	45.4	47.1	58.7	68.9	134.3%
Sri Lanka	2.9	2.9	3.9	3.7	4.0	5.8	10.6	12.4	11.9	12.1	13.1	230.5%
Thailand	17.3	21.8	34.3	40.7	81.3	141.2	158.9	221.8	234.8	231.4	249.9	207.5%
Vietnam	16.1	16.7	14.8	17.1	17.2	27.8	44.0	79.7	101.8	113.8	130.6	659.0%
Other Asia	8.3	10.1	16.4	10.0	10.1	9.3	11.2	14.8	16.5	18.8	20.2	98.9%
Asia	**439.4**	**539.6**	**727.9**	**935.5**	**1 303.0**	**1 757.0**	**2 167.7**	**2 692.4**	**3 055.5**	**3 229.3**	**3 386.8**	**159.9%**
People's Rep. of China	867.6	1 133.9	1 489.2	1 794.7	2 371.1	2 957.8	3 052.2	5 125.0	6 558.4	7 150.1	7 669.4	223.4%
Hong Kong, China	9.1	11.1	14.3	22.8	30.9	34.9	39.2	40.1	44.3	47.1	42.0	36.0%
China	**876.7**	**1 145.0**	**1 503.5**	**1 817.5**	**2 402.0**	**2 992.7**	**3 091.4**	**5 165.1**	**6 602.7**	**7 197.2**	**7 711.4**	**221.0%**
Argentina	86.0	89.8	101.2	92.7	106.8	118.0	134.1	147.7	173.7	166.5	166.8	56.2%
Bolivia	2.2	3.4	4.6	4.3	4.8	7.6	7.7	11.3	12.5	13.1	14.2	197.5%
Brazil	93.9	143.9	189.8	180.5	205.0	253.4	309.9	330.0	368.3	345.6	398.2	94.2%
Colombia	27.2	32.0	35.0	39.1	48.9	57.9	57.6	60.1	63.1	69.1	73.4	50.2%
Costa Rica	1.4	1.8	2.3	2.0	2.9	4.0	5.1	5.3	6.7	6.4	6.6	123.5%
Cuba	20.1	23.7	31.1	32.2	32.3	23.0	27.2	25.8	26.8	29.9	28.6	-11.3%
Dominican Republic	3.4	5.6	6.5	7.1	9.3	13.5	19.3	18.1	19.0	18.6	19.2	105.6%
Ecuador	3.4	6.5	10.9	12.3	13.1	16.9	19.0	27.9	26.5	27.9	30.0	129.3%
El Salvador	1.5	2.1	1.8	1.9	2.3	4.8	5.3	6.0	6.0	5.9	5.7	144.1%
Guatemala	2.4	2.6	4.3	3.3	3.6	5.8	9.0	10.6	10.2	11.1	10.3	186.6%
Haiti	0.4	0.4	0.6	0.8	0.9	0.9	1.4	2.0	2.4	2.2	2.0	116.6%
Honduras	1.1	1.3	1.7	1.6	2.2	3.5	4.5	6.9	7.9	7.1	7.3	237.7%
Jamaica	5.2	7.4	6.4	4.5	7.1	8.4	10.0	10.4	11.6	8.2	7.8	10.7%
Netherlands Antilles	13.6	9.6	10.0	4.9	4.0	3.3	3.9	3.7	3.9	5.2	4.0	-0.8%
Nicaragua	1.5	1.9	1.9	1.9	1.7	2.6	3.4	4.1	4.1	4.2	4.2	142.9%
Panama	3.8	3.8	2.6	2.8	2.6	4.1	5.4	6.7	6.7	7.9	8.9	247.2%
Paraguay	0.6	0.7	1.4	1.4	1.9	3.5	3.2	3.4	3.8	4.1	4.7	141.5%
Peru	16.1	19.4	21.8	18.4	18.2	22.8	26.1	29.3	33.4	33.0	40.7	123.3%
Trinidad and Tobago	5.0	4.8	8.3	11.0	12.7	12.8	21.4	33.1	38.9	40.6	42.9	237.3%
Uruguay	5.8	5.9	6.0	3.4	4.0	4.7	6.1	5.6	8.2	7.8	6.5	61.3%
Venezuela	43.6	60.3	88.8	99.2	104.9	116.6	125.7	152.5	160.2	160.1	182.1	73.5%
Other Non-OECD Americas	11.6	15.5	15.1	9.3	12.5	13.5	14.4	15.9	17.1	17.7	18.4	47.0%
Non-OECD Americas	**350.0**	**442.4**	**552.0**	**534.6**	**601.8**	**701.7**	**819.6**	**916.7**	**1 011.0**	**992.5**	**1 082.5**	**79.9%**
Bahrain	3.1	4.8	6.3	9.8	10.2	11.6	13.8	17.7	22.0	22.4	23.2	127.6%
Islamic Republic of Iran	43.5	70.1	105.2	150.6	186.9	266.6	322.7	442.3	506.5	527.6	512.0	174.0%
Iraq	11.2	16.4	27.1	39.9	56.2	99.7	74.1	75.4	79.7	91.2	106.9	90.1%
Jordan	1.4	2.2	4.4	7.6	9.4	12.4	14.1	18.4	18.7	19.5	19.0	102.0%
Kuwait	14.0	15.1	26.0	37.5	24.1	38.3	50.6	72.4	76.6	83.9	91.8	281.7%
Lebanon	5.0	6.0	6.9	6.6	5.5	12.8	14.1	14.5	15.8	19.1	18.6	238.0%
Oman	0.7	0.7	3.1	5.5	10.8	15.7	20.0	26.0	39.2	36.4	50.1	365.6%
Qatar	2.2	5.1	7.7	12.3	13.9	17.7	23.6	38.4	49.2	54.0	64.9	366.8%
Saudi Arabia	17.8	22.8	86.3	119.6	143.7	217.6	246.4	344.8	359.6	366.8	394.8	174.8%
Syrian Arab Republic	7.2	9.0	12.3	21.9	29.6	33.8	40.6	55.8	63.5	58.0	57.2	93.0%
United Arab Emirates	2.4	4.9	18.9	34.8	50.5	67.6	80.3	100.6	137.9	142.0	145.9	188.9%
Yemen	1.9	1.8	3.4	4.8	7.1	9.9	13.9	19.3	20.9	21.4	20.4	185.6%
Middle East	**110.5**	**158.9**	**307.5**	**451.0**	**547.9**	**803.9**	**914.2**	**1 225.7**	**1 389.5**	**1 442.4**	**1 504.8**	**174.7%**

CO_2 emissions from international marine bunkers

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World	**344.25**	**331.73**	**347.90**	**297.73**	**362.49**	**419.49**	**488.78**	**565.76**	**620.23**	**601.85**	**643.72**	**77.6%**
Annex I Parties	*..*	*..*	*..*	*..*	*233.65*	*231.01*	*250.90*	*271.97*	*277.24*	*252.71*	*264.38*	*13.2%*
Annex II Parties	*202.63*	*216.81*	*234.71*	*171.25*	*223.39*	*227.72*	*245.78*	*263.43*	*268.83*	*244.72*	*250.76*	*12.3%*
North America	*26.41*	*36.12*	*93.91*	*56.43*	*93.55*	*93.68*	*92.24*	*83.63*	*83.62*	*78.67*	*84.81*	*-9.3%*
Europe	*120.20*	*110.37*	*97.05*	*87.88*	*109.00*	*112.20*	*132.89*	*156.28*	*164.11*	*147.08*	*147.83*	*35.6%*
Asia Oceania	*56.02*	*70.31*	*43.75*	*26.94*	*20.84*	*21.84*	*20.65*	*23.52*	*21.10*	*18.97*	*18.12*	*-13.1%*
Annex I EIT	*..*	*..*	*..*	*..*	*9.80*	*2.58*	*1.79*	*3.14*	*3.46*	*3.57*	*7.83*	*-20.1%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*128.84*	*188.48*	*237.88*	*293.79*	*342.99*	*349.14*	*379.34*	*194.4%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*142.50*	*139.79*	*158.67*	*184.82*	*190.35*	*171.74*	*175.96*	*23.5%*
Non-OECD Total *	**137.33**	**111.51**	**109.39**	**121.14**	**130.70**	**164.82**	**203.70**	**257.51**	**310.33**	**321.77**	**356.78**	**173.0%**
OECD Total **	**206.91**	**220.22**	**238.51**	**176.59**	**231.79**	**254.68**	**285.08**	**308.24**	**309.90**	**280.08**	**286.94**	**23.8%**
Canada	3.07	2.58	4.71	1.18	2.87	3.17	3.34	1.88	1.67	2.13	2.18	-24.0%
Chile	0.60	0.37	0.27	0.09	0.57	1.12	1.94	3.30	3.64	2.61	1.28	124.3%
Mexico	0.26	0.38	1.00	1.33	..	2.55	3.83	2.70	3.18	2.39	2.50	..
United States	23.34	33.54	89.20	55.26	90.68	90.51	88.90	81.76	81.94	76.54	82.63	-8.9%
OECD Americas	**27.27**	**36.88**	**95.18**	**57.85**	**94.12**	**97.35**	**98.02**	**89.63**	**90.44**	**83.67**	**88.60**	**-5.9%**
Australia	5.10	5.03	3.68	2.28	2.14	2.79	2.96	2.73	3.02	2.80	2.25	5.4%
Israel	..	..	..	0.35	0.38	0.65	0.58	0.81	1.16	1.10	1.06	179.1%
Japan	49.88	64.20	38.90	23.92	17.66	17.92	16.93	19.80	16.97	15.08	14.80	-16.2%
Korea	1.53	0.17	0.31	1.69	5.27	21.35	30.46	33.24	29.16	26.81	28.75	445.6%
New Zealand	1.04	1.08	1.18	0.74	1.04	1.13	0.76	0.99	1.11	1.09	1.07	2.5%
OECD Asia Oceania	**57.55**	**70.48**	**44.06**	**28.98**	**26.49**	**43.84**	**51.69**	**57.57**	**51.43**	**46.88**	**47.93**	**80.9%**
Austria	-	-	-	-	-	-	-	-	-	-	-	-
Belgium	8.06	8.64	7.52	7.30	12.91	12.31	17.02	24.40	30.49	22.34	24.29	88.2%
Czech Republic	-	-	-	-	-	-	-	-	-	-	-	-
Denmark	2.09	1.67	1.32	1.34	3.02	4.96	4.03	2.41	2.87	1.60	2.16	-28.4%
Estonia	..	..	..	..	0.57	0.28	0.33	0.38	0.79	0.71	0.69	21.9%
Finland	0.24	0.30	1.84	1.45	1.78	1.04	2.10	1.59	1.26	0.78	0.66	-62.8%
France	12.71	14.53	12.52	7.52	7.96	7.94	9.42	8.65	8.04	8.02	7.79	-2.2%
Germany	12.93	10.52	11.00	10.85	7.79	6.43	6.85	7.83	9.36	8.57	8.72	11.9%
Greece	1.78	2.70	2.63	3.51	7.97	11.17	11.28	9.02	9.72	8.25	8.60	7.9%
Hungary	-	-	-	-	-	-	-	-	-	-	-	-
Iceland	..	..	..	0.02	0.10	0.14	0.21	0.20	0.23	0.16	0.18	85.4%
Ireland	0.24	0.20	0.23	0.09	0.06	0.36	0.47	0.32	0.27	0.35	0.26	359.8%
Italy	22.80	17.97	13.08	10.75	8.37	7.59	5.16	7.06	7.98	7.43	9.43	12.7%
Luxembourg	-	-	-	-	-	-	-	-	-	-	-	-
Netherlands	28.26	32.86	29.39	27.45	34.29	35.59	41.98	53.31	48.58	44.61	43.72	27.5%
Norway	1.90	1.49	0.87	1.03	1.39	2.19	2.56	2.16	1.49	1.54	1.21	-12.9%
Poland	1.63	2.21	2.22	1.63	1.24	0.44	0.90	1.01	0.87	0.78	0.68	-45.1%
Portugal	2.32	2.00	1.34	1.48	1.91	1.52	2.08	1.82	1.68	1.51	1.46	-23.5%
Slovak Republic	-	-	-	-	-	-	-	-	-	-	-	-
Slovenia	..	..	..	..	..	..	..	0.07	0.21	0.10	0.06	..
Spain	5.94	3.44	5.07	6.76	11.46	10.00	18.97	25.00	27.69	27.52	26.53	131.5%
Sweden	3.58	3.45	2.66	1.76	2.09	3.30	4.28	6.12	6.43	6.70	6.19	195.7%
Switzerland	..	..	..	..	0.06	0.05	0.03	0.04	0.03	0.02	0.03	-44.4%
Turkey	0.26	0.29	..	0.25	0.37	0.58	1.25	3.31	2.06	0.85	1.15	209.3%
United Kingdom	17.37	10.60	7.57	6.56	7.84	7.62	6.44	6.34	7.99	7.67	6.60	-15.8%
OECD Europe **	**122.10**	**112.87**	**99.26**	**89.76**	**111.18**	**113.49**	**135.37**	**161.04**	**168.03**	**149.52**	**150.41**	**35.3%**
European Union - 27	*..*	*..*	*..*	*..*	*111.51*	*112.64*	*134.49*	*159.93*	*169.42*	*153.15*	*154.64*	*38.7%*

* Includes Estonia and Slovenia prior to 1990.

** Excludes Estonia and Slovenia prior to 1990.

CO_2 emissions from international marine bunkers

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**137.33**	**111.51**	**109.39**	**121.14**	**130.70**	**164.82**	**203.70**	**257.51**	**310.33**	**321.77**	**356.78**	**173.0%**
Albania	..	..	..	..	..	..	..	..	..	..	..	..
Armenia	..	..	..	..	-	-	-	-	-	-	-	-
Azerbaijan	..	..	..	..	..	..	..	..	..	..	..	..
Belarus	..	..	..	..	-	-	-	-	-	-	-	-
Bosnia and Herzegovina	..	..	..	..	..	..	..	..	..	..	..	..
Bulgaria	..	..	..	0.71	0.18	0.84	0.20	0.34	0.38	0.64	0.30	67.2%
Croatia	..	..	..	..	0.15	0.10	0.06	0.08	0.07	0.02	0.02	-85.2%
Cyprus	0.01	0.06	0.05	0.11	0.18	0.21	0.60	0.90	0.78	0.68	0.58	221.6%
Georgia	..	..	..	..	..	0.16	..	..	..	..	..	..
Gibraltar	0.55	0.58	0.41	0.88	1.38	2.69	3.22	4.82	6.09	7.60	7.76	463.7%
Kazakhstan	..	..	..	..	..	..	..	..	..	..	..	..
Kosovo **	..	..	..	..	..	..	..	..	..	..	..	..
Kyrgyzstan	..	..	..	..	-	-	-	-	-	-	-	-
Latvia	..	..	..	..	1.50	0.48	0.02	0.82	0.65	0.87	0.80	-46.8%
Lithuania	..	..	..	..	0.30	0.44	0.29	0.45	0.28	0.40	0.44	49.4%
FYR of Macedonia	-	-	-	-	-	-	-	-	-	-	-	-
Malta	0.19	0.08	0.09	0.06	0.09	0.14	2.07	2.09	2.89	3.57	4.64	+
Republic of Moldova	..	..	..	..	..	..	..	..	..	..	..	..
Montenegro **	..	..	..	..	..	..	..	..	..	..	..	..
Romania	..	..	..	..	..	..	..	..	0.22	0.05	0.05	..
Russian Federation	..	..	..	..	5.87	..	..	..	..	..	4.79	-18.4%
Serbia **	..	..	..	..	..	..	..	..	..	..	..	..
Tajikistan	..	..	..	..	-	-	-	-	-	-	-	-
Turkmenistan	..	..	..	..	..	..	..	..	..	..	..	..
Ukraine	..	..	..	..	..	..	..	..	..	..	..	..
Uzbekistan	..	..	..	..	-	-	-	-	-	-	-	-
Former Soviet Union ***	13.17	14.09	14.09	13.79	..	..	..	..	..	..	..	..
Former Yugoslavia ***	..	..	..	..	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**13.92**	**14.81**	**14.64**	**15.53**	**9.63**	**5.06**	**6.45**	**9.50**	**11.35**	**13.83**	**19.37**	**101.0%**
Algeria	0.61	0.77	1.29	1.16	1.36	1.17	0.77	1.17	1.01	0.91	1.01	-26.0%
Angola	0.77	0.48	0.83	0.10	0.02	0.03	..	0.34	0.04	0.59	0.56	+
Benin	..	..	..	..	..	..	..	..	..	..	..	..
Botswana	..	..	..	..	..	..	..	..	..	..	..	..
Cameroon	..	..	0.12	0.03	0.04	0.09	0.06	0.04	0.16	0.16	0.14	229.8%
Congo	..	..	..	..	..	..	..	..	0.13	..	..	..
Dem. Rep. of Congo	0.40	0.22	0.08	0.09	0.10	0.01	..	..	..	..	..	..
Côte d'Ivoire	0.06	0.01	1.35	0.73	0.12	0.27	0.29	0.35	0.21	0.05	0.05	-61.7%
Egypt	0.06	1.08	3.19	4.71	5.25	7.73	8.58	4.51	1.51	0.96	1.36	-74.1%
Eritrea	..	..	..	..	..	0.42	..	..	..	..	..	..
Ethiopia	0.07	0.01	0.01	0.03	0.04	0.52	..	..	..	..	..	..
Gabon	0.20	0.14	0.19	0.22	0.08	0.44	0.60	0.71	0.79	0.81	0.93	+
Ghana	0.16	0.14	0.10	..	..	..	0.16	0.12	0.18	0.23	0.30	..
Kenya	1.47	1.05	0.56	0.45	0.55	0.17	0.21	0.00	0.00	0.02	0.02	-96.6%
Libya	0.01	0.01	0.02	0.04	0.25	0.28	0.28	0.28	0.28	0.28	0.28	12.5%
Morocco	0.24	0.18	0.21	0.04	0.06	0.04	0.05	0.05	0.04	0.03	0.05	-24.9%
Mozambique	0.76	0.35	0.27	0.10	0.09	0.01	0.00	0.01	..	..	..	..
Namibia	..	..	..	..	..	..	..	..	..	..	..	..
Nigeria	0.02	0.11	0.25	0.34	0.58	1.42	1.15	1.55	1.86	1.99	2.14	269.0%
Senegal	2.99	2.09	0.84	0.33	0.11	0.09	0.30	0.36	0.23	0.19	0.20	78.2%
South Africa	10.81	7.15	5.25	3.41	5.95	10.30	8.51	8.52	8.60	8.46	8.70	46.1%
Sudan	..	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.06	0.06	0.06	171.4%
United Rep. of Tanzania	0.05	0.05	0.12	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	-15.5%
Togo	..	..	..	..	..	..	0.01	0.01	0.01	0.01	0.01	..
Tunisia	0.06	0.02	0.02	0.01	0.07	0.06	0.06	0.05	0.12	0.08	0.04	-34.9%
Zambia	-	-	-	-	-	-	-	-	-	-	-	-
Zimbabwe	..	..	..	..	..	..	..	..	..	..	..	..
Other Africa	3.02	2.08	1.77	1.82	1.71	1.42	1.71	1.43	1.52	1.58	1.64	-4.3%
Africa	**21.76**	**15.95**	**16.48**	**13.70**	**16.49**	**24.55**	**22.83**	**19.61**	**16.81**	**16.47**	**17.55**	**6.4%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

CO_2 emissions from international marine bunkers

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	0.06	0.05	0.19	0.07	0.06	0.11	0.11	0.11	0.11	0.11	0.11	78.6%
Brunei Darussalam	..	..	..	..	..	..	..	..	..	..	..	..
Cambodia	..	..	..	..	..	..	..	..	..	..	..	..
Chinese Taipei	0.39	0.33	0.66	1.62	4.86	7.57	11.02	7.50	5.71	5.05	5.45	12.3%
India	0.71	0.57	0.72	0.34	0.47	0.39	0.27	0.08	0.45	0.46	0.53	12.7%
Indonesia	0.70	1.09	0.79	0.68	1.68	1.28	0.36	0.42	0.50	0.52	0.72	-57.2%
DPR of Korea	..	..	..	..	..	..	..	..	..	..	..	..
Malaysia	0.11	0.22	0.18	0.31	0.29	0.53	0.69	0.19	0.21	0.15	0.19	-35.6%
Mongolia	..	..	..	..	..	..	..	..	..	..	..	..
Myanmar	0.01	0.00	-	-	-	0.01	0.01	0.01	0.01	0.01	0.01	x
Nepal	-	-	-	-	-	-	-	-	-	-	-	-
Pakistan	0.29	0.21	0.47	0.08	0.11	0.05	0.08	0.25	0.54	0.73	0.55	419.0%
Philippines	1.29	0.45	0.59	0.49	0.21	0.35	0.67	0.38	0.84	0.63	0.58	181.1%
Singapore	8.89	10.43	14.96	15.14	33.87	35.28	57.58	78.60	107.72	112.19	125.94	271.9%
Sri Lanka	1.19	1.29	1.10	1.01	1.21	1.09	0.50	0.53	0.63	0.57	0.61	-49.8%
Thailand	0.21	0.25	0.50	0.65	1.70	3.02	2.46	5.18	5.18	4.75	4.42	159.9%
Vietnam	..	..	..	0.07	0.09	0.22	0.46	0.79	0.89	0.92	1.02	+
Other Asia	0.57	0.53	0.46	0.20	0.21	0.33	0.33	0.44	0.41	0.35	0.38	80.9%
Asia	**14.42**	**15.43**	**20.62**	**20.66**	**44.75**	**50.23**	**74.54**	**94.49**	**123.18**	**126.45**	**140.51**	**214.0%**
People's Rep. of China	0.30	0.69	1.87	2.47	4.59	6.62	13.02	26.51	26.22	30.88	31.84	593.5%
Hong Kong, China	1.96	1.69	2.83	3.11	4.52	7.16	10.61	17.79	21.49	32.35	38.59	753.3%
China	**2.26**	**2.37**	**4.70**	**5.58**	**9.11**	**13.78**	**23.63**	**44.30**	**47.71**	**63.22**	**70.43**	**672.8%**
Argentina	0.66	0.28	1.32	2.00	2.22	1.71	1.48	2.19	3.02	2.99	3.75	68.7%
Bolivia	-	-	-	-	-	-	-	-	-	-	-	-
Brazil	1.00	1.17	1.42	1.71	1.72	3.64	9.16	10.92	14.17	11.75	12.61	634.9%
Colombia	0.95	0.49	0.31	0.22	0.33	0.58	0.74	1.13	1.50	1.54	1.97	498.2%
Costa Rica	..	..	..	..	..	..	..	..	..	..	..	..
Cuba	..	..	..	0.12	0.05	0.05	0.06	0.09	0.09	0.09	0.09	75.7%
Dominican Republic	..	..	..	..	..	..	..	..	..	..	..	..
Ecuador	0.28	..	0.34	0.11	0.49	0.99	0.87	0.69	3.26	3.95	3.13	532.9%
El Salvador	..	..	..	..	..	..	..	..	..	..	..	..
Guatemala	0.18	0.27	0.40	0.38	0.43	0.53	0.64	0.74	0.86	0.86	0.89	109.0%
Haiti	..	..	..	..	..	..	..	..	..	..	..	..
Honduras	..	..	..	..	..	..	..	..	..	0.00	0.00	..
Jamaica	0.16	0.26	0.10	0.04	0.10	0.12	0.12	0.13	0.13	0.13	0.13	25.0%
Netherlands Antilles	7.71	7.34	7.27	6.13	5.18	5.32	5.20	5.46	5.88	5.66	5.76	11.2%
Nicaragua	..	..	..	..	..	..	..	..	..	..	..	..
Panama	1.71	3.41	3.10	4.02	4.95	6.43	8.06	7.29	7.04	8.21	8.63	74.3%
Paraguay	-	-	-	-	-	-	-	-	-	-	-	-
Peru	0.10	0.12	0.47	0.62	0.12	0.53	0.31	1.00	0.80	0.55	0.76	544.6%
Trinidad and Tobago	5.12	3.54	1.42	0.31	0.11	0.16	1.19	1.47	1.37	1.38	1.06	874.2%
Uruguay	0.27	0.20	0.24	0.33	0.37	1.21	0.92	1.12	1.41	1.60	1.41	284.1%
Venezuela	9.13	4.82	1.99	1.76	2.50	2.30	2.06	2.33	2.88	2.81	2.72	8.7%
Other Non-OECD Americas	3.08	2.04	2.79	1.87	0.86	0.71	0.79	0.91	0.93	0.96	0.98	13.3%
Non-OECD Americas	**30.34**	**23.94**	**21.19**	**19.63**	**19.42**	**24.24**	**31.58**	**35.47**	**43.36**	**42.48**	**43.88**	**125.9%**
Bahrain	0.56	0.55	0.60	0.47	0.25	0.25	0.25	0.24	0.22	0.22	0.23	-6.3%
Islamic Republic of Iran	1.02	1.23	1.22	0.90	1.23	1.84	2.25	2.95	4.85	6.31	7.31	494.8%
Iraq	0.26	0.29	0.37	0.46	0.40	0.02	0.48	0.32	0.42	0.45	0.44	10.8%
Jordan	..	..	..	..	..	0.03	0.13	0.25	0.10	0.12	0.05	..
Kuwait	6.29	6.32	5.60	2.38	0.55	1.82	1.43	2.15	3.13	1.20	1.25	126.3%
Lebanon	0.71	0.03	..	..	..	0.04	0.05	0.06	0.07	0.07	0.08	..
Oman	3.85	2.54	0.71	0.35	0.06	0.08	0.19	0.12	0.41	0.38	0.57	830.0%
Qatar	..	..	..	..	..	..	..	..	..	..	..	..
Saudi Arabia	40.05	25.86	13.62	28.01	5.74	5.96	6.60	7.09	8.85	8.00	10.29	79.4%
Syrian Arab Republic	0.77	1.26	1.97	2.53	2.82	3.43	3.68	3.17	3.19	3.40	3.16	11.9%
United Arab Emirates	..	..	5.53	9.69	18.99	33.16	29.30	37.44	46.37	38.88	41.36	117.7%
Yemen	1.13	0.91	2.13	1.24	1.24	0.31	0.30	0.36	0.31	0.30	0.30	-75.7%
Middle East	**54.64**	**39.00**	**31.76**	**46.04**	**31.28**	**46.95**	**44.66**	**54.14**	**67.91**	**59.32**	**65.05**	**108.0%**

CO_2 emissions from international aviation bunkers

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World	**167.33**	**171.81**	**199.72**	**222.02**	**255.34**	**286.84**	**350.10**	**413.78**	**447.08**	**427.57**	**455.32**	**78.3%**
Annex I Parties	*..*	*..*	*..*	*..*	*168.67*	*179.33*	*223.55*	*254.02*	*267.39*	*248.40*	*251.90*	*49.3%*
Annex II Parties	*58.57*	*61.75*	*70.77*	*81.47*	*131.19*	*159.76*	*204.47*	*229.79*	*239.51*	*220.94*	*223.60*	*70.4%*
North America	*16.61*	*17.53*	*21.18*	*21.83*	*41.50*	*48.54*	*60.20*	*70.76*	*72.19*	*65.49*	*67.82*	*63.4%*
Europe	*35.96*	*37.67*	*42.70*	*48.59*	*70.77*	*87.26*	*115.76*	*127.38*	*138.43*	*128.60*	*127.02*	*79.5%*
Asia Oceania	*6.01*	*6.55*	*6.90*	*11.05*	*18.92*	*23.96*	*28.52*	*31.65*	*28.88*	*26.85*	*28.76*	*52.0%*
Annex I EIT	*..*	*..*	*..*	*..*	*36.73*	*18.58*	*17.17*	*20.76*	*23.64*	*22.97*	*24.40*	*-33.6%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*86.66*	*107.51*	*126.55*	*159.76*	*179.69*	*179.17*	*203.42*	*134.7%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*129.13*	*132.38*	*164.53*	*182.34*	*192.57*	*180.76*	*183.35*	*42.0%*
Non-OECD Total *	**103.69**	**103.63**	**119.14**	**129.91**	**113.41**	**112.62**	**128.74**	**157.79**	**175.13**	**176.40**	**200.81**	**77.1%**
OECD Total **	**63.64**	**68.18**	**80.58**	**92.11**	**141.93**	**174.22**	**221.36**	**256.00**	**271.95**	**251.17**	**254.51**	**79.3%**
Canada	1.25	1.93	1.35	1.22	2.71	2.58	3.08	2.55	1.61	2.33	3.17	17.2%
Chile	0.43	0.35	0.54	0.49	0.57	0.64	1.04	1.05	1.59	1.30	1.52	169.3%
Mexico	1.39	2.40	4.23	4.53	5.23	6.75	8.05	8.52	9.42	7.96	8.08	54.5%
United States	15.35	15.60	19.83	20.61	38.79	45.96	57.11	68.21	70.58	63.16	64.65	66.7%
OECD Americas	**18.43**	**20.27**	**25.95**	**26.85**	**47.29**	**55.93**	**69.29**	**80.33**	**83.20**	**74.75**	**77.42**	**63.7%**
Australia	1.57	1.89	2.40	2.76	4.29	5.75	7.15	8.08	9.05	9.24	10.09	135.1%
Israel	1.79	1.88	2.21	1.99	1.56	2.10	2.35	3.16	2.46	2.37	2.37	51.6%
Japan	3.80	4.32	3.92	7.63	13.31	16.61	19.57	21.37	17.55	15.43	16.36	22.9%
Korea	-	0.36	0.83	1.69	0.84	2.05	1.70	7.25	11.28	10.93	11.89	+
New Zealand	0.64	0.34	0.57	0.66	1.32	1.60	1.79	2.20	2.29	2.18	2.31	74.7%
OECD Asia Oceania	**7.80**	**8.79**	**9.93**	**14.74**	**21.33**	**28.10**	**32.56**	**42.06**	**42.63**	**40.16**	**43.02**	**101.7%**
Austria	0.28	0.24	0.38	0.65	0.86	1.28	1.63	1.89	2.11	1.83	1.98	131.3%
Belgium	1.21	1.05	1.22	1.62	2.82	2.61	4.37	3.80	6.05	5.72	4.56	61.9%
Czech Republic	0.69	0.58	0.85	0.63	0.65	0.56	0.48	0.94	1.05	1.00	0.92	41.8%
Denmark	1.92	1.56	1.59	1.56	1.70	1.84	2.32	2.55	2.62	2.29	2.39	40.4%
Estonia	..	..	..	..	0.10	0.05	0.06	0.14	0.08	0.10	0.11	5.9%
Finland	0.18	0.40	0.46	0.48	0.97	0.86	1.02	1.24	1.72	1.51	1.59	63.1%
France	4.57	5.71	5.62	6.43	9.32	11.44	15.07	16.10	17.58	16.01	16.32	75.1%
Germany	7.57	8.16	8.22	9.46	13.34	15.76	19.50	22.56	24.99	24.39	24.05	80.2%
Greece	1.29	1.31	2.23	2.33	2.34	2.52	2.41	2.30	2.94	2.53	2.02	-13.7%
Hungary	0.15	0.20	0.36	0.44	0.49	0.54	0.69	0.79	0.82	0.70	0.70	43.1%
Iceland	0.22	0.13	0.09	0.18	0.22	0.20	0.39	0.40	0.41	0.33	0.37	69.0%
Ireland	0.96	0.73	0.60	0.57	1.03	1.11	1.73	2.35	2.69	1.64	2.14	107.4%
Italy	3.47	2.44	4.15	4.33	4.50	5.80	8.38	8.88	9.76	8.88	9.39	108.8%
Luxembourg	0.11	0.15	0.19	0.22	0.39	0.56	0.95	1.28	1.30	1.24	1.28	227.3%
Netherlands	2.01	2.26	2.72	3.47	4.29	7.38	9.65	10.67	11.02	10.25	10.00	133.0%
Norway	0.70	0.51	0.67	0.92	1.24	1.09	1.05	1.04	1.13	1.06	1.28	2.4%
Poland	0.52	0.53	0.67	0.67	0.68	0.82	0.82	0.96	1.59	1.44	1.52	123.8%
Portugal	0.70	0.80	0.88	1.27	1.49	1.49	1.69	2.13	2.59	2.43	2.63	76.9%
Slovak Republic	-	-	-	-	-	0.12	0.08	0.12	0.19	0.13	0.12	x
Slovenia	..	..	..	..	0.08	0.06	0.07	0.07	0.10	0.08	0.08	-3.8%
Spain	1.74	2.77	2.58	2.67	3.32	6.01	8.03	9.18	10.11	9.40	9.02	171.7%
Sweden	0.33	0.33	0.49	0.51	1.07	1.76	2.06	1.87	2.32	2.11	2.04	90.1%
Switzerland	1.63	1.80	2.02	2.41	3.00	3.63	4.57	3.48	4.14	3.98	4.16	38.6%
Turkey	0.09	0.14	0.12	0.18	0.53	0.78	1.54	3.21	3.86	4.22	3.60	576.6%
United Kingdom	7.08	7.32	8.59	9.53	18.86	21.92	30.93	35.65	34.95	33.00	31.80	68.7%
OECD Europe **	**37.41**	**39.12**	**44.70**	**50.51**	**73.30**	**90.19**	**119.51**	**133.60**	**146.12**	**136.27**	**134.07**	**82.9%**
European Union - 27	*..*	*..*	*..*	*..*	*71.34*	*87.30*	*113.95*	*127.86*	*139.36*	*129.06*	*127.27*	*78.4%*

* Includes Estonia and Slovenia prior to 1990.
** Excludes Estonia and Slovenia prior to 1990.

CO_2 emissions from international aviation bunkers

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**103.69**	**103.63**	**119.14**	**129.91**	**113.41**	**112.62**	**128.74**	**157.79**	**175.13**	**176.40**	**200.81**	**77.1%**
Albania	-	-	-	-	-	-	0.13	0.18	0.08	0.05	0.05	x
Armenia	..	..	..	..	0.59	0.10	0.19	0.13	0.17	0.09	0.13	-77.8%
Azerbaijan	..	..	..	..	0.94	0.24	0.36	1.42	1.31	0.92	1.19	27.3%
Belarus	..	..	..	..	-	-	-	-	-	-	-	-
Bosnia and Herzegovina	..	..	..	..	0.08	0.11	0.03	0.02	0.02	0.02	0.02	-80.0%
Bulgaria	0.61	0.61	0.91	1.11	0.71	0.98	0.24	0.56	0.63	0.45	0.50	-29.7%
Croatia	..	..	..	..	0.15	0.18	0.10	0.12	0.16	0.13	0.16	10.4%
Cyprus	0.15	0.02	0.23	0.44	0.72	0.79	0.82	0.89	0.87	0.81	0.82	14.4%
Georgia	..	..	..	..	0.60	0.01	0.05	0.11	0.12	0.12	0.12	-79.7%
Gibraltar	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02	-28.6%
Kazakhstan	..	..	..	..	2.68	0.78	0.23	0.49	0.10	0.07	0.25	-90.7%
Kosovo **	-	-	-	-	..	..	-	-	-	-	0.00	..
Kyrgyzstan	..	..	..	..	0.26	0.19	0.12	0.38	1.20	1.24	1.22	366.3%
Latvia	..	..	..	..	0.22	0.08	0.08	0.17	0.29	0.30	0.35	60.6%
Lithuania	..	..	..	..	0.40	0.12	0.08	0.14	0.23	0.11	0.14	-64.0%
FYR of Macedonia	..	..	..	..	0.02	0.09	0.09	0.02	0.02	0.01	0.02	39.2%
Malta	0.17	0.18	0.23	0.14	0.21	0.22	0.37	0.26	0.38	0.27	0.30	41.4%
Republic of Moldova	..	..	..	..	0.22	0.03	0.06	0.04	0.04	0.04	0.04	-81.9%
Montenegro **	..	..	..	..	..	..	..	0.04	0.04	0.01	0.01	..
Romania	0.06	0.05	-	-	0.78	0.62	0.42	0.37	0.40	0.45	0.49	-37.2%
Russian Federation	..	..	..	..	26.37	13.99	13.27	15.27	17.34	17.36	18.49	-29.9%
Serbia **	..	..	..	..	0.43	0.11	0.09	0.15	0.15	0.13	0.13	-69.7%
Tajikistan	..	..	..	..	0.05	0.02	0.01	0.04	0.08	0.08	0.08	80.0%
Turkmenistan	..	..	..	..	0.61	0.49	0.79	0.93	1.10	1.03	0.98	61.0%
Ukraine	..	..	..	..	6.11	0.47	0.78	1.11	0.78	0.72	0.82	-86.6%
Uzbekistan	..	..	..	..	-	-	-	-	-	-	-	-
Former Soviet Union ***	66.66	62.09	70.62	76.70	..	..	..	..	..	..	..	..
Former Yugoslavia ***	0.64	0.88	1.00	0.99	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**68.31**	**63.86**	**73.00**	**79.40**	**42.14**	**19.64**	**18.29**	**22.85**	**25.51**	**24.41**	**26.34**	**-37.5%**
Algeria	0.29	0.66	0.93	1.31	1.09	0.96	1.17	1.16	1.25	1.40	1.47	35.4%
Angola	0.23	0.31	0.25	0.99	1.03	1.17	1.42	0.56	0.42	0.61	0.62	-39.6%
Benin	0.02	0.01	0.03	0.06	0.05	0.07	0.07	0.03	0.13	0.27	0.47	831.3%
Botswana	..	..	..	0.01	0.03	0.02	0.02	0.03	0.05	0.05	0.05	45.5%
Cameroon	0.17	0.10	0.15	0.15	0.15	0.17	0.18	0.20	0.21	0.21	0.21	35.4%
Congo	-	0.05	0.11	0.09	0.08	0.05	0.10	0.14	0.18	0.19	0.19	150.0%
Dem. Rep. of Congo	0.28	0.24	0.37	0.40	0.32	0.35	0.24	0.50	0.05	0.05	0.46	44.5%
Côte d'Ivoire	0.13	0.21	0.26	0.28	0.27	0.26	0.37	0.28	0.17	0.17	0.13	-52.4%
Egypt	0.21	0.27	0.51	0.12	0.44	0.79	1.71	2.23	2.75	3.00	2.55	477.1%
Eritrea	..	..	..	..	..	0.02	0.03	0.03	0.01	0.00	0.00	..
Ethiopia	0.14	0.16	0.20	0.34	0.53	0.20	0.24	0.46	0.68	0.78	1.01	90.6%
Gabon	0.03	0.04	0.07	0.08	0.20	0.19	0.23	0.21	0.17	0.17	0.18	-8.4%
Ghana	0.13	0.15	0.12	0.10	0.14	0.18	0.32	0.39	0.39	0.41	0.36	157.1%
Kenya	0.57	0.89	1.10	0.82	0.83	1.37	1.36	1.76	1.76	1.80	1.70	105.3%
Libya	0.27	0.53	0.89	1.05	0.63	0.91	1.33	0.58	0.59	0.73	0.81	27.5%
Morocco	0.35	0.44	0.78	0.70	0.79	0.73	0.90	1.16	1.53	1.54	1.77	124.9%
Mozambique	0.12	0.05	0.08	0.09	0.13	0.06	0.13	0.14	0.18	0.21	0.20	56.1%
Namibia	..	..	..	..	..	0.10	0.12	0.04	0.11	0.11	0.12	..
Nigeria	0.24	0.70	1.14	1.33	0.95	1.25	0.58	0.70	2.63	2.00	0.51	-46.0%
Senegal	0.30	0.37	0.58	0.43	0.45	0.45	0.75	0.74	1.00	0.63	0.65	43.1%
South Africa	0.53	0.73	0.87	0.93	1.09	1.58	2.79	2.21	2.60	2.47	2.55	133.3%
Sudan	0.34	0.14	0.20	0.21	0.09	0.10	0.33	0.82	1.28	0.69	0.75	688.1%
United Rep. of Tanzania	0.08	0.20	0.17	0.13	0.22	0.19	0.18	0.26	0.32	0.31	0.32	44.6%
Togo	-	-	-	-	0.10	0.12	0.03	0.15	0.19	0.19	0.20	90.9%
Tunisia	0.39	0.38	0.56	0.30	0.57	0.74	0.85	0.65	0.70	0.60	0.75	31.7%
Zambia	0.04	0.14	0.23	0.12	0.19	0.10	0.13	0.16	0.12	0.09	0.09	-54.0%
Zimbabwe	0.07	0.17	0.19	0.32	0.23	0.33	0.35	0.02	0.02	0.02	0.02	-90.3%
Other Africa	-	-	0.90	0.90	0.83	0.95	1.49	1.69	1.80	1.74	1.80	118.5%
Africa	**4.91**	**6.93**	**10.70**	**11.28**	**11.44**	**13.39**	**17.41**	**17.32**	**21.28**	**20.44**	**19.94**	**74.4%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

CO_2 emissions from international aviation bunkers

million tonnes of CO_2

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	0.06	0.08	0.15	0.22	0.27	0.30	0.38	0.87	0.65	0.57	0.50	83.7%
Brunei Darussalam	0.00	0.06	0.07	0.05	0.11	0.21	0.21	0.25	0.28	0.27	0.33	188.9%
Cambodia	..	..	..	..	..	0.03	0.04	0.05	0.06	0.07	0.08	..
Chinese Taipei	1.48	1.62	1.66	0.92	1.79	4.09	5.38	6.46	5.86	5.54	6.25	248.6%
India	1.68	1.98	2.49	3.21	3.71	4.60	4.97	7.28	9.85	10.23	11.22	202.8%
Indonesia	0.16	0.32	0.73	0.65	0.96	1.17	1.21	1.52	1.82	1.90	2.01	109.2%
DPR of Korea	-	-	-	-	-	-	-	-	-	-	-	-
Malaysia	0.42	0.74	0.77	0.86	1.88	3.44	4.67	5.96	6.27	6.30	7.07	277.0%
Mongolia	..	..	..	-	0.01	0.06	0.06	0.06	0.10	0.05	0.05	300.0%
Myanmar	0.03	0.02	0.03	0.03	0.02	0.02	0.05	0.03	0.05	0.05	0.06	200.0%
Nepal	0.01	0.02	0.04	0.06	0.05	0.11	0.17	0.19	0.18	0.21	0.26	426.7%
Pakistan	1.13	1.08	1.69	1.41	1.39	1.70	2.28	2.84	2.38	2.54	2.63	88.8%
Philippines	0.70	0.82	0.66	1.02	1.01	1.16	1.42	2.12	2.82	2.89	2.93	191.2%
Singapore	0.70	1.32	2.71	3.19	5.63	7.81	11.89	13.45	15.46	15.09	17.02	202.1%
Sri Lanka	-	0.00	0.00	-	-	-	0.32	0.93	0.30	0.28	0.35	x
Thailand	1.26	2.17	2.39	3.12	5.58	7.51	8.27	10.17	10.97	10.49	11.15	99.7%
Vietnam	6.88	2.60	-	-	-	0.12	0.30	0.94	1.31	1.51	2.01	x
Other Asia	0.66	0.52	0.33	0.47	0.51	0.33	0.61	0.82	0.85	0.69	0.73	42.8%
Asia	**15.16**	**13.36**	**13.71**	**15.20**	**22.93**	**32.67**	**42.20**	**53.94**	**59.22**	**58.66**	**64.65**	**181.9%**
People's Rep. of China	-	-	-	0.22	0.50	0.99	2.13	6.19	6.04	8.00	16.35	+
Hong Kong, China	1.41	1.83	2.24	2.55	5.62	9.22	8.31	14.71	14.15	14.06	16.20	188.0%
China	**1.41**	**1.83**	**2.24**	**2.77**	**6.12**	**10.20**	**10.43**	**20.90**	**20.19**	**22.07**	**32.55**	**431.9%**
Argentina	-	-	-	-	-	1.58	2.83	2.14	1.35	1.40	1.95	x
Bolivia	-	-	-	-	-	-	0.14	0.15	0.13	0.13	0.14	x
Brazil	-	-	0.61	0.74	1.41	2.06	2.00	3.30	4.72	4.90	5.78	308.7%
Colombia	0.59	0.92	1.31	1.31	1.56	2.14	1.89	1.83	1.72	1.79	2.08	33.1%
Costa Rica	-	-	-	-	0.01	0.31	0.36	0.57	0.55	0.48	0.49	+
Cuba	0.27	0.43	0.65	0.89	0.98	0.53	0.64	0.53	0.45	0.43	0.43	-56.0%
Dominican Republic	0.08	0.10	0.17	0.16	0.11	0.17	0.22	0.30	0.29	0.29	0.30	161.1%
Ecuador	0.27	0.14	0.45	0.45	0.39	0.55	0.66	0.96	1.05	1.03	1.03	164.2%
El Salvador	0.03	0.05	0.06	0.11	0.11	0.16	0.22	0.24	0.35	0.35	0.34	200.0%
Guatemala	0.15	0.11	0.13	0.12	0.13	0.14	0.15	0.23	0.08	0.07	0.12	-4.8%
Haiti	0.02	0.03	0.05	0.04	0.07	0.07	0.09	0.07	0.07	0.05	0.06	-13.0%
Honduras	0.02	0.03	0.06	0.12	0.09	0.07	0.11	0.07	0.14	0.15	0.15	58.6%
Jamaica	0.42	0.33	0.30	0.39	0.46	0.52	0.53	0.60	0.98	0.52	0.76	63.3%
Netherlands Antilles	0.15	0.13	0.16	0.13	0.12	0.20	0.20	0.21	0.22	0.21	0.22	86.5%
Nicaragua	0.05	0.06	0.06	0.04	0.08	0.06	0.08	0.05	0.08	0.06	0.05	-30.7%
Panama	0.43	1.11	0.41	0.26	0.20	0.31	0.54	0.57	0.94	0.94	1.07	428.1%
Paraguay	0.03	0.04	0.06	0.06	0.03	0.03	0.04	0.05	0.06	0.06	0.07	144.8%
Peru	0.51	0.74	0.92	0.71	0.64	1.10	1.06	0.96	1.78	1.74	1.94	200.5%
Trinidad and Tobago	0.21	0.12	0.17	0.22	0.20	0.17	0.39	0.38	0.19	0.20	0.20	3.2%
Uruguay	-	-	-	-	-	-	0.12	0.12	0.21	0.21	0.24	x
Venezuela	0.29	0.37	0.73	0.81	1.02	1.00	0.94	2.03	0.45	0.48	1.88	83.5%
Other Non-OECD Americas	1.10	0.63	0.90	0.86	1.02	1.06	1.73	1.31	1.42	1.47	1.50	48.1%
Non-OECD Americas	**4.63**	**5.34**	**7.20**	**7.42**	**8.64**	**12.25**	**14.94**	**16.67**	**17.23**	**16.99**	**20.79**	**140.5%**
Bahrain	0.43	0.84	1.53	1.21	1.43	1.15	1.12	1.72	2.12	2.10	1.97	37.7%
Islamic Republic of Iran	7.02	7.01	2.15	1.64	1.48	1.97	2.71	2.69	3.23	3.70	3.80	156.4%
Iraq	0.24	0.81	1.05	0.58	0.98	1.26	1.63	1.98	2.14	2.19	2.22	126.5%
Jordan	0.12	0.18	0.57	0.61	0.66	0.75	0.75	0.96	0.91	0.98	1.08	62.3%
Kuwait	0.34	0.34	1.04	0.97	0.51	1.12	1.15	1.82	2.15	2.41	2.40	369.8%
Lebanon	0.28	0.23	0.15	0.32	0.16	0.66	0.40	0.46	0.53	0.55	0.70	342.0%
Oman	0.01	0.15	0.38	0.57	0.93	0.46	0.65	1.24	0.96	0.98	1.24	33.1%
Qatar	-	0.16	0.23	0.24	0.34	0.43	0.57	1.43	2.71	2.76	3.84	+
Saudi Arabia	0.47	1.40	3.45	4.57	4.79	5.69	5.85	5.44	6.18	6.11	6.46	34.7%
Syrian Arab Republic	0.24	0.65	0.72	0.87	0.87	0.62	0.41	0.33	0.15	0.14	0.09	-89.1%
United Arab Emirates	0.02	0.34	0.80	1.80	9.79	10.08	9.87	7.67	10.29	11.48	12.35	26.1%
Yemen	0.09	0.18	0.21	0.46	0.17	0.28	0.38	0.36	0.36	0.43	0.39	121.9%
Middle East	**9.26**	**12.31**	**12.30**	**13.84**	**22.13**	**24.47**	**25.47**	**26.11**	**31.70**	**33.82**	**36.55**	**65.1%**

CO_2 emissions by sector in 2010 *

million tonnes of CO_2

	Total CO_2 emissions from fuel combustion	Electricity and heat production	Other energy industry own use **	Manufacturing industries and construction	Transport	*of which: road*	Other sectors	*of which: residential*
World ***	**30 276.1**	**12 480.6**	**1 570.8**	**6 186.4**	**6 755.8**	**4 972.1**	**3 282.6**	**1 880.4**
Annex I Parties	*13 398.1*	*5 526.6*	*674.8*	*1 980.5*	*3 369.4*	*2 908.3*	*1 846.9*	*1 090.5*
Annex II Parties	*10 519.3*	*4 104.1*	*562.5*	*1 460.3*	*2 921.2*	*2 582.9*	*1 471.2*	*824.5*
North America	*5 905.3*	*2 424.2*	*325.1*	*687.9*	*1 791.4*	*1 540.1*	*676.8*	*360.6*
Europe	*3 056.6*	*1 006.6*	*160.7*	*467.9*	*811.4*	*760.4*	*610.1*	*394.6*
Asia Oceania	*1 557.4*	*673.3*	*76.8*	*304.5*	*318.5*	*282.3*	*184.3*	*69.3*
Annex I EIT	*2 610.5*	*1 320.4*	*101.3*	*469.2*	*403.6*	*285.9*	*316.0*	*225.0*
Non-Annex I Parties	*15 779.0*	*6 954.0*	*896.0*	*4 205.9*	*2 287.4*	*2 063.8*	*1 435.7*	*789.9*
Annex I Kyoto Parties	*7 695.8*	*3 081.9*	*397.6*	*1 332.2*	*1 695.7*	*1 462.1*	*1 188.4*	*719.8*
Non-OECD Total	**16 736.8**	**7 542.6**	**883.6**	**4 432.3**	**2 331.0**	**2 004.5**	**1 547.3**	**898.5**
OECD Total	**12 440.3**	**4 937.9**	**687.2**	**1 754.1**	**3 325.8**	**2 967.6**	**1 735.3**	**982.0**
Canada	536.6	114.5	63.1	100.8	169.7	139.6	88.6	38.9
Chile	69.7	24.8	2.4	15.4	21.2	18.7	5.9	3.4
Mexico	416.9	123.2	55.5	54.8	151.4	147.3	32.0	18.9
United States	5 368.6	2 309.7	262.0	587.1	1 621.7	1 400.5	588.2	321.7
OECD Americas	**6 391.9**	**2 572.2**	**383.0**	**758.1**	**1 964.0**	**1 706.2**	**714.7**	**382.9**
Australia	383.5	203.1	31.2	48.6	82.2	69.1	18.4	8.0
Israel	68.1	40.3	3.1	3.5	11.9	11.9	9.2	2.6
Japan	1 143.1	463.5	44.0	249.8	222.7	201.1	163.1	60.8
Korea	563.1	279.2	36.2	98.6	86.8	81.8	62.3	32.9
New Zealand	30.9	6.7	1.6	6.1	13.6	12.2	2.8	0.5
OECD Asia Oceania	**2 188.6**	**992.9**	**116.2**	**406.5**	**417.2**	**376.0**	**255.8**	**104.9**
Austria	69.3	16.5	7.4	12.8	21.9	21.2	10.7	7.6
Belgium	106.4	22.8	5.6	24.6	24.8	24.2	28.7	18.6
Czech Republic	114.5	62.8	2.4	19.8	16.7	15.9	12.8	7.9
Denmark	47.0	22.0	2.2	4.0	12.9	11.9	5.9	3.2
Estonia	18.5	14.7	0.1	0.8	2.2	2.0	0.6	0.2
Finland	62.9	31.2	3.6	10.1	12.5	11.5	5.5	1.9
France	357.8	55.0	16.3	62.6	123.6	118.3	100.2	57.0
Germany	761.6	326.9	26.3	116.0	145.5	141.0	146.9	101.0
Greece	84.3	41.4	3.4	8.2	21.8	18.7	9.5	6.6
Hungary	48.9	16.0	1.6	5.9	11.6	11.4	13.8	8.6
Iceland	1.9	0.0	-	0.5	0.8	0.8	0.6	0.0
Ireland	38.7	13.0	0.4	3.5	11.5	11.2	10.3	7.2
Italy	398.5	135.0	18.2	53.4	108.1	101.9	83.8	53.3
Luxembourg	10.6	1.3	-	1.2	6.5	6.5	1.7	1.0
Netherlands	187.0	59.4	10.4	42.3	33.3	32.5	41.6	20.5
Norway	39.2	2.8	11.2	7.5	14.0	10.4	3.5	0.6
Poland	305.1	157.7	7.6	34.1	46.8	45.7	58.9	37.3
Portugal	48.2	15.1	2.4	7.3	18.4	17.4	5.0	2.2
Slovak Republic	35.0	8.7	4.8	7.8	6.9	5.9	6.8	3.4
Slovenia	15.3	6.1	0.0	2.0	5.1	5.1	2.1	1.2
Spain	268.3	71.4	17.7	47.9	97.7	85.1	33.7	19.6
Sweden	47.6	11.2	2.4	9.1	21.5	20.4	3.2	0.4
Switzerland	43.8	2.8	1.0	5.8	17.0	16.7	17.2	11.4
Turkey	265.9	100.3	10.9	51.0	44.0	39.0	59.7	40.9
United Kingdom	483.5	178.7	32.3	51.1	119.3	110.7	102.1	82.4
OECD Europe	**3 859.8**	**1 372.9**	**188.1**	**589.4**	**944.6**	**885.4**	**764.8**	**494.1**
European Union - 27	*3 659.5*	*1 340.9*	*173.3*	*546.9*	*900.4*	*848.2*	*698.1*	*449.4*

* This table shows CO_2 emissions for the same sectors which are present throughout this publication. In particular, the emissions from electricity and heat production are shown separately and not reallocated as in the table on pages 72-74.
** Includes emissions from own use in petroleum refining, the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries.
*** World includes international bunkers in the transport sector.

CO_2 emissions by sector in 2010

million tonnes of CO_2

	Total CO_2 emissions from fuel combustion	Electricity and heat production	Other energy industry own use	Manufacturing industries and construction	Transport	*of which: road*	Other sectors	*of which: residential*
Non-OECD Total	**16 736.8**	**7 542.6**	**883.6**	**4 432.3**	**2 331.0**	**2 004.5**	**1 547.3**	**898.5**
Albania	3.8	0.0	0.1	0.8	2.3	2.2	0.6	0.2
Armenia	4.0	0.6	-	0.5	1.3	1.3	1.6	0.9
Azerbaijan	24.7	9.1	2.4	1.0	5.1	4.5	7.0	5.9
Belarus	65.3	32.9	4.3	10.2	7.4	6.1	10.6	7.9
Bosnia and Herzegovina	19.9	13.1	0.4	1.6	3.2	3.2	1.6	0.6
Bulgaria	43.8	29.3	1.0	4.3	7.7	7.2	1.6	0.8
Croatia	19.0	4.2	1.9	3.5	6.0	5.6	3.5	2.1
Cyprus	7.2	3.8	-	0.7	2.2	2.2	0.6	0.3
Georgia	4.9	0.8	0.2	0.7	2.1	2.0	1.2	0.8
Gibraltar	0.5	0.1	-	0.1	0.3	0.3	-	-
Kazakhstan	232.1	74.9	47.2	52.4	12.9	11.8	44.8	9.6
Kosovo	8.5	6.7	-	0.5	1.0	1.0	0.4	0.2
Kyrgyzstan	7.0	1.3	-	1.9	2.6	2.6	1.2	-
Latvia	8.1	2.4	-	1.2	3.2	2.9	1.4	0.5
Lithuania	13.4	3.7	1.8	2.2	4.3	4.0	1.3	0.7
FYR of Macedonia	8.2	5.4	0.0	1.1	1.3	1.3	0.4	0.1
Malta	2.5	1.8	-	0.0	0.5	0.5	0.1	0.1
Republic of Moldova	6.1	2.7	0.0	0.2	1.0	1.0	2.2	1.8
Montenegro	2.1	1.7	-	0.2	0.2	-	0.0	0.0
Romania	75.6	33.0	5.6	13.8	13.8	12.8	9.4	5.8
Russian Federation	1 581.4	832.6	63.2	294.3	242.0	139.9	149.3	113.5
Serbia	46.0	30.4	0.5	5.5	6.5	5.5	3.1	1.5
Tajikistan	2.7	0.5	-	-	0.3	0.3	2.0	-
Turkmenistan	52.7	16.4	8.0	3.1	4.3	2.4	21.0	-
Ukraine	266.6	116.3	7.2	69.1	30.0	21.3	44.0	34.9
Uzbekistan	100.2	36.0	3.3	17.1	7.9	4.7	36.0	27.3
Non-OECD Europe and Eurasia	**2 606.3**	**1 259.7**	**146.8**	**486.0**	**369.2**	**246.8**	**344.6**	**215.6**
Algeria	98.6	25.0	11.1	12.7	33.3	29.7	16.4	13.1
Angola	16.6	2.3	0.3	2.7	7.5	6.8	3.9	1.3
Benin	4.5	0.1	-	0.1	3.1	3.1	1.1	1.1
Botswana	4.6	1.2	-	1.2	2.0	2.0	0.2	0.1
Cameroon	5.0	1.2	0.4	0.4	2.7	2.5	0.4	0.4
Congo	1.7	0.1	-	0.1	1.4	1.4	0.1	0.1
Dem. Rep. of Congo	3.1	0.0	-	1.1	0.7	0.7	1.2	0.3
Côte d'Ivoire	5.8	2.7	0.2	0.5	1.3	1.0	1.2	0.4
Egypt	177.6	66.0	14.8	33.4	38.4	35.4	24.9	15.2
Eritrea	0.5	0.2	-	0.0	0.1	0.1	0.1	0.0
Ethiopia	5.4	0.0	-	1.3	2.7	2.7	1.3	0.7
Gabon	2.7	0.7	0.0	1.0	0.6	0.6	0.3	0.1
Ghana	9.5	2.2	0.1	1.4	4.9	4.5	0.9	0.5
Kenya	10.9	2.1	0.2	2.3	4.7	4.5	1.6	1.0
Libya	51.6	28.0	3.1	6.3	12.1	12.1	2.2	2.2
Morocco	46.0	16.0	0.8	7.6	10.6	10.6	11.0	4.2
Mozambique	2.5	0.0	0.0	0.4	1.7	1.5	0.4	0.1
Namibia	3.3	0.3	-	0.3	1.8	1.7	1.0	-
Nigeria	45.9	10.6	5.8	3.8	19.0	15.5	6.7	1.7
Senegal	5.5	1.9	0.0	1.0	2.0	1.9	0.6	0.4
South Africa	346.8	237.8	2.3	49.5	38.2	35.5	19.1	9.0
Sudan	13.7	2.7	0.5	2.3	6.8	6.7	1.4	0.8
United Rep. of Tanzania	6.0	1.5	-	0.9	3.0	3.0	0.6	0.5
Togo	1.2	0.0	-	0.1	0.9	0.9	0.1	0.1
Tunisia	21.9	7.4	0.1	5.1	6.0	6.0	3.3	1.6
Zambia	1.9	0.0	0.1	0.8	0.6	0.4	0.4	-
Zimbabwe	9.1	5.3	0.1	1.1	1.2	1.1	1.4	0.1
Other Africa	27.9	8.1	-	3.4	12.4	10.9	4.0	2.4
Africa	**929.7**	**423.4**	**39.8**	**140.9**	**219.7**	**203.0**	**105.9**	**57.6**

CO_2 emissions by sector in 2010

million tonnes of CO_2

	Total CO_2 emissions from fuel combustion	Electricity and heat production	Other energy industry own use	Manufacturing industries and construction	Transport	*of which: road*	Other sectors	*of which: residential*
Bangladesh	53.0	25.1	0.2	9.2	8.4	6.4	10.1	5.7
Brunei Darussalam	8.2	2.8	1.8	2.3	1.2	1.2	0.1	0.1
Cambodia	3.8	0.8	-	0.7	1.9	1.5	0.4	0.4
Chinese Taipei	270.2	152.2	13.3	59.7	35.5	34.3	9.6	4.5
India	1 625.8	875.8	61.1	400.9	161.5	144.7	126.5	74.8
Indonesia	410.9	120.4	29.2	124.9	105.8	92.8	30.5	16.8
DPR of Korea	63.0	10.1	0.0	39.7	0.9	0.9	12.2	0.1
Malaysia	185.0	91.1	10.5	32.2	42.4	42.2	8.7	1.9
Mongolia	11.9	8.1	0.0	1.3	1.4	1.0	1.0	0.9
Myanmar	8.0	2.0	0.7	2.5	2.3	1.8	0.6	0.0
Nepal	3.7	0.0	-	0.8	1.9	1.9	1.0	0.4
Pakistan	134.6	40.1	1.4	42.5	32.7	31.6	18.0	13.1
Philippines	76.4	32.6	1.7	12.7	23.5	20.6	6.0	2.5
Singapore	62.9	22.7	6.0	25.9	8.0	8.0	0.3	0.2
Sri Lanka	13.3	4.1	0.0	1.2	6.9	6.5	1.0	0.4
Thailand	248.5	81.8	15.5	77.7	55.4	54.9	18.1	4.4
Vietnam	130.5	41.0	3.1	44.0	30.2	29.5	12.2	7.2
Other Asia	20.9	6.6	-	3.7	8.0	6.8	2.6	0.8
Asia	**3 330.6**	**1 517.1**	**144.7**	**882.0**	**527.8**	**486.4**	**258.9**	**133.9**
People's Rep. of China	7 217.1	3 549.2	275.5	2 327.6	508.0	395.3	556.8	302.4
Hong Kong, China	41.5	27.7	-	5.7	5.6	5.6	2.4	0.8
China	**7 258.5**	**3 576.9**	**275.5**	**2 333.4**	**513.6**	**400.9**	**559.2**	**303.1**
Argentina	170.2	46.0	17.1	30.1	41.3	38.0	35.8	21.5
Bolivia	14.1	2.9	1.2	1.6	6.8	6.5	1.6	1.2
Brazil	387.7	44.7	25.1	114.0	166.0	148.2	37.7	17.0
Colombia	60.7	10.0	6.7	14.8	21.6	20.6	7.6	3.7
Costa Rica	6.5	0.5	0.1	1.0	4.5	4.5	0.4	0.1
Cuba	30.0	17.6	0.4	8.8	1.4	1.3	1.8	0.6
Dominican Republic	18.6	9.4	0.0	1.6	5.2	4.2	2.3	2.1
Ecuador	30.1	6.9	1.1	4.1	14.6	12.3	3.3	2.8
El Salvador	5.9	1.3	0.0	1.3	2.5	2.5	0.6	0.6
Guatemala	10.3	2.5	0.1	1.4	5.6	5.6	0.7	0.7
Haiti	2.1	0.3	-	0.5	1.1	0.4	0.2	0.2
Honduras	7.3	2.2	-	1.3	3.0	3.0	0.8	0.2
Jamaica	8.0	3.0	0.2	0.2	2.8	1.4	1.7	0.1
Netherlands Antilles	3.8	0.9	0.8	0.7	1.2	1.2	0.2	0.2
Nicaragua	4.5	1.7	0.1	0.6	1.7	1.6	0.4	0.1
Panama	8.4	2.2	-	1.9	3.5	3.5	0.7	0.5
Paraguay	4.7	-	-	0.2	4.3	4.2	0.3	0.2
Peru	41.9	10.4	3.9	8.6	16.3	15.4	2.8	1.7
Trinidad and Tobago	42.8	5.9	8.7	24.6	3.1	3.1	0.4	0.4
Uruguay	6.4	0.9	0.6	0.8	3.0	2.9	1.2	0.5
Venezuela	183.0	31.3	49.7	47.7	48.2	48.2	6.2	5.3
Other Non-OECD Americas	18.4	9.4	0.0	1.5	5.2	4.6	2.3	1.1
Non-OECD Americas	**1 065.4**	**210.1**	**115.9**	**267.4**	**362.9**	**333.3**	**109.1**	**60.8**
Bahrain	23.6	8.5	4.5	6.8	3.6	3.6	0.2	0.2
Islamic Rep. of Iran	509.0	131.5	30.2	95.9	118.7	117.4	132.7	100.4
Iraq	104.5	50.3	4.0	8.2	29.7	29.7	12.2	12.2
Jordan	18.6	8.4	0.6	2.3	5.2	5.1	2.2	1.3
Kuwait	87.4	48.0	12.2	15.0	11.7	11.7	0.5	0.5
Lebanon	18.6	11.1	-	1.3	5.0	5.0	1.2	1.2
Oman	40.3	15.7	7.9	8.5	6.3	6.3	1.9	0.5
Qatar	64.9	13.9	20.3	21.2	9.2	9.2	0.3	0.3
Saudi Arabia	446.0	176.9	74.4	86.3	104.4	102.3	4.0	4.0
Syrian Arab Republic	57.8	27.6	1.5	8.8	12.2	12.0	7.7	4.4
United Arab Emirates	154.0	58.4	2.1	67.2	25.7	25.7	0.6	0.6
Yemen	21.7	5.1	3.3	0.9	6.2	6.2	6.2	1.9
Middle East	**1 546.3**	**555.4**	**160.9**	**322.6**	**337.8**	**334.1**	**169.6**	**127.4**

CO_2 emissions with electricity and heat allocated to consuming sectors * in 2010

million tonnes of CO_2

	Total CO_2 emissions from fuel combustion	Other energy industry own use **	Manufacturing industries and construction	Transport	*of which: road*	Other sectors	*of which: residential*
World * **	**30 276.1**	**2 175.7**	**11 166.7**	**6 912.9**	**4 972.1**	**10 020.8**	**5 376.3**
Annex I Parties	*13 398.1*	*956.1*	*3 653.4*	*3 445.5*	*2 908.3*	*5 343.1*	*2 907.1*
Annex II Parties	*10 519.3*	*686.3*	*2 632.0*	*2 957.9*	*2 582.9*	*4 243.1*	*2 183.1*
North America	*5 905.3*	*394.8*	*1 271.4*	*1 796.7*	*1 540.1*	*2 442.4*	*1 231.3*
Europe	*3 056.6*	*198.5*	*830.5*	*830.3*	*760.4*	*1 197.3*	*683.9*
Asia Oceania	*1 557.4*	*92.9*	*530.1*	*330.9*	*282.3*	*603.4*	*267.9*
Annex I EIT	*2 610.5*	*257.7*	*920.6*	*442.7*	*285.9*	*989.4*	*660.1*
Non-Annex I Parties	*15 779.0*	*1 219.6*	*7 513.2*	*2 368.4*	*2 063.8*	*4 677.7*	*2 469.3*
Annex I Kyoto Parties	*7 695.8*	*611.8*	*2 399.8*	*1 766.5*	*1 462.1*	*2 917.7*	*1 665.4*
Non-OECD Total	**16 736.8**	**1 284.1**	**8 205.7**	**2 425.5**	**2 004.5**	**4 821.6**	**2 659.6**
OECD Total	**12 440.3**	**845.3**	**3 281.9**	**3 369.2**	**2 967.6**	**4 943.8**	**2 548.2**
Canada	536.6	69.4	139.7	170.5	139.6	157.0	72.4
Chile	69.7	2.6	31.5	21.4	18.7	14.2	7.6
Mexico	416.9	59.8	120.7	152.1	147.3	84.4	47.2
United States	5 368.6	325.4	1 131.6	1 626.1	1 400.5	2 285.4	1 158.9
OECD Americas	**6 391.9**	**457.2**	**1 423.6**	**1 970.2**	**1 706.2**	**2 541.0**	**1 286.1**
Australia	383.5	40.5	120.7	85.9	69.1	136.3	65.9
Israel	68.1	3.4	13.7	11.9	11.9	39.0	15.2
Japan	1 143.1	50.6	400.9	231.4	201.1	460.1	199.2
Korea	563.1	41.8	238.4	88.0	81.8	195.0	77.7
New Zealand	30.9	1.7	8.5	13.6	12.2	7.0	2.8
OECD Asia Oceania	**2 188.6**	**138.1**	**782.2**	**430.8**	**376.0**	**837.4**	**360.8**
Austria	69.3	7.7	18.7	22.6	21.2	20.4	13.0
Belgium	106.4	6.7	35.1	25.3	24.2	39.4	23.5
Czech Republic	114.5	6.9	40.8	18.2	15.9	48.5	28.2
Denmark	47.0	2.6	7.4	13.0	11.9	24.0	13.7
Estonia	18.5	0.8	3.6	2.3	2.0	11.8	6.8
Finland	62.9	3.9	24.0	12.7	11.5	22.3	11.6
France	357.8	19.3	75.1	125.0	118.3	138.4	74.4
Germany	761.6	33.9	244.5	153.6	141.0	329.5	194.9
Greece	84.3	5.0	18.7	21.9	18.7	38.7	20.5
Hungary	48.9	2.5	10.2	12.0	11.4	24.2	14.3
Iceland	1.9	0.0	0.5	0.8	0.8	0.6	0.0
Ireland	38.7	0.5	7.0	11.5	11.2	19.6	11.6
Italy	398.5	28.8	113.8	112.0	101.9	143.8	79.4
Luxembourg	10.6	-	1.8	6.5	6.5	2.3	1.2
Netherlands	187.0	15.1	63.9	34.1	32.5	73.9	32.3
Norway	39.2	11.3	8.6	14.1	10.4	5.2	1.5
Poland	305.1	23.9	75.4	49.0	45.7	156.8	96.0
Portugal	48.2	3.1	13.0	18.5	17.4	13.6	6.1
Slovak Republic	35.0	5.2	10.8	7.0	5.9	12.1	5.8
Slovenia	15.3	0.1	4.6	5.2	5.1	5.4	3.1
Spain	268.3	19.7	70.1	98.6	85.1	79.9	40.3
Sweden	47.6	2.7	12.6	21.7	20.4	10.6	4.9
Switzerland	43.8	1.0	6.7	17.2	16.7	19.0	12.3
Turkey	265.9	12.1	100.2	44.3	39.0	109.3	63.2
United Kingdom	483.5	37.2	109.0	121.3	110.7	216.1	142.8
OECD Europe	**3 859.8**	**250.0**	**1 076.1**	**968.3**	**885.4**	**1 565.4**	**901.3**
European Union - 27	*3 659.5*	*239.2*	*1 005.9*	*924.6*	*848.2*	*1 489.9*	*859.8*

* CO_2 emissions from electricity and heat generation have been allocated to final consuming sectors in proportion to the electricity and heat consumed. The detailed unallocated emissions are shown in the table on pages 69-71.
** Includes emissions from own use in petroleum refining, the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries.
*** World includes international bunkers in the transport sector.

CO_2 emissions with electricity and heat allocated to consuming sectors in 2010

million tonnes of CO_2

	Total CO_2 emissions from fuel combustion	Other energy industry own use	Manufacturing industries and construction	Transport	*of which: road*	Other sectors	*of which: residential*
Non-OECD Total	**16 736.8**	**1 284.1**	**8 205.7**	**2 425.5**	**2 004.5**	**4 821.6**	**2 659.6**
Albania	3.8	0.1	0.8	2.3	2.2	0.6	0.2
Armenia	4.0	-	0.7	1.3	1.3	2.1	1.1
Azerbaijan	24.7	3.4	3.3	5.4	4.5	12.6	9.0
Belarus	65.3	6.8	21.3	8.0	6.1	29.3	19.0
Bosnia and Herzegovina	19.9	0.8	5.7	3.4	3.2	10.0	6.7
Bulgaria	43.8	3.2	13.8	8.0	7.2	18.9	11.2
Croatia	19.0	1.9	4.4	6.0	5.6	6.6	4.0
Cyprus	7.2	0.0	1.1	2.2	2.2	3.9	1.6
Georgia	4.9	0.2	0.9	2.1	2.0	1.6	1.2
Gibraltar	0.5	-	0.1	0.3	0.3	0.1	-
Kazakhstan	232.1	53.8	91.0	14.5	11.8	72.8	28.3
Kosovo	8.5	0.0	2.3	1.0	1.0	5.2	3.8
Kyrgyzstan	7.0	0.0	2.4	2.6	2.6	1.9	0.2
Latvia	8.1	-	1.5	3.2	2.9	3.4	1.8
Lithuania	13.4	2.0	3.1	4.3	4.0	4.0	2.3
FYR of Macedonia	8.2	0.3	2.7	1.3	1.3	3.9	2.5
Malta	2.5	-	0.6	0.5	0.5	1.4	0.6
Republic of Moldova	6.1	0.1	0.8	1.0	1.0	4.1	3.1
Montenegro	2.1	0.1	1.0	0.2	-	0.8	0.7
Romania	75.6	8.4	25.6	14.5	12.8	27.1	18.0
Russian Federation	1 581.4	175.8	589.5	271.8	139.9	544.3	372.8
Serbia	46.0	1.1	14.8	6.7	5.5	23.4	16.7
Tajikistan	2.7	0.0	0.2	0.3	0.3	2.2	0.1
Turkmenistan	52.7	10.1	7.2	4.6	2.4	30.8	2.4
Ukraine	266.6	20.2	116.1	33.3	21.3	97.0	76.9
Uzbekistan	100.2	4.0	25.4	8.6	4.7	62.2	31.2
Non-OECD Europe and Eurasia	**2 606.3**	**292.4**	**936.4**	**407.3**	**246.8**	**970.3**	**615.4**
Algeria	98.6	11.6	22.0	33.8	29.7	31.2	21.7
Angola	16.6	0.3	3.4	7.5	6.8	5.5	2.9
Benin	4.5	-	0.2	3.1	3.1	1.2	1.2
Botswana	4.6	-	1.7	2.0	2.0	0.9	0.4
Cameroon	5.0	0.4	1.1	2.7	2.5	0.9	0.6
Congo	1.7	-	0.1	1.4	1.4	0.1	0.1
Dem. Rep. of Congo	3.1	-	1.1	0.7	0.7	1.2	0.3
Côte d'Ivoire	5.8	0.2	1.1	1.3	1.0	3.2	1.6
Egypt	177.6	14.8	54.9	38.4	35.4	69.4	42.3
Eritrea	0.5	-	0.1	0.1	0.1	0.3	0.1
Ethiopia	5.4	-	1.3	2.7	2.7	1.3	0.8
Gabon	2.7	0.0	1.2	0.6	0.6	0.8	0.5
Ghana	9.5	0.1	2.4	4.9	4.5	2.1	1.4
Kenya	10.9	0.2	3.5	4.7	4.5	2.4	1.5
Libya	51.6	3.1	10.9	12.1	12.1	25.6	9.8
Morocco	46.0	1.3	13.5	10.7	10.6	20.5	9.3
Mozambique	2.5	0.0	0.5	1.7	1.5	0.4	0.1
Namibia	3.3	-	0.3	1.8	1.7	1.2	-
Nigeria	45.9	5.8	5.5	19.0	15.5	15.6	7.8
Senegal	5.5	0.0	1.4	2.0	1.9	2.0	1.1
South Africa	346.8	14.4	173.6	42.0	35.5	116.8	53.2
Sudan	13.7	0.5	2.6	6.8	6.7	3.8	2.2
United Rep. of Tanzania	6.0	0.1	1.6	3.0	3.0	1.3	1.2
Togo	1.2	-	0.1	0.9	0.9	0.2	0.2
Tunisia	21.9	0.1	7.9	6.1	6.0	7.9	3.6
Zambia	1.9	0.1	0.8	0.7	0.4	0.4	0.0
Zimbabwe	9.1	0.1	3.5	1.2	1.1	4.3	1.7
Other Africa	27.9	0.2	5.4	12.4	10.9	10.0	5.3
Africa	**929.7**	**53.2**	**321.8**	**224.4**	**203.0**	**330.4**	**170.8**

CO_2 emissions with electricity and heat allocated to consuming sectors in 2010

million tonnes of CO_2

	Total CO_2 emissions from fuel combustion	Other energy industry own use	Manufacturing industries and construction	Transport	*of which: road*	Other sectors	*of which: residential*
Bangladesh	53.0	0.2	23.1	8.4	6.4	21.2	13.8
Brunei Darussalam	8.2	1.8	2.8	1.2	1.2	2.4	1.1
Cambodia	3.8	-	0.8	1.9	1.5	1.0	0.8
Chinese Taipei	270.2	15.9	144.7	36.3	34.3	73.3	34.3
India	1 625.8	61.1	797.1	178.0	144.7	589.7	263.5
Indonesia	410.9	29.2	166.6	105.8	92.8	109.3	65.7
DPR of Korea	63.0	0.0	44.8	0.9	0.9	17.3	0.1
Malaysia	185.0	10.5	75.5	42.6	42.2	56.3	20.4
Mongolia	11.9	0.0	4.2	1.5	1.0	6.1	4.0
Myanmar	8.0	0.7	3.2	2.3	1.8	1.8	0.9
Nepal	3.7	-	0.8	1.9	1.9	1.0	0.4
Pakistan	134.6	1.4	53.5	32.7	31.6	47.1	31.7
Philippines	76.4	1.7	23.6	23.6	20.6	27.5	13.6
Singapore	62.9	6.0	33.6	9.0	8.0	14.4	4.0
Sri Lanka	13.3	0.0	2.6	6.9	6.5	3.7	2.0
Thailand	248.5	15.5	112.6	55.4	54.9	65.0	22.6
Vietnam	130.5	3.1	65.9	30.2	29.5	31.3	22.0
Other Asia	20.9	0.5	6.0	8.0	6.8	6.5	2.2
Asia	**3 330.6**	**147.8**	**1 561.5**	**546.4**	**486.4**	**1 074.8**	**502.9**
People's Rep. of China	7 217.1	489.3	4 607.4	540.0	395.3	1 580.4	865.3
Hong Kong, China	41.5	-	7.8	5.6	5.6	28.1	8.0
China	**7 258.5**	**489.3**	**4 615.2**	**545.6**	**400.9**	**1 608.5**	**873.3**
Argentina	170.2	17.1	49.8	41.6	38.0	61.8	35.5
Bolivia	14.1	1.2	2.4	6.8	6.5	3.7	2.2
Brazil	387.7	27.2	133.8	166.2	148.2	60.4	27.6
Colombia	60.7	6.7	17.9	21.6	20.6	14.5	7.8
Costa Rica	6.5	0.1	1.1	4.5	4.5	0.8	0.3
Cuba	30.0	0.4	13.7	1.7	1.3	14.3	9.1
Dominican Republic	18.6	0.0	5.4	5.2	4.2	7.9	5.2
Ecuador	30.1	1.1	6.3	14.6	12.3	8.0	5.3
El Salvador	5.9	0.0	1.9	2.5	2.5	1.4	1.0
Guatemala	10.3	0.1	2.4	5.6	5.6	2.2	1.5
Haiti	2.1	-	0.6	1.1	0.4	0.4	0.3
Honduras	7.3	-	1.9	3.0	3.0	2.5	1.1
Jamaica	8.0	0.2	0.9	2.8	1.4	4.0	1.2
Netherlands Antilles	3.8	0.8	1.2	1.2	1.2	0.6	0.2
Nicaragua	4.5	0.1	1.1	1.7	1.6	1.6	0.7
Panama	8.4	-	2.2	3.5	3.5	2.7	1.2
Paraguay	4.7	-	0.2	4.3	4.2	0.3	0.2
Peru	41.9	3.9	14.1	16.3	15.4	7.6	4.2
Trinidad and Tobago	42.8	8.7	28.2	3.1	3.1	2.8	2.1
Uruguay	6.4	0.6	1.1	3.0	2.9	1.8	0.8
Venezuela	183.0	50.4	61.3	48.3	48.2	23.0	14.1
Other Non-OECD Americas	18.4	0.0	3.7	5.2	4.6	9.5	4.2
Non-OECD Americas	**1 065.4**	**118.7**	**351.0**	**363.7**	**333.3**	**231.9**	**125.9**
Bahrain	23.6	4.5	7.8	3.6	3.6	7.7	4.4
Islamic Rep. of Iran	509.0	31.5	140.1	118.9	117.4	218.6	143.0
Iraq	104.5	4.0	16.6	29.7	29.7	54.2	34.2
Jordan	18.6	0.7	4.4	5.2	5.1	8.4	4.7
Kuwait	87.4	18.9	15.0	11.7	11.7	41.8	27.4
Lebanon	18.6	-	4.2	5.0	5.0	9.4	5.4
Oman	40.3	7.9	10.0	6.3	6.3	16.1	8.7
Qatar	64.9	20.3	25.6	9.2	9.2	9.8	3.4
Saudi Arabia	446.0	88.2	104.2	104.4	102.3	149.1	94.5
Syrian Arab Republic	57.8	1.5	18.1	12.2	12.0	26.0	17.0
United Arab Emirates	154.0	2.1	72.8	25.7	25.7	53.4	23.3
Yemen	21.7	3.3	0.9	6.2	6.2	11.2	5.3
Middle East	**1 546.3**	**182.8**	**419.8**	**338.0**	**334.1**	**605.7**	**371.3**

Total primary energy supply

petajoules

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World *	231 428	259 118	302 052	324 001	367 298	386 656	419 055	479 455	513 426	509 603	534 434	45.5%
Annex I Parties	..	..	..	..	233 722	229 465	241 484	250 834	249 028	235 948	245 230	4.9%
Annex II Parties	130 359	138 423	153 297	154 085	167 903	180 342	194 917	201 276	197 316	187 892	193 303	15.1%
North America	72 382	76 179	83 622	82 358	88 908	96 212	105 707	108 482	106 419	101 141	103 337	16.2%
Europe	44 325	46 578	51 959	53 014	56 452	58 854	62 241	65 512	64 226	60 980	63 180	11.9%
Asia Oceania	13 651	15 666	17 715	18 712	22 543	25 276	26 969	27 281	26 670	25 771	26 786	18.8%
Annex I EIT	..	..	..	..	63 581	46 516	43 343	45 988	47 553	43 933	47 491	-25.3%
Non-Annex I Parties	..	..	..	..	125 186	147 609	166 185	215 334	249 937	259 706	274 312	119.1%
Annex I Kyoto Parties	..	..	..	..	149 400	139 272	142 046	149 053	148 356	140 062	146 839	-1.7%
Intl. marine bunkers	4 525	4 362	4 577	3 920	4 783	5 529	6 439	7 441	8 144	7 908	8 459	76.9%
Intl. aviation bunkers	2 366	2 428	2 822	3 137	3 608	4 053	4 946	5 846	6 316	6 041	6 433	78.3%
Non-OECD Total **	83 346	100 867	124 322	144 310	169 560	173 048	186 081	235 260	269 812	276 697	293 209	72.9%
OECD Total ***	141 192	151 462	170 330	172 634	189 348	204 026	221 588	230 908	229 154	218 957	226 333	19.5%
Canada	5 918	6 948	8 064	8 080	8 731	9 662	10 527	11 396	11 084	10 498	10 544	20.8%
Chile	364	320	397	401	587	768	1 054	1 187	1 269	1 234	1 295	120.7%
Mexico	1 800	2 477	3 982	4 547	5 129	5 435	6 076	7 124	7 582	7 312	7 457	45.4%
United States	66 464	69 231	75 558	74 278	80 177	86 550	95 180	97 086	95 335	90 643	92 793	15.7%
OECD Americas	74 546	78 975	88 002	87 307	94 623	102 415	112 837	116 793	115 270	109 688	112 089	18.5%
Australia	2 161	2 528	2 914	3 049	3 610	3 875	4 526	4 782	5 202	5 274	5 222	44.7%
Israel	240	294	328	317	480	650	764	774	958	901	959	99.7%
Japan	11 201	12 772	14 424	15 194	18 394	20 777	21 728	21 794	20 739	19 766	20 802	13.1%
Korea	711	1 024	1 725	2 241	3 897	6 061	7 878	8 800	9 502	9 595	10 467	168.6%
New Zealand	289	366	376	469	539	623	714	705	729	731	762	41.4%
OECD Asia Oceania	14 602	16 984	19 768	21 270	26 920	31 986	35 611	36 855	37 130	36 268	38 213	41.9%
Austria	788	842	969	967	1 040	1 121	1 196	1 414	1 405	1 330	1 417	36.2%
Belgium	1 660	1 772	1 958	1 846	2 022	2 251	2 450	2 457	2 453	2 391	2 548	26.0%
Czech Republic	1 900	1 828	1 966	2 061	2 075	1 737	1 716	1 882	1 879	1 761	1 847	-11.0%
Denmark	775	732	801	808	727	812	780	791	804	768	806	10.9%
Estonia	..	..	..	..	415	211	197	216	228	199	233	-43.8%
Finland	761	825	1 030	1 082	1 188	1 211	1 349	1 434	1 477	1 392	1 524	28.3%
France	6 639	6 907	8 029	8 533	9 374	9 909	10 545	11 331	11 086	10 613	10 981	17.2%
Germany	12 772	13 126	14 954	14 956	14 702	14 089	14 092	14 162	13 988	13 277	13 707	-6.8%
Greece	364	492	627	735	898	949	1 134	1 266	1 274	1 232	1 156	28.8%
Hungary	797	959	1 187	1 246	1 204	1 083	1 047	1 155	1 108	1 041	1 075	-10.7%
Iceland	38	46	63	74	87	94	130	146	224	225	225	157.1%
Ireland	281	278	345	361	418	445	575	606	626	603	603	44.1%
Italy	4 413	4 889	5 478	5 414	6 136	6 662	7 181	7 698	7 369	6 902	7 128	16.2%
Luxembourg	170	158	149	128	143	132	139	184	176	165	177	24.0%
Netherlands	2 130	2 471	2 695	2 539	2 750	2 962	3 066	3 300	3 331	3 273	3 493	27.0%
Norway	557	611	767	836	879	981	1 092	1 120	1 248	1 179	1 359	54.5%
Poland	3 606	4 314	5 301	5 221	4 317	4 165	3 731	3 868	4 099	3 935	4 248	-1.6%
Portugal	263	322	418	459	701	846	1 033	1 108	1 023	1 011	986	40.6%
Slovak Republic	597	702	831	868	893	744	743	788	766	700	746	-16.5%
Slovenia	..	..	..	..	239	254	269	305	324	297	302	26.3%
Spain	1 784	2 407	2 834	2 969	3 772	4 220	5 107	5 940	5 821	5 336	5 348	41.8%
Sweden	1 509	1 634	1 695	1 977	1 976	2 107	1 991	2 159	2 077	1 901	2 147	8.7%
Switzerland	686	719	839	924	1 018	1 007	1 047	1 086	1 121	1 129	1 097	7.8%
Turkey	818	1 120	1 317	1 646	2 209	2 577	3 197	3 533	4 124	4 089	4 402	99.3%
United Kingdom	8 737	8 347	8 308	8 406	8 621	9 055	9 334	9 310	8 725	8 251	8 479	-1.7%
OECD Europe ***	52 044	55 502	62 561	64 057	67 804	69 625	73 140	77 259	76 754	73 002	76 031	12.1%
European Union - 27	..	..	..	..	68 500	68 546	70 544	74 512	73 247	69 247	71 774	4.8%

* Total world includes non-OECD total, OECD total as well as international marine bunkers and international aviation bunkers.
** Includes Estonia and Slovenia prior to 1990.
*** Excludes Estonia and Slovenia prior to 1990.

Total primary energy supply

petajoules

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**83 346**	**100 867**	**124 322**	**144 310**	**169 560**	**173 048**	**186 081**	**235 260**	**269 812**	**276 697**	**293 209**	**72.9%**
Albania	72	83	129	114	112	56	75	92	87	87	87	-22.3%
Armenia	..	..	..	..	322	68	84	105	125	109	102	-68.2%
Azerbaijan	..	..	..	..	1 095	534	479	580	556	489	496	-54.7%
Belarus	..	..	..	..	1 907	1 036	1 033	1 125	1 178	1 121	1 161	-39.1%
Bosnia and Herzegovina	..	..	..	..	294	63	182	211	249	253	268	-8.7%
Bulgaria	797	973	1 189	1 283	1 196	969	782	835	829	732	748	-37.5%
Croatia	..	..	..	..	377	294	325	372	379	364	357	-5.1%
Cyprus	25	24	36	39	57	73	89	93	108	106	102	79.7%
Georgia	..	..	..	..	520	156	120	119	126	130	131	-74.9%
Gibraltar	1	1	2	2	2	4	5	6	7	7	7	192.0%
Kazakhstan	..	..	..	..	3 075	2 187	1 494	2 127	2 939	2 651	3 140	2.1%
Kosovo **	..	..	..	..	..	..	62	78	88	99	102	..
Kyrgyzstan	..	..	..	..	313	100	101	111	114	126	122	-61.0%
Latvia	..	..	..	..	330	193	156	185	188	177	185	-44.0%
Lithuania	..	..	..	..	673	366	298	370	395	362	290	-56.9%
FYR of Macedonia	..	..	..	..	104	105	112	121	126	118	121	16.6%
Malta	9	9	13	14	29	30	28	37	35	34	35	20.5%
Republic of Moldova	..	..	..	..	413	184	105	129	119	103	109	-73.6%
Montenegro **	..	..	..	..	..	..	..	30	35	27	34	..
Romania	1 764	2 169	2 731	2 719	2 605	1 950	1 516	1 618	1 656	1 457	1 465	-43.8%
Russian Federation	..	..	..	..	36 810	26 655	25 927	27 286	28 825	27 085	29 371	-20.2%
Serbia **	..	..	..	..	810	569	557	672	706	638	654	-19.3%
Tajikistan	..	..	..	..	222	93	90	98	103	98	97	-56.5%
Turkmenistan	..	..	..	..	735	575	596	762	925	807	892	21.3%
Ukraine	..	..	..	..	10 541	6 859	5 602	5 982	5 700	4 703	5 464	-48.2%
Uzbekistan	..	..	..	..	1 941	1 782	2 124	1 967	2 114	1 881	1 833	-5.6%
Former Soviet Union ***	32 169	39 351	46 453	52 248	..	..	..	..	..	..	..	..
Former Yugoslavia ***	918	1 068	1 411	1 722	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**35 753**	**43 678**	**51 963**	**58 140**	**64 483**	**44 900**	**41 943**	**45 112**	**47 716**	**43 762**	**47 374**	**-26.5%**
Algeria	145	231	469	743	929	1 009	1 131	1 355	1 568	1 706	1 690	81.9%
Angola	161	173	191	209	246	268	314	393	497	528	572	132.4%
Benin	46	52	57	65	70	77	83	105	137	144	153	119.9%
Botswana	..	..	..	37	53	63	77	81	90	85	95	79.5%
Cameroon	113	127	153	187	209	230	264	292	268	289	298	42.7%
Congo	21	23	26	32	32	32	34	45	53	59	62	89.4%
Dem. Rep. of Congo	280	313	354	417	494	548	698	836	931	960	995	101.4%
Côte d'Ivoire	103	124	150	155	181	213	282	403	430	396	401	121.4%
Egypt	326	411	635	1 077	1 354	1 477	1 702	2 626	3 009	2 989	3 067	126.6%
Eritrea	..	..	..	..	..	42	30	32	28	30	31	..
Ethiopia	360	395	454	518	622	687	780	893	1 317	1 354	1 390	123.3%
Gabon	45	54	58	57	49	57	61	78	83	86	89	80.6%
Ghana	125	153	168	182	222	271	324	345	375	368	390	76.2%
Kenya	221	253	308	363	447	505	575	672	742	786	819	83.2%
Libya	66	153	288	418	474	661	694	735	805	919	802	69.0%
Morocco	102	143	204	234	291	360	429	547	628	632	691	137.8%
Mozambique	289	280	281	267	248	263	300	355	393	409	427	72.2%
Namibia	..	..	..	..	..	37	41	54	68	66	67	..
Nigeria	1 510	1 747	2 196	2 572	2 955	3 246	3 793	4 459	4 656	4 574	4 733	60.2%
Senegal	52	58	65	65	71	78	100	117	129	137	142	100.5%
South Africa	1 902	2 260	2 737	3 617	3 808	4 337	4 575	5 367	6 185	6 041	5 730	50.5%
Sudan	294	313	350	396	445	502	559	633	632	664	676	52.0%
United Rep. of Tanzania	317	321	336	367	407	461	561	719	794	812	841	106.3%
Togo	30	33	37	41	53	66	88	99	107	110	113	112.9%
Tunisia	69	91	137	174	207	243	306	348	395	379	403	94.7%
Zambia	147	163	188	206	226	244	261	302	320	329	340	50.3%
Zimbabwe	228	248	272	310	389	412	414	406	388	394	402	3.3%
Other Africa	1 102	1 201	1 373	1 535	1 751	1 968	2 279	2 655	2 948	3 038	3 128	78.7%
Africa	**8 055**	**9 321**	**11 488**	**14 243**	**16 233**	**18 356**	**20 756**	**24 953**	**27 976**	**28 284**	**28 547**	**75.9%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

Total primary energy supply

petajoules

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	238	282	352	417	533	666	779	998	1 164	1 232	1 300	143.8%
Brunei Darussalam	7	31	57	75	74	97	103	96	152	131	139	88.1%
Cambodia	..	..	..	..	..	119	143	144	147	205	210	..
Chinese Taipei	419	599	1 170	1 392	2 020	2 670	3 573	4 278	4 424	4 287	4 575	126.5%
India	6 551	7 441	8 589	10 667	13 261	16 089	19 143	22 578	26 213	28 269	29 002	118.7%
Indonesia	1 468	1 722	2 333	2 756	4 129	5 477	6 495	7 558	7 826	8 311	8 702	110.8%
DPR of Korea	813	932	1 271	1 507	1 391	920	826	893	844	803	776	-44.2%
Malaysia	255	308	498	649	902	1 419	1 972	2 659	3 057	2 925	3 042	237.1%
Mongolia	..	..	..	131	143	113	100	110	132	136	137	-4.1%
Myanmar	331	351	394	460	447	494	538	620	629	596	586	31.1%
Nepal	153	169	191	213	242	281	339	382	402	417	428	76.5%
Pakistan	713	851	1 039	1 351	1 786	2 248	2 658	3 162	3 417	3 520	3 542	98.3%
Philippines	641	764	938	995	1 198	1 404	1 669	1 623	1 675	1 595	1 695	41.4%
Singapore	114	155	215	283	482	788	784	940	998	1 150	1 372	184.6%
Sri Lanka	159	172	190	209	231	249	349	377	374	381	413	78.9%
Thailand	573	726	921	1 036	1 756	2 593	3 026	4 152	4 507	4 492	4 917	180.0%
Vietnam	554	582	603	668	748	916	1 203	1 736	2 051	2 238	2 480	231.5%
Other Asia	151	181	315	263	289	288	344	398	438	471	497	72.4%
Asia	**13 141**	**15 266**	**19 076**	**23 073**	**29 634**	**36 831**	**44 044**	**52 704**	**58 449**	**61 160**	**63 812**	**115.3%**
People's Rep. of China	16 400	20 266	25 057	28 973	36 130	43 846	45 840	71 024	88 655	95 711	102 814	184.6%
Hong Kong, China	126	152	194	275	362	446	561	530	592	625	577	59.3%
China	**16 526**	**20 418**	**25 251**	**29 248**	**36 493**	**44 292**	**46 401**	**71 555**	**89 247**	**96 336**	**103 391**	**183.3%**
Argentina	1 409	1 505	1 751	1 731	1 929	2 262	2 552	2 804	3 209	3 121	3 125	62.0%
Bolivia	43	62	102	106	109	156	156	217	249	260	307	180.5%
Brazil	2 921	3 815	4 767	5 416	5 871	6 746	7 846	9 012	10 398	10 059	11 121	89.4%
Colombia	580	646	741	837	1 014	1 156	1 081	1 134	1 223	1 290	1 350	33.1%
Costa Rica	47	55	64	70	85	98	124	162	192	191	195	129.3%
Cuba	450	503	627	654	741	463	538	450	440	489	460	-37.9%
Dominican Republic	98	129	144	153	172	247	327	321	343	339	349	103.4%
Ecuador	96	137	211	242	252	300	336	460	462	480	506	100.9%
El Salvador	73	95	105	110	103	141	166	189	188	177	176	69.8%
Guatemala	114	140	159	158	185	223	295	329	342	390	429	132.2%
Haiti	63	72	87	79	65	71	84	108	116	109	96	46.6%
Honduras	58	64	78	84	100	118	125	167	195	186	191	91.9%
Jamaica	84	112	95	72	117	134	160	157	179	136	128	9.6%
Netherlands Antilles	229	161	164	75	61	55	83	81	87	89	70	15.2%
Nicaragua	52	62	64	81	88	98	114	139	128	128	131	49.9%
Panama	70	71	59	65	62	83	108	120	130	144	158	153.0%
Paraguay	57	62	87	95	129	164	161	166	182	187	200	55.9%
Peru	382	434	471	443	408	459	512	571	630	663	812	99.3%
Trinidad and Tobago	110	97	160	213	251	257	447	702	810	849	894	256.5%
Uruguay	101	102	111	84	94	108	129	124	174	176	174	85.0%
Venezuela	824	1 053	1 490	1 661	1 833	2 171	2 377	2 802	2 938	2 935	3 222	75.8%
Other Non-OECD Americas	198	251	251	163	204	219	242	271	289	295	301	47.9%
Non-OECD Americas	**8 061**	**9 628**	**11 790**	**12 590**	**13 872**	**15 729**	**17 964**	**20 488**	**22 901**	**22 692**	**24 395**	**75.9%**
Bahrain	59	89	117	174	182	206	246	314	387	396	410	124.9%
Islamic Republic of Iran	695	1 115	1 594	2 252	2 903	4 238	5 149	7 205	8 533	8 913	8 724	200.5%
Iraq	173	255	404	578	825	1 446	1 086	1 125	1 191	1 360	1 583	91.8%
Jordan	21	32	64	110	137	180	204	280	296	312	302	120.0%
Kuwait	256	271	438	587	381	623	787	1 105	1 167	1 263	1 398	266.6%
Lebanon	77	91	104	98	82	185	205	210	227	276	270	230.2%
Oman	9	10	48	88	177	255	338	451	665	624	837	374.1%
Qatar	39	87	140	227	258	331	436	709	900	983	1 266	389.9%
Saudi Arabia	308	367	1 302	1 926	2 502	3 665	4 242	6 093	6 451	6 609	7 088	183.3%
Syrian Arab Republic	100	128	187	328	438	507	660	871	965	889	910	107.7%
United Arab Emirates	42	81	303	574	855	1 159	1 421	1 810	2 442	2 527	2 601	204.2%
Yemen	31	29	53	73	105	143	198	276	299	308	300	185.1%
Middle East	**1 810**	**2 556**	**4 753**	**7 015**	**8 846**	**12 939**	**14 974**	**20 449**	**23 523**	**24 462**	**25 689**	**190.4%**

Total primary energy supply

million tonnes of oil equivalent

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World *	**5 527.6**	**6 188.9**	**7 214.4**	**7 738.6**	**8 772.8**	**9 235.1**	**10 008.9**	**11 451.6**	**12 263.0**	**12 171.7**	**12 764.7**	**45.5%**
Annex I Parties	*..*	*..*	*..*	*..*	*5 582.3*	*5 480.7*	*5 767.8*	*5 991.1*	*5 947.9*	*5 635.5*	*5 857.2*	*4.9%*
Annex II Parties	*3 113.6*	*3 306.2*	*3 661.4*	*3 680.2*	*4 010.3*	*4 307.4*	*4 655.5*	*4 807.4*	*4 712.8*	*4 487.7*	*4 617.0*	*15.1%*
North America	*1 728.8*	*1 819.5*	*1 997.3*	*1 967.1*	*2 123.5*	*2 298.0*	*2 524.8*	*2 591.1*	*2 541.8*	*2 415.7*	*2 468.2*	*16.2%*
Europe	*1 058.7*	*1 112.5*	*1 241.0*	*1 266.2*	*1 348.3*	*1 405.7*	*1 486.6*	*1 564.7*	*1 534.0*	*1 456.5*	*1 509.0*	*11.9%*
Asia Oceania	*326.1*	*374.2*	*423.1*	*446.9*	*538.4*	*603.7*	*644.1*	*651.6*	*637.0*	*615.5*	*639.8*	*18.8%*
Annex I EIT	*..*	*..*	*..*	*..*	*1 518.6*	*1 111.0*	*1 035.2*	*1 098.4*	*1 135.8*	*1 049.3*	*1 134.3*	*-25.3%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*2 990.0*	*3 525.6*	*3 969.3*	*5 143.2*	*5 969.6*	*6 203.0*	*6 551.8*	*119.1%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*3 568.3*	*3 326.5*	*3 392.7*	*3 560.1*	*3 543.4*	*3 345.3*	*3 507.2*	*-1.7%*
Intl. marine bunkers	**108.1**	**104.2**	**109.3**	**93.6**	**114.2**	**132.1**	**153.8**	**177.7**	**194.5**	**188.9**	**202.0**	**76.9%**
Intl. aviation bunkers	**56.5**	**58.0**	**67.4**	**74.9**	**86.2**	**96.8**	**118.1**	**139.6**	**150.9**	**144.3**	**153.6**	**78.3%**
Non-OECD Total **	**1 990.7**	**2 409.2**	**2 969.4**	**3 446.8**	**4 049.9**	**4 133.2**	**4 444.5**	**5 619.1**	**6 444.3**	**6 608.8**	**7 003.2**	**72.9%**
OECD Total ***	**3 372.3**	**3 617.6**	**4 068.3**	**4 123.3**	**4 522.5**	**4 873.1**	**5 292.5**	**5 515.1**	**5 473.2**	**5 229.7**	**5 405.9**	**19.5%**
Canada	141.4	165.9	192.6	193.0	208.5	230.8	251.4	272.2	264.7	250.7	251.8	20.8%
Chile	8.7	7.6	9.5	9.6	14.0	18.3	25.2	28.4	30.3	29.5	30.9	120.7%
Mexico	43.0	59.2	95.1	108.6	122.5	129.8	145.1	170.2	181.1	174.6	178.1	45.4%
United States	1 587.5	1 653.5	1 804.7	1 774.1	1 915.0	2 067.2	2 273.3	2 318.9	2 277.0	2 165.0	2 216.3	15.7%
OECD Americas	**1 780.5**	**1 886.3**	**2 101.9**	**2 085.3**	**2 260.0**	**2 446.1**	**2 695.1**	**2 789.6**	**2 753.2**	**2 619.8**	**2 677.2**	**18.5%**
Australia	51.6	60.4	69.6	72.8	86.2	92.6	108.1	114.2	124.2	126.0	124.7	44.7%
Israel	5.7	7.0	7.8	7.6	11.5	15.5	18.2	18.5	22.9	21.5	22.9	99.7%
Japan	267.5	305.1	344.5	362.9	439.3	496.3	519.0	520.5	495.4	472.1	496.8	13.1%
Korea	17.0	24.5	41.2	53.5	93.1	144.8	188.2	210.2	226.9	229.2	250.0	168.6%
New Zealand	6.9	8.8	9.0	11.2	12.9	14.9	17.1	16.8	17.4	17.5	18.2	41.4%
OECD Asia Oceania	**348.8**	**405.7**	**472.1**	**508.0**	**643.0**	**764.0**	**850.5**	**880.3**	**886.8**	**866.2**	**912.7**	**41.9%**
Austria	18.8	20.1	23.2	23.1	24.8	26.8	28.6	33.8	33.5	31.8	33.8	36.2%
Belgium	39.7	42.3	46.8	44.1	48.3	53.8	58.5	58.7	58.6	57.1	60.9	26.0%
Czech Republic	45.4	43.7	46.9	49.2	49.6	41.5	41.0	44.9	44.9	42.1	44.1	-11.0%
Denmark	18.5	17.5	19.1	19.3	17.4	19.4	18.6	18.9	19.2	18.4	19.3	10.9%
Estonia	..	..	..	..	9.9	5.0	4.7	5.2	5.4	4.7	5.6	-43.8%
Finland	18.2	19.7	24.6	25.8	28.4	28.9	32.2	34.3	35.3	33.2	36.4	28.3%
France	158.6	165.0	191.8	203.8	223.9	236.7	251.9	270.6	264.8	253.5	262.3	17.2%
Germany	305.0	313.5	357.2	357.2	351.1	336.5	336.6	338.3	334.1	317.1	327.4	-6.8%
Greece	8.7	11.7	15.0	17.6	21.4	22.7	27.1	30.2	30.4	29.4	27.6	28.8%
Hungary	19.0	22.9	28.4	29.8	28.8	25.9	25.0	27.6	26.5	24.9	25.7	-10.7%
Iceland	0.9	1.1	1.5	1.8	2.1	2.3	3.1	3.5	5.4	5.4	5.4	157.1%
Ireland	6.7	6.6	8.2	8.6	10.0	10.6	13.7	14.5	15.0	14.4	14.4	44.1%
Italy	105.4	116.8	130.8	129.3	146.6	159.1	171.5	183.9	176.0	164.9	170.2	16.2%
Luxembourg	4.1	3.8	3.6	3.1	3.4	3.2	3.3	4.4	4.2	4.0	4.2	24.0%
Netherlands	50.9	59.0	64.4	60.6	65.7	70.7	73.2	78.8	79.6	78.2	83.4	27.0%
Norway	13.3	14.6	18.3	20.0	21.0	23.4	26.1	26.8	29.8	28.2	32.5	54.5%
Poland	86.1	103.0	126.6	124.7	103.1	99.5	89.1	92.4	97.9	94.0	101.5	-1.6%
Portugal	6.3	7.7	10.0	11.0	16.7	20.2	24.7	26.5	24.4	24.2	23.5	40.6%
Slovak Republic	14.3	16.8	19.8	20.7	21.3	17.8	17.7	18.8	18.3	16.7	17.8	-16.5%
Slovenia	..	..	..	..	5.7	6.1	6.4	7.3	7.7	7.1	7.2	26.3%
Spain	42.6	57.5	67.7	70.9	90.1	100.8	122.0	141.9	139.0	127.5	127.7	41.8%
Sweden	36.0	39.0	40.5	47.2	47.2	50.3	47.6	51.6	49.6	45.4	51.3	8.7%
Switzerland	16.4	17.2	20.0	22.1	24.3	24.1	25.0	25.9	26.8	27.0	26.2	7.8%
Turkey	19.5	26.8	31.4	39.3	52.8	61.5	76.3	84.4	98.5	97.7	105.1	99.3%
United Kingdom	208.7	199.4	198.4	200.8	205.9	216.3	222.9	222.4	208.4	197.1	202.5	-1.7%
OECD Europe ***	**1 243.0**	**1 325.7**	**1 494.2**	**1 530.0**	**1 619.5**	**1 663.0**	**1 746.9**	**1 845.3**	**1 833.2**	**1 743.6**	**1 816.0**	**12.1%**
European Union - 27	*..*	*..*	*..*	*..*	*1 636.1*	*1 637.2*	*1 684.9*	*1 779.7*	*1 749.5*	*1 653.9*	*1 714.3*	*4.8%*

* Total world includes non-OECD total, OECD total as well as international marine bunkers and international aviation bunkers.
** Includes Estonia and Slovenia prior to 1990.
*** Excludes Estonia and Slovenia prior to 1990.

Total primary energy supply

million tonnes of oil equivalent

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**1 990.7**	**2 409.2**	**2 969.4**	**3 446.8**	**4 049.9**	**4 133.2**	**4 444.5**	**5 619.1**	**6 444.3**	**6 608.8**	**7 003.2**	**72.9%**
Albania	1.7	2.0	3.1	2.7	2.7	1.3	1.8	2.2	2.1	2.1	2.1	-22.3%
Armenia	..	..	..	..	7.7	1.6	2.0	2.5	3.0	2.6	2.4	-68.2%
Azerbaijan	..	..	..	..	26.1	12.8	11.4	13.8	13.3	11.7	11.8	-54.7%
Belarus	..	..	..	..	45.5	24.7	24.7	26.9	28.1	26.8	27.7	-39.1%
Bosnia and Herzegovina	..	..	..	..	7.0	1.5	4.3	5.0	6.0	6.0	6.4	-8.7%
Bulgaria	19.0	23.2	28.4	30.6	28.6	23.1	18.7	19.9	19.8	17.5	17.9	-37.5%
Croatia	..	..	..	..	9.0	7.0	7.8	8.9	9.1	8.7	8.5	-5.1%
Cyprus	0.6	0.6	0.9	0.9	1.4	1.7	2.1	2.2	2.6	2.5	2.4	79.7%
Georgia	..	..	..	..	12.4	3.7	2.9	2.8	3.0	3.1	3.1	-74.9%
Gibraltar	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	192.0%
Kazakhstan	..	..	..	..	73.4	52.2	35.7	50.8	70.2	63.3	75.0	2.1%
Kosovo **	..	..	..	..	..	..	1.5	1.9	2.1	2.4	2.4	..
Kyrgyzstan	..	..	..	..	7.5	2.4	2.4	2.7	2.7	3.0	2.9	-61.0%
Latvia	..	..	..	..	7.9	4.6	3.7	4.4	4.5	4.2	4.4	-44.0%
Lithuania	..	..	..	..	16.1	8.7	7.1	8.8	9.4	8.6	6.9	-56.9%
FYR of Macedonia	..	..	..	..	2.5	2.5	2.7	2.9	3.0	2.8	2.9	16.6%
Malta	0.2	0.2	0.3	0.3	0.7	0.7	0.7	0.9	0.8	0.8	0.8	20.5%
Republic of Moldova	..	..	..	..	9.9	4.4	2.5	3.1	2.9	2.4	2.6	-73.6%
Montenegro **	..	..	..	..	..	..	..	0.7	0.8	0.7	0.8	..
Romania	42.1	51.8	65.2	64.9	62.2	46.6	36.2	38.7	39.6	34.8	35.0	-43.8%
Russian Federation	..	..	..	..	879.2	636.6	619.3	651.7	688.5	646.9	701.5	-20.2%
Serbia **	..	..	..	..	19.3	13.6	13.3	16.1	16.9	15.2	15.6	-19.3%
Tajikistan	..	..	..	..	5.3	2.2	2.1	2.3	2.5	2.3	2.3	-56.5%
Turkmenistan	..	..	..	..	17.6	13.7	14.2	18.2	22.1	19.3	21.3	21.3%
Ukraine	..	..	..	..	251.8	163.8	133.8	142.9	136.1	112.3	130.5	-48.2%
Uzbekistan	..	..	..	..	46.4	42.6	50.7	47.0	50.5	44.9	43.8	-5.6%
Former Soviet Union ***	768.3	939.9	1 109.5	1 247.9	..	..	..	..	..	..	..	..
Former Yugoslavia ***	21.9	25.5	33.7	41.1	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**853.9**	**1 043.2**	**1 241.1**	**1 388.7**	**1 540.2**	**1 072.4**	**1 001.8**	**1 077.5**	**1 139.7**	**1 045.2**	**1 131.5**	**-26.5%**
Algeria	3.5	5.5	11.2	17.7	22.2	24.1	27.0	32.4	37.4	40.7	40.4	81.9%
Angola	3.9	4.1	4.6	5.0	5.9	6.4	7.5	9.4	11.9	12.6	13.7	132.4%
Benin	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.5	3.3	3.4	3.7	119.9%
Botswana	..	..	..	0.9	1.3	1.5	1.8	1.9	2.2	2.0	2.3	79.5%
Cameroon	2.7	3.0	3.7	4.5	5.0	5.5	6.3	7.0	6.4	6.9	7.1	42.7%
Congo	0.5	0.6	0.6	0.8	0.8	0.8	0.8	1.1	1.3	1.4	1.5	89.4%
Dem. Rep. of Congo	6.7	7.5	8.5	10.0	11.8	13.1	16.7	20.0	22.2	22.9	23.8	101.4%
Côte d'Ivoire	2.5	3.0	3.6	3.7	4.3	5.1	6.7	9.6	10.3	9.5	9.6	121.4%
Egypt	7.8	9.8	15.2	25.7	32.3	35.3	40.7	62.7	71.9	71.4	73.3	126.6%
Eritrea	..	..	..	..	..	1.0	0.7	0.8	0.7	0.7	0.7	..
Ethiopia	8.6	9.4	10.8	12.4	14.9	16.4	18.6	21.3	31.5	32.3	33.2	123.3%
Gabon	1.1	1.3	1.4	1.4	1.2	1.4	1.5	1.9	2.0	2.1	2.1	80.6%
Ghana	3.0	3.7	4.0	4.4	5.3	6.5	7.7	8.2	9.0	8.8	9.3	76.2%
Kenya	5.3	6.0	7.4	8.7	10.7	12.1	13.7	16.0	17.7	18.8	19.6	83.2%
Libya	1.6	3.7	6.9	10.0	11.3	15.8	16.6	17.6	19.2	21.9	19.1	69.0%
Morocco	2.4	3.4	4.9	5.6	6.9	8.6	10.2	13.1	15.0	15.1	16.5	137.8%
Mozambique	6.9	6.7	6.7	6.4	5.9	6.3	7.2	8.5	9.4	9.8	10.2	72.2%
Namibia	..	..	..	..	..	0.9	1.0	1.3	1.6	1.6	1.6	..
Nigeria	36.1	41.7	52.5	61.4	70.6	77.5	90.6	106.5	111.2	109.2	113.1	60.2%
Senegal	1.2	1.4	1.6	1.6	1.7	1.9	2.4	2.8	3.1	3.3	3.4	100.5%
South Africa	45.4	54.0	65.4	86.4	91.0	103.6	109.3	128.2	147.7	144.3	136.9	50.5%
Sudan	7.0	7.5	8.4	9.5	10.6	12.0	13.3	15.1	15.1	15.9	16.2	52.0%
United Rep. of Tanzania	7.6	7.7	8.0	8.8	9.7	11.0	13.4	17.2	19.0	19.4	20.1	106.3%
Togo	0.7	0.8	0.9	1.0	1.3	1.6	2.1	2.4	2.6	2.6	2.7	112.9%
Tunisia	1.7	2.2	3.3	4.2	4.9	5.8	7.3	8.3	9.4	9.0	9.6	94.7%
Zambia	3.5	3.9	4.5	4.9	5.4	5.8	6.2	7.2	7.6	7.9	8.1	50.3%
Zimbabwe	5.4	5.9	6.5	7.4	9.3	9.8	9.9	9.7	9.3	9.4	9.6	3.3%
Other Africa	26.3	28.7	32.8	36.7	41.8	47.0	54.4	63.4	70.4	72.6	74.7	78.7%
Africa	**192.4**	**222.6**	**274.4**	**340.2**	**387.7**	**438.4**	**495.7**	**596.0**	**668.2**	**675.5**	**681.8**	**75.9%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

Total primary energy supply

million tonnes of oil equivalent

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	5.7	6.7	8.4	9.9	12.7	15.9	18.6	23.8	27.8	29.4	31.1	143.8%
Brunei Darussalam	0.2	0.7	1.4	1.8	1.8	2.3	2.5	2.3	3.6	3.1	3.3	88.1%
Cambodia	..	..	..	..	..	2.8	3.4	3.4	3.5	4.9	5.0	..
Chinese Taipei	10.0	14.3	27.9	33.2	48.3	63.8	85.3	102.2	105.7	102.4	109.3	126.5%
India	156.5	177.7	205.2	254.8	316.7	384.3	457.2	539.3	626.1	675.2	692.7	118.7%
Indonesia	35.1	41.1	55.7	65.8	98.6	130.8	155.1	180.5	186.9	198.5	207.8	110.8%
DPR of Korea	19.4	22.3	30.4	36.0	33.2	22.0	19.7	21.3	20.2	19.2	18.5	-44.2%
Malaysia	6.1	7.3	11.9	15.5	21.5	33.9	47.1	63.5	73.0	69.9	72.6	237.1%
Mongolia	..	..	..	3.1	3.4	2.7	2.4	2.6	3.2	3.3	3.3	-4.1%
Myanmar	7.9	8.4	9.4	11.0	10.7	11.8	12.8	14.8	15.0	14.2	14.0	31.1%
Nepal	3.7	4.0	4.6	5.1	5.8	6.7	8.1	9.1	9.6	10.0	10.2	76.5%
Pakistan	17.0	20.3	24.8	32.3	42.7	53.7	63.5	75.5	81.6	84.1	84.6	98.3%
Philippines	15.3	18.2	22.4	23.8	28.6	33.5	39.9	38.8	40.0	38.1	40.5	41.4%
Singapore	2.7	3.7	5.1	6.8	11.5	18.8	18.7	22.5	23.8	27.5	32.8	184.6%
Sri Lanka	3.8	4.1	4.5	5.0	5.5	5.9	8.3	9.0	8.9	9.1	9.9	78.9%
Thailand	13.7	17.3	22.0	24.7	41.9	61.9	72.3	99.2	107.7	107.3	117.4	180.0%
Vietnam	13.2	13.9	14.4	16.0	17.9	21.9	28.7	41.5	49.0	53.4	59.2	231.5%
Other Asia	3.6	4.3	7.5	6.3	6.9	6.9	8.2	9.5	10.5	11.2	11.9	72.4%
Asia	**313.9**	**364.6**	**455.6**	**551.1**	**707.8**	**879.7**	**1 052.0**	**1 258.8**	**1 396.0**	**1 460.8**	**1 524.1**	**115.3%**
People's Rep. of China	391.7	484.0	598.5	692.0	863.0	1 047.2	1 094.9	1 696.4	2 117.5	2 286.0	2 455.7	184.6%
Hong Kong, China	3.0	3.6	4.6	6.6	8.7	10.6	13.4	12.7	14.1	14.9	13.8	59.3%
China	**394.7**	**487.7**	**603.1**	**698.6**	**871.6**	**1 057.9**	**1 108.3**	**1 709.1**	**2 131.6**	**2 300.9**	**2 469.5**	**183.3%**
Argentina	33.7	35.9	41.8	41.3	46.1	54.0	61.0	67.0	76.7	74.5	74.6	62.0%
Bolivia	1.0	1.5	2.4	2.5	2.6	3.7	3.7	5.2	5.9	6.2	7.3	180.5%
Brazil	69.8	91.1	113.9	129.4	140.2	161.1	187.4	215.2	248.3	240.3	265.6	89.4%
Colombia	13.9	15.4	17.7	20.0	24.2	27.6	25.8	27.1	29.2	30.8	32.2	33.1%
Costa Rica	1.1	1.3	1.5	1.7	2.0	2.3	3.0	3.9	4.6	4.6	4.6	129.3%
Cuba	10.7	12.0	15.0	15.6	17.7	11.1	12.9	10.8	10.5	11.7	11.0	-37.9%
Dominican Republic	2.3	3.1	3.4	3.6	4.1	5.9	7.8	7.7	8.2	8.1	8.3	103.4%
Ecuador	2.3	3.3	5.0	5.8	6.0	7.2	8.0	11.0	11.0	11.5	12.1	100.9%
El Salvador	1.8	2.3	2.5	2.6	2.5	3.4	4.0	4.5	4.5	4.2	4.2	69.8%
Guatemala	2.7	3.3	3.8	3.8	4.4	5.3	7.0	7.9	8.2	9.3	10.3	132.2%
Haiti	1.5	1.7	2.1	1.9	1.6	1.7	2.0	2.6	2.8	2.6	2.3	46.6%
Honduras	1.4	1.5	1.9	2.0	2.4	2.8	3.0	4.0	4.6	4.5	4.6	91.9%
Jamaica	2.0	2.7	2.3	1.7	2.8	3.2	3.8	3.8	4.3	3.3	3.1	9.6%
Netherlands Antilles	5.5	3.8	3.9	1.8	1.5	1.3	2.0	1.9	2.1	2.1	1.7	15.2%
Nicaragua	1.2	1.5	1.5	1.9	2.1	2.3	2.7	3.3	3.0	3.0	3.1	49.9%
Panama	1.7	1.7	1.4	1.6	1.5	2.0	2.6	2.9	3.1	3.4	3.8	153.0%
Paraguay	1.4	1.5	2.1	2.3	3.1	3.9	3.9	4.0	4.3	4.5	4.8	55.9%
Peru	9.1	10.4	11.3	10.6	9.7	11.0	12.2	13.6	15.0	15.8	19.4	99.3%
Trinidad and Tobago	2.6	2.3	3.8	5.1	6.0	6.1	10.7	16.8	19.3	20.3	21.3	256.5%
Uruguay	2.4	2.4	2.6	2.0	2.3	2.6	3.1	3.0	4.2	4.2	4.2	85.0%
Venezuela	19.7	25.1	35.6	39.7	43.8	51.9	56.8	66.9	70.2	70.1	76.9	75.8%
Other Non-OECD Americas	4.7	6.0	6.0	3.9	4.9	5.2	5.8	6.5	6.9	7.0	7.2	47.9%
Non-OECD Americas	**192.5**	**230.0**	**281.6**	**300.7**	**331.3**	**375.7**	**429.1**	**489.3**	**547.0**	**542.0**	**582.7**	**75.9%**
Bahrain	1.4	2.1	2.8	4.2	4.4	4.9	5.9	7.5	9.2	9.5	9.8	124.9%
Islamic Republic of Iran	16.6	26.6	38.1	53.8	69.3	101.2	123.0	172.1	203.8	212.9	208.4	200.5%
Iraq	4.1	6.1	9.6	13.8	19.7	34.5	25.9	26.9	28.5	32.5	37.8	91.8%
Jordan	0.5	0.8	1.5	2.6	3.3	4.3	4.9	6.7	7.1	7.5	7.2	120.0%
Kuwait	6.1	6.5	10.5	14.0	9.1	14.9	18.8	26.4	27.9	30.2	33.4	266.6%
Lebanon	1.8	2.2	2.5	2.3	2.0	4.4	4.9	5.0	5.4	6.6	6.5	230.2%
Oman	0.2	0.2	1.1	2.1	4.2	6.1	8.1	10.8	15.9	14.9	20.0	374.1%
Qatar	0.9	2.1	3.3	5.4	6.2	7.9	10.4	16.9	21.5	23.5	30.2	389.9%
Saudi Arabia	7.4	8.8	31.1	46.0	59.8	87.5	101.3	145.5	154.1	157.9	169.3	183.3%
Syrian Arab Republic	2.4	3.1	4.5	7.8	10.5	12.1	15.8	20.8	23.1	21.2	21.7	107.7%
United Arab Emirates	1.0	1.9	7.2	13.7	20.4	27.7	33.9	43.2	58.3	60.4	62.1	204.2%
Yemen	0.7	0.7	1.3	1.7	2.5	3.4	4.7	6.6	7.1	7.4	7.2	185.1%
Middle East	**43.2**	**61.0**	**113.5**	**167.6**	**211.3**	**309.0**	**357.6**	**488.4**	**561.8**	**584.3**	**613.6**	**190.4%**

GDP using exchange rates

billion 2005 US dollars

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World	**16 059.5**	**18 628.4**	**22 495.4**	**25 502.6**	**30 153.2**	**33 419.1**	**39 638.9**	**45 617.3**	**50 115.6**	**48 950.1**	**50 942.5**	**68.9%**
Annex I Parties	..	..	..	..	*24 881.0*	*26 806.0*	*31 375.1*	*34 964.7*	*37 064.3*	*35 522.4*	*36 536.1*	*46.8%*
Annex II Parties	*12 656.1*	*14 316.0*	*16 980.6*	*19 343.5*	*22 969.1*	*25 287.1*	*29 638.3*	*32 738.9*	*34 420.0*	*33 034.6*	*33 935.8*	*47.7%*
North America	*4 756.8*	*5 310.5*	*6 364.7*	*7 446.3*	*8 712.5*	*9 836.6*	*12 158.0*	*13 698.1*	*14 296.8*	*13 801.6*	*14 220.9*	*63.2%*
Europe	*5 957.9*	*6 712.4*	*7 813.2*	*8 469.9*	*9 941.3*	*10 769.6*	*12 474.8*	*13 610.9*	*14 471.9*	*13 857.3*	*14 140.6*	*42.2%*
Asia Oceania	*1 941.3*	*2 293.2*	*2 802.8*	*3 427.3*	*4 315.3*	*4 680.9*	*5 005.4*	*5 430.0*	*5 651.3*	*5 375.7*	*5 574.3*	*29.2%*
Annex I EIT	..	..	..	..	*1 638.8*	*1 198.6*	*1 344.7*	*1 736.8*	*2 093.7*	*1 963.6*	*2 029.3*	*23.8%*
Non-Annex I Parties	..	..	..	..	*5 272.2*	*6 613.1*	*8 263.8*	*10 652.6*	*13 051.2*	*13 427.8*	*14 406.4*	*173.3%*
Annex I Kyoto Parties	..	..	..	..	*16 621.6*	*17 450.3*	*19 803.8*	*21 881.2*	*23 376.7*	*22 323.2*	*22 905.2*	*37.8%*
Non-OECD Total *	**2 627.5**	**3 327.1**	**4 289.5**	**4 742.1**	**5 446.7**	**6 086.8**	**7 413.0**	**9 810.4**	**12 228.5**	**12 548.8**	**13 448.4**	**146.9%**
OECD Total **	**13 431.9**	**15 301.3**	**18 205.8**	**20 760.5**	**24 706.5**	**27 332.2**	**32 225.9**	**35 806.9**	**37 887.0**	**36 401.3**	**37 494.1**	**51.8%**
Canada	397.7	473.6	568.3	650.7	749.9	816.7	999.9	1 133.8	1 199.6	1 166.4	1 203.9	60.5%
Chile	29.4	25.2	35.8	37.4	51.8	78.5	96.2	118.3	134.1	131.9	138.7	167.9%
Mexico	251.8	331.8	458.0	504.1	547.8	591.0	770.7	846.1	930.0	871.5	920.0	67.9%
United States	4 359.1	4 836.9	5 796.4	6 795.6	7 962.6	9 019.9	11 158.1	12 564.3	13 097.2	12 635.2	13 017.0	63.5%
OECD Americas	**5 038.0**	**5 667.5**	**6 858.4**	**7 987.8**	**9 312.1**	**10 506.1**	**13 025.0**	**14 662.4**	**15 360.9**	**14 805.0**	**15 279.6**	**64.1%**
Australia	259.8	288.3	333.9	387.1	451.4	531.4	644.7	764.8	834.3	853.3	874.5	93.7%
Israel	31.3	40.7	47.1	54.9	68.1	94.3	120.9	134.0	155.3	156.6	164.1	140.9%
Japan	1 631.8	1 946.1	2 411.7	2 973.4	3 794.1	4 068.4	4 266.9	4 552.2	4 699.4	4 403.9	4 578.6	20.7%
Korea	66.7	95.7	142.5	219.5	360.3	526.7	678.3	844.9	955.5	958.5	1 017.6	182.4%
New Zealand	49.8	58.8	57.1	66.8	69.8	81.1	93.8	113.1	117.6	118.5	121.3	73.9%
OECD Asia Oceania	**2 039.3**	**2 429.6**	**2 992.3**	**3 701.7**	**4 743.7**	**5 301.9**	**5 804.6**	**6 408.9**	**6 762.0**	**6 490.8**	**6 756.0**	**42.4%**
Austria	127.3	146.8	172.8	185.7	215.3	240.3	280.6	305.0	332.5	319.8	327.2	52.0%
Belgium	170.8	196.2	229.3	240.4	279.8	302.9	348.6	377.3	402.5	391.1	399.9	42.9%
Czech Republic	70.7	80.6	89.8	94.3	102.0	97.2	106.4	130.1	151.7	144.6	148.6	45.7%
Denmark	125.9	133.3	152.6	174.4	187.4	210.3	242.1	257.7	268.5	252.9	256.1	36.7%
Estonia	..	..	..	..	10.1	7.1	9.8	13.9	15.9	13.6	13.9	37.2%
Finland	73.3	88.8	103.7	118.8	140.2	136.0	171.9	195.8	216.0	197.9	205.3	46.4%
France	942.1	1 086.9	1 283.6	1 385.9	1 623.8	1 725.6	1 973.0	2 136.6	2 237.5	2 176.4	2 208.6	36.0%
Germany	1 365.1	1 492.0	1 760.6	1 884.1	2 216.3	2 448.7	2 685.2	2 766.3	2 994.5	2 840.9	2 945.8	32.9%
Greece	100.4	119.0	145.9	146.9	156.3	166.2	197.0	240.1	260.6	252.1	243.2	55.7%
Hungary	51.3	65.7	78.3	85.4	87.7	77.8	90.0	110.3	115.8	107.9	109.3	24.6%
Iceland	4.8	5.8	7.8	8.8	10.3	10.4	13.2	16.3	18.3	17.1	16.4	59.6%
Ireland	37.6	46.2	57.8	65.5	82.4	103.4	159.8	203.3	218.5	203.2	202.3	145.5%
Italy	802.3	920.5	1 144.3	1 244.0	1 451.6	1 547.7	1 701.0	1 786.3	1 834.8	1 734.0	1 765.3	21.6%
Luxembourg	9.5	10.7	11.9	13.5	19.3	23.4	31.6	37.7	42.5	40.2	41.3	113.8%
Netherlands	269.5	305.1	351.2	371.3	437.8	490.4	598.0	638.5	698.4	673.7	685.1	56.5%
Norway	98.8	118.5	147.8	174.2	189.5	227.6	272.7	304.1	319.9	314.6	316.7	67.1%
Poland	136.0	173.9	181.4	183.0	180.1	200.6	261.1	303.9	362.4	368.2	382.8	112.5%
Portugal	67.0	77.8	99.8	104.3	137.4	149.6	184.1	191.8	199.2	193.4	196.1	42.7%
Slovak Republic	23.8	27.1	30.2	32.6	34.9	31.9	37.7	47.9	60.6	57.6	60.1	71.9%
Slovenia	..	..	..	..	24.9	24.2	29.9	35.7	41.9	38.5	39.0	56.8%
Spain	401.2	496.6	547.3	586.6	730.9	787.6	963.1	1 130.8	1 228.7	1 182.7	1 181.9	61.7%
Sweden	176.6	198.7	212.4	232.6	263.9	273.0	324.5	370.6	396.9	376.9	400.0	51.6%
Switzerland	231.7	231.8	252.0	271.6	313.9	315.5	349.0	372.5	408.4	400.8	411.7	31.1%
Turkey	115.0	144.4	162.3	205.8	269.7	315.9	386.6	483.0	543.9	517.7	564.3	109.3%
United Kingdom	954.2	1 037.8	1 132.2	1 261.3	1 485.1	1 611.1	1 979.3	2 280.5	2 394.4	2 289.7	2 337.6	57.4%
OECD Europe **	**6 354.6**	**7 204.1**	**8 355.1**	**9 071.0**	**10 650.8**	**11 524.3**	**13 396.3**	**14 735.7**	**15 764.1**	**15 105.5**	**15 458.5**	**45.1%**
European Union - 27	..	..	..	..	*10 033.5*	*10 795.8*	*12 520.7*	*13 752.6*	*14 708.7*	*14 069.6*	*14 365.4*	*43.2%*

* Includes Estonia and Slovenia prior to 1990.

** Excludes Estonia and Slovenia prior to 1990.

GDP using exchange rates

billion 2005 US dollars

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**2 627.5**	**3 327.1**	**4 289.5**	**4 742.1**	**5 446.7**	**6 086.8**	**7 413.0**	**9 810.4**	**12 228.5**	**12 548.8**	**13 448.4**	**146.9%**
Albania	3.0	3.8	5.0	5.5	5.6	4.9	6.4	8.4	10.0	10.4	10.7	90.8%
Armenia	..	..	..	..	4.1	2.1	2.8	4.9	6.7	5.8	5.9	45.5%
Azerbaijan	..	..	..	..	11.9	5.0	7.0	13.2	24.7	27.0	28.3	137.1%
Belarus	..	..	..	..	23.7	15.5	21.0	30.2	39.8	39.9	42.9	80.9%
Bosnia and Herzegovina	..	..	..	..	2.3	2.5	8.5	10.8	12.9	12.5	12.6	446.6%
Bulgaria	10.7	14.6	19.7	23.2	25.0	21.9	22.1	28.9	34.8	32.9	32.9	31.9%
Croatia	..	..	..	..	42.1	30.5	36.0	44.8	50.5	47.5	46.9	11.4%
Cyprus	2.3	2.8	5.3	6.9	9.7	12.0	14.5	17.0	19.3	19.0	19.2	98.7%
Georgia	..	..	..	..	12.0	3.4	4.5	6.4	8.1	7.8	8.3	-31.3%
Gibraltar	0.5	0.5	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.0	1.1	47.7%
Kazakhstan	..	..	..	..	50.2	30.9	34.9	57.1	71.1	72.0	77.2	53.7%
Kosovo **	..	..	..	..	..	..	2.6	3.7	4.5	4.6	4.8	..
Kyrgyzstan	..	..	..	..	3.1	1.6	2.0	2.5	3.0	3.1	3.0	-1.2%
Latvia	..	..	..	..	14.4	8.2	10.8	16.0	19.0	15.6	15.5	7.7%
Lithuania	..	..	..	..	24.8	14.4	17.8	26.0	31.7	27.0	27.3	10.5%
FYR of Macedonia	..	..	..	..	6.1	4.8	5.5	6.0	7.0	6.9	7.1	16.4%
Malta	0.9	1.4	2.3	2.5	3.4	4.5	5.6	6.0	6.7	6.5	6.7	95.0%
Republic of Moldova	..	..	..	..	6.0	2.4	2.1	3.0	3.5	3.3	3.5	-41.3%
Montenegro **	..	..	..	..	..	..	..	2.3	2.9	2.7	2.8	..
Romania	38.0	57.5	82.8	97.4	89.0	79.9	75.0	98.9	123.8	113.3	114.3	28.5%
Russian Federation	..	..	..	..	843.0	523.7	567.4	764.0	943.9	870.1	905.2	7.4%
Serbia **	..	..	..	..	41.6	21.6	21.4	25.3	28.6	27.6	27.9	-33.0%
Tajikistan	..	..	..	..	3.8	1.4	1.4	2.3	2.8	3.1	3.2	-15.0%
Turkmenistan	..	..	..	..	4.9	3.1	3.7	8.1	11.6	12.3	13.4	172.1%
Ukraine	..	..	..	..	137.0	65.8	59.5	86.1	102.0	86.9	90.6	-33.9%
Uzbekistan	..	..	..	..	11.2	9.1	11.0	14.3	18.3	19.8	21.5	91.5%
Former Soviet Union ***	645.8	807.4	985.2	1 094.9	..	..	..	..	..	..	..	..
Former Yugoslavia ***	64.8	79.6	107.1	109.1	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**766.0**	**967.4**	**1 207.9**	**1 340.1**	**1 375.6**	**869.8**	**944.8**	**1 287.2**	**1 588.3**	**1 478.4**	**1 532.9**	**11.4%**
Algeria	25.8	38.5	51.9	65.7	68.2	69.1	80.6	102.3	110.1	112.4	115.8	69.7%
Angola	13.4	13.5	13.5	14.8	17.4	13.7	18.7	30.6	50.7	51.0	54.0	211.3%
Benin	1.3	1.4	1.7	2.1	2.2	2.7	3.5	4.3	4.9	5.1	5.2	136.3%
Botswana	..	..	..	2.6	4.6	5.5	7.9	10.3	11.6	11.1	11.8	160.3%
Cameroon	4.8	6.4	8.7	13.6	12.1	11.0	13.8	16.6	18.2	18.6	19.2	59.1%
Congo	1.6	2.1	2.7	4.4	4.3	4.4	5.0	6.1	6.7	7.2	7.8	81.3%
Dem. Rep. of Congo	9.7	10.3	9.5	10.4	10.4	7.1	5.8	7.1	8.4	8.7	9.3	-10.6%
Côte d'Ivoire	7.9	9.9	12.1	12.3	13.0	14.0	16.4	16.4	17.1	17.8	18.3	40.6%
Egypt	15.9	18.2	29.1	40.3	49.5	58.5	75.4	89.7	110.0	115.1	121.0	144.4%
Eritrea	..	..	..	..	..	0.9	1.0	1.1	1.0	1.0	1.1	..
Ethiopia	5.4	5.5	5.7	5.3	6.9	7.2	9.0	12.3	16.8	18.3	20.1	194.0%
Gabon	3.0	6.1	5.6	6.4	6.7	7.8	8.0	8.7	9.5	9.3	9.9	46.4%
Ghana	4.5	4.2	4.4	4.4	5.5	6.8	8.4	10.7	13.2	13.7	14.8	168.0%
Kenya	4.9	6.4	8.7	9.9	13.0	14.1	15.7	18.7	21.6	22.2	23.5	80.1%
Libya	43.0	34.7	54.8	39.1	35.3	34.0	35.9	44.0	51.3	52.3	54.5	54.2%
Morocco	16.1	19.4	25.3	29.8	37.0	38.7	46.7	59.5	69.6	72.9	75.5	104.4%
Mozambique	2.9	2.5	2.5	2.0	2.6	3.0	4.4	6.6	8.2	8.7	9.4	264.8%
Namibia	..	..	..	..	..	4.8	5.7	7.3	8.5	8.5	8.9	..
Nigeria	41.0	47.1	57.0	48.9	63.4	71.7	83.4	112.2	134.5	143.9	155.2	144.7%
Senegal	3.3	3.8	4.0	4.6	5.1	5.7	6.9	8.7	9.7	9.9	10.3	101.7%
South Africa	110.1	126.3	147.1	157.4	170.9	178.4	204.7	247.1	285.3	280.5	288.5	68.8%
Sudan	6.8	8.4	9.4	9.8	12.1	15.5	21.1	27.4	35.9	37.3	39.0	223.1%
United Rep. of Tanzania	3.9	4.7	5.4	5.7	7.5	8.1	10.1	14.1	17.4	18.4	19.7	164.4%
Togo	0.9	1.1	1.4	1.4	1.5	1.5	1.9	2.1	2.3	2.4	2.5	60.6%
Tunisia	5.6	7.6	11.6	14.2	16.4	19.9	26.1	32.3	37.9	39.1	40.5	146.5%
Zambia	4.2	4.7	4.8	4.9	5.3	4.9	5.7	7.2	8.6	9.1	9.8	84.6%
Zimbabwe	3.7	4.3	4.7	5.7	7.2	7.6	8.3	5.6	4.3	4.5	5.0	-30.9%
Other Africa	33.1	35.0	39.4	40.5	46.3	45.6	59.0	80.7	96.2	97.6	101.2	118.8%
Africa	**372.9**	**422.2**	**521.2**	**555.9**	**624.4**	**662.6**	**789.1**	**989.6**	**1 169.5**	**1 196.7**	**1 251.8**	**100.5%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

GDP using exchange rates

billion 2005 US dollars

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	17.5	16.4	20.1	24.1	29.0	35.9	46.3	60.3	72.6	76.8	81.5	181.4%
Brunei Darussalam	4.2	5.1	8.3	6.9	6.9	8.1	8.6	9.5	9.8	9.6	10.0	44.9%
Cambodia	..	..	..	..	..	2.8	4.0	6.3	8.2	8.2	8.7	..
Chinese Taipei	30.6	46.5	80.1	109.3	167.0	236.8	305.8	364.9	410.7	402.8	446.4	167.2%
India	154.1	174.9	203.9	262.2	350.0	448.5	595.5	834.0	1 050.2	1 145.8	1 246.7	256.2%
Indonesia	40.6	55.2	80.9	106.4	150.1	219.2	226.9	285.9	340.0	355.6	377.3	151.4%
DPR of Korea	7.9	12.4	21.4	34.3	40.9	32.1	28.5	29.7	29.2	30.3	27.6	-32.6%
Malaysia	15.3	20.5	30.8	39.5	55.1	86.6	109.4	138.0	163.0	160.3	171.8	211.9%
Mongolia	..	..	..	1.5	1.8	1.6	1.8	2.5	3.3	3.2	3.5	86.9%
Myanmar	1.9	2.1	2.9	3.7	3.3	4.4	6.6	12.0	16.8	18.6	20.5	522.4%
Nepal	2.1	2.4	2.7	3.4	4.2	5.4	6.9	8.1	9.2	9.6	10.1	138.1%
Pakistan	20.2	23.5	31.7	44.0	58.4	73.2	85.9	109.6	124.9	129.4	134.8	131.0%
Philippines	31.2	39.1	52.5	49.3	62.1	69.1	82.4	103.1	120.4	121.8	131.1	111.2%
Singapore	10.9	15.0	23.2	32.3	48.9	73.7	97.8	123.5	148.2	147.1	168.3	244.3%
Sri Lanka	5.3	6.2	8.0	10.2	12.1	15.7	20.1	24.4	29.7	30.8	33.3	175.2%
Thailand	22.6	28.5	41.8	54.5	88.9	134.5	137.5	176.4	199.5	194.9	210.1	136.3%
Vietnam	9.5	9.6	10.2	14.1	17.8	26.3	36.9	52.9	66.1	69.6	74.3	318.4%
Other Asia	15.1	17.0	19.7	21.8	24.0	30.0	32.3	42.5	54.6	56.8	60.8	153.5%
Asia	**389.1**	**474.6**	**638.3**	**817.4**	**1 120.5**	**1 504.0**	**1 833.1**	**2 383.6**	**2 856.5**	**2 971.2**	**3 216.6**	**187.1%**
People's Rep. of China	126.9	158.0	216.3	360.0	525.6	937.3	1 417.0	2 256.9	3 183.3	3 476.2	3 837.7	630.1%
Hong Kong, China	22.2	29.7	51.6	68.1	98.9	127.5	145.2	177.8	207.1	201.6	215.6	118.1%
China	**149.1**	**187.7**	**267.9**	**428.1**	**624.5**	**1 064.8**	**1 562.2**	**2 434.7**	**3 390.4**	**3 677.8**	**4 053.3**	**549.0%**
Argentina	97.9	107.9	123.9	109.0	106.4	146.2	166.0	183.2	230.5	232.4	253.7	138.4%
Bolivia	4.0	5.1	5.6	5.1	5.7	6.9	8.2	9.5	11.1	11.5	12.0	111.0%
Brazil	253.7	371.7	513.3	541.8	598.5	696.1	769.0	882.2	1 023.2	1 016.6	1 092.7	82.6%
Colombia	41.1	51.1	66.4	74.2	94.4	115.5	122.7	146.6	173.1	175.6	183.2	94.1%
Costa Rica	4.7	5.9	7.7	7.7	9.8	12.8	16.3	20.0	24.1	23.8	24.8	152.4%
Cuba	18.3	22.0	25.8	38.9	38.5	26.7	33.4	42.6	53.5	52.8	55.0	42.7%
Dominican Republic	7.0	9.7	12.6	13.8	15.9	20.5	28.6	34.0	43.0	44.5	47.9	201.9%
Ecuador	10.4	14.8	19.2	20.5	23.5	26.8	28.1	36.9	42.3	42.5	44.0	87.5%
El Salvador	8.4	10.1	10.1	8.8	9.7	13.1	15.2	17.1	18.7	18.1	18.4	89.2%
Guatemala	8.7	10.9	14.4	13.6	15.7	19.3	23.4	27.2	31.5	31.7	32.5	107.8%
Haiti	3.2	3.4	4.5	4.3	4.3	3.8	4.3	4.2	4.4	4.6	4.3	0.6%
Honduras	2.7	3.1	4.4	4.8	5.6	6.7	7.8	9.8	11.5	11.3	11.6	105.8%
Jamaica	7.2	7.7	6.5	6.7	8.5	10.3	10.1	11.2	11.6	11.2	11.1	31.2%
Netherlands Antilles	1.1	1.2	1.4	1.5	1.7	1.9	2.3	2.5	2.7	2.6	2.7	56.1%
Nicaragua	3.4	4.2	3.4	3.5	3.0	3.3	4.2	4.9	5.6	5.4	5.8	94.7%
Panama	4.9	5.6	6.7	7.9	7.6	10.0	12.5	15.5	20.8	21.3	22.4	192.6%
Paraguay	1.9	2.5	4.2	4.6	5.5	6.6	6.6	7.5	8.8	8.5	9.7	76.5%
Peru	34.6	42.4	47.4	48.2	43.8	57.2	64.7	79.4	102.3	103.1	112.2	156.2%
Trinidad and Tobago	6.0	6.8	10.0	8.9	8.0	8.5	10.9	16.0	19.4	18.7	18.8	135.4%
Uruguay	9.2	9.9	12.3	10.2	12.3	14.9	17.2	17.4	21.1	21.7	23.5	90.8%
Venezuela	74.8	85.2	96.2	91.8	104.3	123.6	128.3	145.5	183.1	177.2	174.6	67.3%
Other Non-OECD Americas	12.6	13.1	17.6	18.4	24.1	25.6	31.0	34.5	38.8	35.8	36.6	52.3%
Non-OECD Americas	**615.7**	**794.3**	**1 013.4**	**1 044.0**	**1 146.7**	**1 356.4**	**1 510.8**	**1 747.5**	**2 081.0**	**2 070.8**	**2 197.4**	**91.6%**
Bahrain	1.7	3.1	5.0	4.7	5.8	8.1	10.0	13.5	16.5	17.0	17.7	203.5%
Islamic Republic of Iran	67.3	95.5	82.7	100.2	101.5	120.0	146.3	192.0	224.3	228.3	230.7	127.2%
Iraq	83.0	105.5	158.6	101.5	54.2	20.7	42.6	31.3	37.0	38.5	38.8	-28.3%
Jordan	2.3	2.2	4.6	5.9	5.6	7.9	9.2	12.6	15.9	16.2	16.7	198.8%
Kuwait	54.8	45.3	40.3	31.8	36.6	49.6	54.5	80.8	93.1	88.3	90.0	146.1%
Lebanon	14.3	14.1	11.9	16.7	9.5	16.9	18.2	21.9	25.8	28.0	30.0	215.4%
Oman	4.1	5.4	7.0	14.2	16.6	22.0	26.0	30.9	39.3	39.7	41.4	150.2%
Qatar	15.1	15.3	17.8	15.0	14.8	16.4	28.9	43.0	81.2	88.2	102.6	594.0%
Saudi Arabia	73.5	153.0	213.8	169.3	200.4	230.8	262.0	315.6	346.2	346.7	359.7	79.5%
Syrian Arab Republic	4.7	8.1	11.1	12.8	13.8	20.3	22.7	28.9	33.5	35.5	36.6	165.0%
United Arab Emirates	12.0	30.9	83.2	77.6	88.3	106.2	139.1	180.6	211.6	208.2	211.2	139.3%
Yemen	1.9	2.7	4.7	6.7	7.9	10.4	13.6	16.7	18.5	19.2	20.7	161.1%
Middle East	**334.7**	**481.0**	**640.8**	**556.5**	**555.0**	**629.3**	**773.1**	**967.8**	**1 142.8**	**1 153.9**	**1 196.3**	**115.6%**

GDP using purchasing power parities

billion 2005 US dollars

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World	**18 889.7**	**22 270.0**	**27 167.8**	**30 797.1**	**36 208.9**	**40 251.1**	**48 313.0**	**57 729.2**	**65 647.3**	**65 162.6**	**68 431.1**	**89.0%**
Annex I Parties	*..*	*..*	*..*	*..*	*25 294.7*	*26 536.4*	*31 058.5*	*34 978.4*	*37 396.4*	*35 788.3*	*36 842.2*	*45.7%*
Annex II Parties	*11 782.0*	*13 328.7*	*15 818.1*	*18 016.6*	*21 380.9*	*23 570.7*	*27 711.6*	*30 648.7*	*32 221.0*	*30 939.1*	*31 778.3*	*48.6%*
North America	*4 756.2*	*5 309.8*	*6 363.8*	*7 445.3*	*8 711.3*	*9 835.3*	*12 156.5*	*13 696.3*	*14 295.0*	*13 799.8*	*14 219.0*	*63.2%*
Europe	*5 346.5*	*6 037.0*	*7 034.8*	*7 614.7*	*8 951.4*	*9 698.0*	*11 230.1*	*12 253.6*	*13 032.3*	*12 478.2*	*12 727.0*	*42.2%*
Asia Oceania	*1 679.3*	*1 982.0*	*2 419.6*	*2 956.6*	*3 718.2*	*4 037.5*	*4 325.0*	*4 698.8*	*4 893.8*	*4 661.1*	*4 832.3*	*30.0%*
Annex I EIT	*..*	*..*	*..*	*..*	*3 472.7*	*2 448.4*	*2 713.6*	*3 540.0*	*4 286.1*	*4 002.5*	*4 141.6*	*19.3%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*10 914.2*	*13 714.7*	*17 254.5*	*22 750.9*	*28 250.8*	*29 374.3*	*31 589.0*	*189.4%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*16 825.4*	*16 956.4*	*19 208.9*	*21 540.9*	*23 299.9*	*22 196.3*	*22 784.3*	*35.4%*
Non-OECD Total *	**5 886.5**	**7 397.3**	**9 444.4**	**10 596.4**	**12 186.2**	**13 604.6**	**16 716.2**	**22 477.4**	**28 220.0**	**29 174.7**	**31 317.8**	**157.0%**
OECD Total **	**13 003.2**	**14 872.7**	**17 723.4**	**20 200.7**	**24 022.7**	**26 646.5**	**31 596.7**	**35 251.9**	**37 427.3**	**35 987.9**	**37 113.4**	**54.5%**
Canada	397.1	472.9	567.4	649.7	748.7	815.4	998.4	1 132.0	1 197.8	1 164.6	1 202.0	60.5%
Chile	49.4	42.3	60.0	62.7	86.9	131.7	161.4	198.4	225.0	221.2	232.7	167.9%
Mexico	385.0	507.4	700.3	770.9	837.7	903.7	1 178.6	1 293.8	1 422.1	1 332.7	1 406.8	67.9%
United States	4 359.1	4 836.9	5 796.4	6 795.6	7 962.6	9 019.9	11 158.1	12 564.3	13 097.2	12 635.2	13 017.0	63.5%
OECD Americas	**5 190.5**	**5 859.5**	**7 124.1**	**8 278.9**	**9 635.8**	**10 870.7**	**13 496.5**	**15 188.5**	**15 942.0**	**15 353.7**	**15 858.5**	**64.6%**
Australia	245.0	271.9	315.0	365.1	425.8	501.2	608.1	721.3	786.9	804.8	824.8	93.7%
Israel	37.8	49.2	56.8	66.3	82.2	113.9	146.0	161.7	187.4	189.0	198.2	141.0%
Japan	1 388.3	1 655.7	2 051.8	2 529.7	3 227.9	3 461.2	3 630.1	3 872.8	3 998.1	3 746.7	3 895.3	20.7%
Korea	86.6	124.3	184.9	284.9	467.7	683.8	880.5	1 096.7	1 240.3	1 244.3	1 320.9	182.4%
New Zealand	46.1	54.4	52.8	61.8	64.5	75.0	86.8	104.6	108.8	109.7	112.2	73.9%
OECD Asia Oceania	**1 803.7**	**2 155.4**	**2 661.4**	**3 307.8**	**4 268.1**	**4 835.1**	**5 351.4**	**5 957.3**	**6 321.5**	**6 094.4**	**6 351.4**	**48.8%**
Austria	115.5	133.2	156.8	168.5	195.3	218.0	254.6	276.7	301.6	290.1	296.8	52.0%
Belgium	152.7	175.4	205.0	214.9	250.1	270.7	311.6	337.2	359.8	349.6	357.5	42.9%
Czech Republic	118.3	134.9	150.2	157.8	170.7	162.6	178.1	217.7	253.9	242.0	248.6	45.7%
Denmark	87.9	93.0	106.5	121.8	130.8	146.8	169.0	179.9	187.5	176.5	178.8	36.7%
Estonia	..	..	..	..	16.2	11.4	15.8	22.3	25.4	21.8	22.3	37.2%
Finland	60.3	73.0	85.4	97.8	115.4	111.9	141.5	161.1	177.7	162.9	168.9	46.4%
France	820.5	946.5	1 117.9	1 207.0	1 414.2	1 502.8	1 718.3	1 860.7	1 948.6	1 895.4	1 923.5	36.0%
Germany	1 266.2	1 384.0	1 633.2	1 747.7	2 055.8	2 271.4	2 490.8	2 566.0	2 777.7	2 635.3	2 732.5	32.9%
Greece	113.1	134.0	164.3	165.5	176.0	187.2	221.8	270.4	293.4	283.9	273.9	55.7%
Hungary	79.6	102.0	121.5	132.6	136.1	120.8	139.6	171.2	179.7	167.5	169.6	24.6%
Iceland	3.0	3.7	5.0	5.6	6.5	6.6	8.4	10.4	11.6	10.9	10.4	59.6%
Ireland	29.9	36.8	46.0	52.1	65.6	82.3	127.2	161.8	173.9	161.7	161.0	145.5%
Italy	744.4	854.1	1 061.8	1 154.2	1 346.9	1 436.0	1 578.3	1 657.4	1 702.4	1 608.9	1 637.9	21.6%
Luxembourg	8.0	9.0	10.1	11.4	16.3	19.8	26.6	31.8	35.8	33.9	34.9	113.8%
Netherlands	241.8	273.7	315.1	333.2	392.9	440.0	536.5	572.9	626.7	604.5	614.7	56.5%
Norway	71.5	85.8	107.1	126.1	137.3	164.8	197.5	220.2	231.7	227.8	229.3	67.1%
Poland	235.4	301.1	314.0	316.7	311.8	347.2	452.0	526.1	627.4	637.4	662.6	112.5%
Portugal	78.7	91.5	117.3	122.6	161.5	175.7	216.3	225.4	234.1	227.3	230.5	42.7%
Slovak Republic	43.2	49.3	54.9	59.3	63.6	58.0	68.6	87.1	110.3	104.9	109.3	71.9%
Slovenia	..	..	..	..	32.7	31.8	39.3	47.0	55.0	50.6	51.3	56.8%
Spain	421.7	522.0	575.4	616.6	768.3	828.0	1 012.5	1 188.8	1 291.6	1 243.3	1 242.5	61.7%
Sweden	140.7	158.4	169.2	185.4	210.3	217.5	258.6	295.3	316.2	300.3	318.8	51.6%
Switzerland	165.6	165.6	180.1	194.0	224.3	225.4	249.4	266.1	291.8	286.4	294.1	31.1%
Turkey	186.0	233.6	262.5	332.9	436.2	510.9	625.3	781.2	879.8	837.4	912.8	109.3%
United Kingdom	825.0	897.2	978.8	1 090.4	1 284.0	1 392.8	1 711.2	1 971.6	2 070.1	1 979.5	2 020.9	57.4%
OECD Europe **	**6 008.9**	**6 857.8**	**7 937.9**	**8 614.0**	**10 118.7**	**10 940.7**	**12 748.8**	**14 106.2**	**15 163.8**	**14 539.8**	**14 903.4**	**47.3%**
European Union - 27	*..*	*..*	*..*	*..*	*9 651.1*	*10 315.9*	*11 957.5*	*13 212.5*	*14 219.2*	*13 605.4*	*13 888.2*	*43.9%*

* Includes Estonia and Slovenia prior to 1990.
** Excludes Estonia and Slovenia prior to 1990.

GDP using purchasing power parities

billion 2005 US dollars

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**5 886.5**	**7 397.3**	**9 444.4**	**10 596.4**	**12 186.2**	**13 604.6**	**16 716.2**	**22 477.4**	**28 220.0**	**29 174.7**	**31 317.8**	**157.0%**
Albania	6.9	8.6	11.3	12.5	12.9	11.3	14.8	19.2	23.0	23.7	24.6	90.8%
Armenia	..	..	..	..	10.4	5.5	7.1	12.6	17.3	14.8	15.2	45.5%
Azerbaijan	..	..	..	..	34.0	14.2	20.0	37.7	70.3	76.9	80.7	137.1%
Belarus	..	..	..	..	65.6	42.8	58.1	83.5	110.0	110.2	118.6	80.9%
Bosnia and Herzegovina	..	..	..	..	5.1	5.5	18.5	23.6	28.2	27.4	27.6	446.6%
Bulgaria	28.1	38.4	51.7	61.0	65.7	57.5	58.2	76.0	91.5	86.5	86.6	31.9%
Croatia	..	..	..	..	64.1	46.4	54.8	68.2	76.8	72.2	71.3	11.4%
Cyprus	2.5	3.0	5.7	7.5	10.5	13.1	15.8	18.5	21.0	20.7	20.9	98.7%
Georgia	..	..	..	..	29.5	8.3	11.1	15.7	19.8	19.1	20.3	-31.3%
Gibraltar	0.4	0.4	0.5	0.5	0.6	0.7	0.8	0.9	0.9	0.9	0.9	47.6%
Kazakhstan	..	..	..	..	115.9	71.2	80.5	131.8	164.1	166.1	178.2	53.7%
Kosovo **	..	..	..	..	..	..	6.6	9.4	11.3	11.7	12.1	..
Kyrgyzstan	..	..	..	..	11.1	5.6	7.4	8.9	10.8	11.1	10.9	-1.3%
Latvia	..	..	..	..	26.9	15.4	20.3	30.0	35.5	29.1	29.0	7.7%
Lithuania	..	..	..	..	46.3	26.8	33.3	48.5	59.2	50.4	51.1	10.5%
FYR of Macedonia	..	..	..	..	16.3	12.8	14.9	16.1	18.8	18.6	19.0	16.4%
Malta	1.3	1.9	3.3	3.6	4.9	6.3	8.0	8.5	9.5	9.2	9.5	95.1%
Republic of Moldova	..	..	..	..	16.9	6.8	6.0	8.5	9.9	9.3	9.9	-41.3%
Montenegro **	..	..	..	..	..	..	..	5.2	6.6	6.3	6.4	..
Romania	77.8	117.8	169.7	199.7	182.4	163.8	153.6	202.7	253.7	232.1	234.3	28.5%
Russian Federation	..	..	..	..	1 872.3	1 163.0	1 260.1	1 696.7	2 096.2	1 932.4	2 010.4	7.4%
Serbia **	..	..	..	..	104.2	53.7	53.4	63.4	71.9	69.4	70.0	-32.8%
Tajikistan	..	..	..	..	15.7	6.0	6.0	9.7	11.9	12.9	13.3	-15.0%
Turkmenistan	..	..	..	..	13.8	8.6	10.5	22.6	32.3	34.3	37.4	172.1%
Ukraine	..	..	..	..	418.4	200.8	181.8	263.0	311.5	265.4	276.5	-33.9%
Uzbekistan	..	..	..	..	41.1	33.3	40.2	52.4	67.1	72.5	78.6	91.5%
Former Soviet Union ***	1 522.1	1 902.8	2 321.9	2 580.5	..	..	..	..	..	..	..	..
Former Yugoslavia ***	116.5	143.0	192.4	195.9	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**1 755.5**	**2 215.9**	**2 756.6**	**3 061.2**	**3 184.3**	**1 979.5**	**2 141.7**	**2 933.2**	**3 629.1**	**3 383.0**	**3 513.5**	**10.3%**
Algeria	59.3	88.6	119.6	151.3	157.1	159.2	185.7	235.8	253.6	259.0	266.7	69.8%
Angola	26.2	26.5	26.5	29.0	34.0	26.9	36.7	60.0	99.4	100.0	105.9	211.3%
Benin	3.1	3.4	4.1	5.1	5.3	6.6	8.5	10.3	11.8	12.2	12.6	136.3%
Botswana	..	..	..	5.5	9.6	11.7	16.8	21.6	24.5	23.3	25.0	160.4%
Cameroon	10.1	13.4	18.3	28.6	25.4	23.0	29.1	34.9	38.3	39.1	40.3	59.1%
Congo	3.1	4.2	5.3	8.6	8.5	8.7	9.8	11.9	13.2	14.2	15.4	81.3%
Dem. Rep. of Congo	21.4	22.7	21.0	23.1	23.0	15.8	12.9	15.7	18.6	19.2	20.5	-10.6%
Côte d'Ivoire	14.6	18.2	22.3	22.6	23.9	25.7	30.0	30.0	31.5	32.6	33.6	40.6%
Egypt	59.0	67.7	108.1	149.7	184.0	217.5	280.2	333.2	408.5	427.7	449.7	144.4%
Eritrea	..	..	..	..	..	2.3	2.4	2.7	2.4	2.5	2.6	..
Ethiopia	20.8	21.3	21.8	20.5	26.4	27.7	34.6	47.2	64.6	70.3	77.5	193.9%
Gabon	6.1	12.5	11.6	13.1	13.9	16.2	16.4	17.8	19.5	19.2	20.3	46.4%
Ghana	11.0	10.3	10.8	10.6	13.4	16.5	20.4	26.1	32.1	33.4	36.0	168.0%
Kenya	12.7	16.5	22.4	25.3	33.3	36.1	40.1	48.0	55.4	56.9	60.0	80.1%
Libya	79.0	63.8	100.7	71.8	65.0	62.6	66.0	80.9	94.2	96.2	100.2	54.2%
Morocco	29.3	35.3	46.0	54.1	67.2	70.3	84.8	108.2	126.4	132.4	137.3	104.4%
Mozambique	6.2	5.2	5.3	4.2	5.4	6.4	9.2	13.9	17.3	18.4	19.8	264.8%
Namibia	..	..	..	..	..	7.2	8.5	10.8	12.7	12.7	13.3	..
Nigeria	89.4	102.6	124.3	106.5	138.2	156.3	181.7	244.6	293.2	313.7	338.3	144.7%
Senegal	7.0	7.9	8.3	9.5	10.7	11.9	14.5	18.2	20.3	20.7	21.6	101.7%
South Africa	180.9	207.5	241.6	258.5	280.7	293.0	336.2	405.8	468.5	460.6	473.8	68.8%
Sudan	15.4	19.0	21.3	22.1	27.3	35.0	47.8	62.0	81.2	84.4	88.1	223.1%
United Rep. of Tanzania	11.2	13.3	15.4	16.1	21.3	23.2	28.7	40.4	49.6	52.6	56.2	164.4%
Togo	2.0	2.4	3.0	3.0	3.4	3.4	4.2	4.6	5.1	5.2	5.4	60.6%
Tunisia	12.5	17.0	25.8	31.7	36.7	44.3	58.1	72.0	84.5	87.1	90.4	146.5%
Zambia	7.7	8.7	8.8	9.1	9.8	9.1	10.5	13.3	15.8	16.8	18.1	84.6%
Zimbabwe	2.5	2.9	3.2	3.9	4.9	5.1	5.6	3.8	2.9	3.1	3.3	-30.9%
Other Africa	76.5	80.9	90.6	93.9	107.5	108.4	138.0	187.6	223.2	227.3	237.3	120.7%
Africa	**766.8**	**871.6**	**1 086.2**	**1 177.3**	**1 335.8**	**1 430.0**	**1 717.4**	**2 161.3**	**2 568.4**	**2 640.8**	**2 769.2**	**107.3%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

GDP using purchasing power parities

billion 2005 US dollars

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	47.6	44.5	54.6	65.5	78.6	97.5	125.7	163.7	197.3	208.6	221.3	181.4%
Brunei Darussalam	7.7	9.4	15.3	12.7	12.7	14.8	15.9	17.6	18.0	17.7	18.4	44.9%
Cambodia	..	..	..	..	..	9.1	12.9	20.1	26.2	26.3	27.8	..
Chinese Taipei	50.9	77.3	133.2	181.7	277.8	393.8	508.5	606.8	683.0	669.8	742.3	167.2%
India	465.2	527.9	615.5	791.3	1 056.5	1 353.7	1 797.4	2 517.3	3 169.7	3 458.3	3 762.9	256.2%
Indonesia	100.1	136.3	199.5	262.4	370.2	540.6	559.7	705.2	838.7	877.1	930.7	151.4%
DPR of Korea	29.8	46.7	80.5	128.8	153.5	120.5	107.0	111.5	109.6	113.7	103.5	-32.6%
Malaysia	33.5	44.7	67.3	86.4	120.3	189.2	239.0	301.3	355.9	350.1	375.3	211.9%
Mongolia	..	..	..	4.5	5.3	4.7	5.3	7.3	9.5	9.4	10.0	86.9%
Myanmar	78.4	87.2	118.6	150.0	134.7	178.8	268.7	492.1	687.2	759.9	839.1	523.1%
Nepal	6.9	7.6	8.5	10.8	13.5	17.4	22.0	26.0	29.5	30.8	32.2	138.1%
Pakistan	62.6	72.9	98.5	136.7	181.2	227.2	266.7	340.3	387.9	401.9	418.5	131.0%
Philippines	78.9	99.1	133.0	124.8	157.3	175.0	208.5	261.0	305.0	308.5	332.1	111.2%
Singapore	17.1	23.6	36.4	50.7	76.6	115.5	153.2	193.6	232.3	230.5	263.8	244.3%
Sri Lanka	15.1	17.7	22.9	29.2	34.5	44.9	57.4	69.7	85.0	88.0	95.0	175.2%
Thailand	57.0	71.8	105.4	137.5	224.5	339.5	347.2	445.2	503.7	491.9	530.4	136.3%
Vietnam	32.1	32.5	34.3	47.3	59.7	88.6	124.0	178.1	222.2	234.0	249.9	318.4%
Other Asia	34.6	36.3	38.4	44.7	43.2	55.3	58.8	80.3	99.1	106.7	119.0	175.2%
Asia	**1 117.4**	**1 335.5**	**1 761.9**	**2 264.8**	**3 000.3**	**3 966.1**	**4 877.8**	**6 537.0**	**7 959.9**	**8 383.2**	**9 072.1**	**202.4%**
People's Rep. of China	301.7	375.4	514.1	855.6	1 249.5	2 228.0	3 368.1	5 364.3	7 566.8	8 262.9	9 122.2	630.1%
Hong Kong, China	30.4	40.7	70.6	93.2	135.2	174.3	198.5	243.1	283.1	275.6	294.8	118.1%
China	**332.0**	**416.1**	**584.7**	**948.8**	**1 384.6**	**2 402.3**	**3 566.6**	**5 607.3**	**7 849.9**	**8 538.5**	**9 417.1**	**580.1%**
Argentina	223.8	246.8	283.4	249.3	243.5	334.4	379.7	419.0	527.2	531.7	580.4	138.4%
Bolivia	14.5	18.3	20.2	18.3	20.5	25.0	29.6	34.5	40.1	41.5	43.2	111.0%
Brazil	455.1	666.8	920.9	972.0	1 073.7	1 248.9	1 379.5	1 582.6	1 835.6	1 823.8	1 960.4	82.6%
Colombia	88.2	109.6	142.4	159.1	202.4	247.9	263.2	314.4	371.3	376.7	392.9	94.1%
Costa Rica	9.2	11.6	14.9	14.9	19.2	25.1	31.9	39.0	47.0	46.4	48.3	152.4%
Cuba	20.8	24.9	29.3	44.1	43.7	30.3	37.8	48.3	60.6	59.8	62.3	42.7%
Dominican Republic	12.2	16.9	21.8	24.0	27.6	35.6	49.7	59.1	74.7	77.3	83.3	201.9%
Ecuador	24.6	35.1	45.3	48.5	55.6	63.4	66.4	87.4	100.2	100.6	104.2	87.5%
El Salvador	16.9	20.4	20.4	17.7	19.6	26.4	30.7	34.5	37.7	36.5	37.0	89.2%
Guatemala	16.6	20.6	27.3	25.8	29.7	36.7	44.5	51.7	59.8	60.1	61.8	107.8%
Haiti	7.3	7.8	10.3	10.0	9.9	8.7	9.8	9.6	10.2	10.5	10.0	0.6%
Honduras	6.3	7.2	10.2	11.1	13.0	15.5	18.0	22.5	26.6	26.0	26.7	105.8%
Jamaica	12.1	12.9	10.9	11.1	14.2	17.2	16.9	18.6	19.3	18.7	18.6	31.2%
Netherlands Antilles	0.9	1.1	1.2	1.3	1.5	1.7	2.1	2.2	2.5	2.4	2.4	56.1%
Nicaragua	8.9	11.0	8.9	9.2	7.8	8.5	10.8	12.7	14.5	14.1	15.1	94.6%
Panama	9.4	10.7	12.8	15.2	14.7	19.2	24.0	29.7	40.0	41.0	42.9	192.6%
Paraguay	5.8	7.6	12.9	14.0	17.0	20.5	20.3	23.0	27.1	26.1	30.0	76.5%
Peru	76.7	93.9	105.2	106.9	97.1	126.8	143.4	176.0	226.8	228.7	248.8	156.2%
Trinidad and Tobago	10.0	11.3	16.5	14.7	13.2	14.1	18.0	26.4	32.1	30.9	31.0	135.4%
Uruguay	16.9	18.2	22.8	18.8	22.7	27.5	31.7	32.0	38.9	39.9	43.3	90.8%
Venezuela	135.6	154.5	174.3	166.4	189.1	224.0	232.5	263.8	331.8	321.2	316.4	67.3%
Other Non-OECD Americas	14.9	15.1	20.1	21.1	26.8	28.7	34.8	39.0	42.8	40.3	41.2	53.8%
Non-OECD Americas	**1 186.6**	**1 522.3**	**1 932.1**	**1 973.5**	**2 162.2**	**2 585.9**	**2 875.5**	**3 326.1**	**3 966.7**	**3 954.0**	**4 200.2**	**94.3%**
Bahrain	2.5	4.6	7.6	7.0	8.8	12.3	15.1	20.3	25.0	25.7	26.8	203.5%
Islamic Republic of Iran	225.4	320.0	277.3	335.9	340.2	402.1	490.2	643.5	751.7	765.2	773.1	127.2%
Iraq	218.6	277.9	418.0	267.5	142.7	54.6	112.2	82.5	97.4	101.5	102.3	-28.3%
Jordan	4.2	4.1	8.6	11.1	10.4	14.7	17.2	23.5	29.6	30.2	31.2	198.8%
Kuwait	74.9	62.0	55.1	43.5	50.0	67.8	74.4	110.4	127.3	120.7	123.1	146.1%
Lebanon	25.5	25.0	21.2	29.7	16.9	30.1	32.3	38.9	46.0	49.9	53.3	215.4%
Oman	6.8	8.9	11.6	23.5	27.4	36.4	43.0	51.1	65.0	65.7	68.5	150.2%
Qatar	20.0	20.3	23.6	19.9	19.6	21.7	38.3	57.1	107.6	117.0	136.0	594.0%
Saudi Arabia	114.3	237.8	332.3	263.2	311.6	358.8	407.3	490.6	538.1	539.0	559.2	79.5%
Syrian Arab Republic	12.6	21.3	29.5	34.0	36.6	53.6	60.0	76.4	88.6	93.9	96.9	165.0%
United Arab Emirates	18.1	46.5	125.3	116.8	132.9	160.0	209.5	272.1	318.8	313.7	318.1	139.3%
Yemen	5.2	7.4	13.0	18.5	21.9	28.7	37.5	46.1	51.0	52.9	57.1	161.1%
Middle East	**728.2**	**1 035.9**	**1 322.9**	**1 170.7**	**1 119.0**	**1 240.8**	**1 537.3**	**1 912.5**	**2 245.9**	**2 275.2**	**2 345.7**	**109.6%**

Population

millions

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World	**3 758.9**	**4 058.5**	**4 431.4**	**4 833.2**	**5 266.2**	**5 675.7**	**6 070.7**	**6 447.3**	**6 673.0**	**6 748.7**	**6 825.4**	**29.6%**
Annex I Parties	*..*	*..*	*..*	*..*	*1 175.9*	*1 207.4*	*1 231.5*	*1 257.8*	*1 275.9*	*1 281.4*	*1 286.8*	*9.4%*
Annex II Parties	*705.3*	*729.4*	*755.0*	*775.9*	*799.3*	*827.8*	*853.1*	*882.0*	*900.0*	*905.2*	*910.0*	*13.8%*
North America	*229.7*	*239.1*	*252.2*	*264.3*	*277.9*	*295.9*	*313.1*	*328.5*	*338.1*	*341.2*	*344.2*	*23.9%*
Europe	*354.6*	*361.4*	*367.8*	*371.3*	*377.3*	*384.4*	*389.9*	*401.1*	*408.2*	*410.0*	*411.4*	*9.0%*
Asia Oceania	*121.0*	*128.8*	*135.0*	*140.2*	*144.2*	*147.5*	*150.1*	*152.5*	*153.7*	*154.0*	*154.3*	*7.1%*
Annex I EIT	*..*	*..*	*..*	*..*	*321.1*	*319.5*	*313.8*	*306.8*	*304.4*	*304.0*	*303.6*	*-5.4%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*4 090.3*	*4 468.3*	*4 839.1*	*5 189.5*	*5 397.1*	*5 467.2*	*5 538.6*	*35.4%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*860.0*	*870.5*	*874.5*	*882.8*	*890.0*	*892.1*	*894.0*	*3.9%*
Non-OECD Total *	**2 864.2**	**3 123.8**	**3 451.5**	**3 813.1**	**4 202.2**	**4 564.2**	**4 918.8**	**5 254.3**	**5 455.2**	**5 523.5**	**5 593.2**	**33.1%**
OECD Total **	**894.7**	**934.7**	**980.0**	**1 020.2**	**1 064.1**	**1 111.5**	**1 151.9**	**1 193.0**	**1 217.8**	**1 225.1**	**1 232.2**	**15.8%**
Canada	22.0	23.1	24.5	25.8	27.7	29.3	30.7	32.2	33.3	33.7	34.1	23.2%
Chile	9.8	10.4	11.2	12.1	13.2	14.4	15.4	16.3	16.8	16.9	17.1	29.7%
Mexico	49.9	56.7	65.7	73.5	81.3	91.2	98.3	103.8	106.6	107.4	108.3	33.3%
United States	207.7	216.0	227.7	238.5	250.2	266.6	282.4	296.2	304.8	307.5	310.1	24.0%
OECD Americas	**289.3**	**306.3**	**329.1**	**350.0**	**372.3**	**401.5**	**426.8**	**448.6**	**461.5**	**465.6**	**469.6**	**26.1%**
Australia	13.2	14.0	14.8	15.9	17.2	18.2	19.3	20.5	21.7	22.2	22.6	31.4%
Israel	3.1	3.5	3.9	4.3	4.7	5.5	6.3	7.0	7.3	7.5	7.6	63.0%
Japan	105.0	111.8	117.1	121.0	123.6	125.6	126.9	127.8	127.7	127.5	127.4	3.1%
Korea	32.9	35.3	38.1	40.8	42.9	45.1	47.0	48.1	48.6	48.7	48.9	14.0%
New Zealand	2.9	3.1	3.1	3.3	3.4	3.7	3.9	4.1	4.3	4.3	4.4	30.0%
OECD Asia Oceania	**157.0**	**167.6**	**177.0**	**185.3**	**191.7**	**198.1**	**203.4**	**207.6**	**209.7**	**210.2**	**210.8**	**10.0%**
Austria	7.5	7.6	7.5	7.6	7.7	7.9	8.0	8.2	8.3	8.4	8.4	9.2%
Belgium	9.7	9.8	9.9	9.9	10.0	10.1	10.2	10.5	10.7	10.8	10.9	9.2%
Czech Republic	9.8	10.1	10.3	10.3	10.4	10.3	10.3	10.2	10.4	10.5	10.5	1.5%
Denmark	5.0	5.1	5.1	5.1	5.1	5.2	5.3	5.4	5.5	5.5	5.5	7.9%
Estonia	..	..	..	..	1.6	1.4	1.4	1.3	1.3	1.3	1.3	-15.6%
Finland	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.2	5.3	5.3	5.4	7.6%
France	52.4	53.9	55.1	56.6	58.2	59.4	60.7	63.0	64.1	64.5	64.8	11.5%
Germany	78.3	78.7	78.3	77.7	79.4	81.7	82.2	82.5	82.1	81.9	81.8	3.0%
Greece	9.0	9.2	9.8	10.1	10.3	10.6	10.9	11.1	11.2	11.3	11.3	9.4%
Hungary	10.4	10.5	10.7	10.6	10.4	10.3	10.2	10.1	10.0	10.0	10.0	-3.5%
Iceland	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	24.7%
Ireland	3.0	3.2	3.4	3.5	3.5	3.6	3.8	4.2	4.4	4.5	4.5	27.7%
Italy	54.1	55.4	56.4	56.6	56.7	56.8	56.9	58.6	59.8	60.2	60.5	6.6%
Luxembourg	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	32.5%
Netherlands	13.2	13.7	14.1	14.5	14.9	15.5	15.9	16.3	16.4	16.5	16.6	11.1%
Norway	3.9	4.0	4.1	4.2	4.2	4.4	4.5	4.6	4.8	4.8	4.9	15.3%
Poland	32.8	34.0	35.6	37.2	38.0	38.3	38.3	38.2	38.1	38.2	38.2	0.4%
Portugal	8.7	9.2	9.9	10.1	10.0	10.0	10.2	10.5	10.6	10.6	10.6	6.4%
Slovak Republic	4.6	4.7	5.0	5.2	5.3	5.4	5.4	5.4	5.4	5.4	5.4	2.5%
Slovenia	..	..	..	..	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.6%
Spain	34.3	35.7	37.7	38.6	39.0	39.4	40.3	43.4	45.6	45.9	46.1	18.1%
Sweden	8.1	8.2	8.3	8.4	8.6	8.8	8.9	9.0	9.2	9.3	9.4	9.6%
Switzerland	6.3	6.4	6.4	6.5	6.8	7.1	7.2	7.5	7.7	7.8	7.8	14.6%
Turkey	36.2	40.1	44.4	50.3	55.1	59.8	64.3	68.6	71.1	71.9	72.8	32.2%
United Kingdom	55.9	56.2	56.3	56.6	57.2	58.0	58.9	60.2	61.4	61.8	62.2	8.6%
OECD Europe **	**448.4**	**460.9**	**473.8**	**484.9**	**500.1**	**511.9**	**521.7**	**536.9**	**546.6**	**549.3**	**551.8**	**10.3%**
European Union - 27	*..*	*..*	*..*	*..*	*472.9*	*478.7*	*482.9*	*492.1*	*498.7*	*500.3*	*501.7*	*6.1%*

* Includes Estonia and Slovenia prior to 1990.
** Excludes Estonia and Slovenia prior to 1990.

Population

millions

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**2 864.2**	**3 123.8**	**3 451.5**	**3 813.1**	**4 202.2**	**4 564.2**	**4 918.8**	**5 254.3**	**5 455.2**	**5 523.5**	**5 593.2**	**33.1%**
Albania	2.2	2.4	2.7	3.0	3.3	3.1	3.1	3.1	3.2	3.2	3.2	-2.6%
Armenia	..	..	..	..	3.5	3.2	3.1	3.1	3.1	3.1	3.1	-12.8%
Azerbaijan	..	..	..	..	7.2	7.7	8.0	8.4	8.8	8.9	9.0	26.4%
Belarus	..	..	..	..	10.2	10.2	10.0	9.8	9.6	9.5	9.5	-6.9%
Bosnia and Herzegovina	..	..	..	..	4.3	3.3	3.7	3.8	3.8	3.8	3.8	-12.7%
Bulgaria	8.5	8.7	8.9	8.9	8.7	8.4	8.1	7.7	7.6	7.6	7.5	-13.5%
Croatia	..	..	..	..	4.8	4.7	4.4	4.4	4.4	4.4	4.4	-7.4%
Cyprus	0.6	0.5	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.8	0.8	38.4%
Georgia	..	..	..	..	4.8	4.7	4.4	4.4	4.4	4.4	4.5	-7.3%
Gibraltar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.7%
Kazakhstan	..	..	..	..	16.3	15.8	14.9	15.1	15.7	15.9	16.3	-0.2%
Kosovo **	..	..	..	..	..	..	1.7	1.8	1.8	1.8	1.8	..
Kyrgyzstan	..	..	..	..	4.4	4.6	4.9	5.1	5.3	5.3	5.4	21.3%
Latvia	..	..	..	..	2.7	2.5	2.4	2.3	2.3	2.3	2.2	-16.0%
Lithuania	..	..	..	..	3.7	3.6	3.5	3.4	3.4	3.3	3.3	-10.2%
FYR of Macedonia	..	..	..	..	1.9	2.0	2.0	2.0	2.1	2.1	2.1	8.0%
Malta	0.3	0.3	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	14.7%
Republic of Moldova	..	..	..	..	3.7	3.7	3.6	3.6	3.6	3.6	3.6	-3.6%
Montenegro **	..	..	..	..	..	..	..	0.6	0.6	0.6	0.6	..
Romania	20.5	21.2	22.2	22.7	23.2	22.7	22.4	21.6	21.5	21.5	21.4	-7.6%
Russian Federation	..	..	..	..	148.3	148.1	146.3	143.2	142.0	141.9	141.8	-4.4%
Serbia **	..	..	..	..	10.1	10.4	8.1	7.4	7.4	7.3	7.3	-27.5%
Tajikistan	..	..	..	..	5.3	5.8	6.2	6.5	6.7	6.8	6.9	29.7%
Turkmenistan	..	..	..	..	3.7	4.2	4.5	4.7	4.9	5.0	5.0	37.5%
Ukraine	..	..	..	..	51.9	51.5	49.2	47.1	46.3	46.1	45.9	-11.6%
Uzbekistan	..	..	..	..	20.5	22.8	24.7	26.2	27.3	27.8	28.2	37.3%
Former Soviet Union ***	245.2	254.4	265.8	277.7	..	..	..	..	..	..	..	..
Former Yugoslavia ***	20.3	20.9	21.7	22.4	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**297.6**	**308.5**	**322.1**	**335.6**	**343.4**	**344.1**	**340.3**	**336.6**	**336.7**	**337.3**	**338.0**	**-1.6%**
Algeria	14.2	16.0	18.8	22.1	25.3	28.3	30.5	32.9	34.4	35.0	35.5	40.2%
Angola	6.0	6.6	7.6	9.1	10.3	12.1	13.9	16.5	18.0	18.6	19.1	84.6%
Benin	2.9	3.2	3.6	4.1	4.8	5.7	6.5	7.6	8.4	8.6	8.9	85.4%
Botswana	..	..	..	1.2	1.4	1.6	1.8	1.9	2.0	2.0	2.0	45.2%
Cameroon	7.0	7.8	9.1	10.5	12.2	13.9	15.7	17.6	18.8	19.2	19.6	60.9%
Congo	1.4	1.6	1.8	2.1	2.4	2.7	3.1	3.5	3.8	3.9	4.0	69.2%
Dem. Rep. of Congo	20.8	23.3	27.0	31.0	36.4	44.1	49.6	57.4	62.5	64.2	66.0	81.2%
Côte d'Ivoire	5.7	6.8	8.5	10.5	12.5	14.7	16.6	18.0	19.0	19.4	19.7	57.7%
Egypt	36.8	40.1	45.0	50.7	56.8	62.1	67.6	74.2	78.3	79.7	81.1	42.7%
Eritrea	..	..	..	..	..	3.2	3.7	4.5	4.9	5.1	5.3	..
Ethiopia	31.7	35.1	37.9	43.9	51.5	57.0	65.6	74.3	79.4	81.2	83.0	61.1%
Gabon	0.5	0.6	0.7	0.8	0.9	1.1	1.2	1.4	1.5	1.5	1.5	62.0%
Ghana	8.9	9.9	10.9	12.9	14.8	17.0	19.2	21.6	23.3	23.8	24.4	64.9%
Kenya	11.7	13.5	16.3	19.7	23.4	27.4	31.3	35.6	38.5	39.5	40.5	72.8%
Libya	2.1	2.5	3.1	3.9	4.3	4.8	5.2	5.8	6.2	6.3	6.4	46.6%
Morocco	15.7	17.3	19.6	22.3	24.8	26.9	28.8	30.4	31.3	31.6	32.0	28.9%
Mozambique	9.7	10.6	12.1	13.3	13.5	15.9	18.2	20.8	22.3	22.9	23.4	72.7%
Namibia	..	..	..	..	..	1.7	1.9	2.1	2.2	2.2	2.3	..
Nigeria	58.7	65.1	75.5	85.8	97.6	110.0	123.7	139.8	150.7	154.5	158.4	62.4%
Senegal	4.2	4.8	5.4	6.2	7.2	8.4	9.5	10.9	11.8	12.1	12.4	71.7%
South Africa	22.6	24.7	27.6	31.3	35.2	39.1	44.0	47.2	48.8	49.3	50.0	42.0%
Sudan	15.2	17.1	20.1	23.5	26.5	30.1	34.2	38.4	41.4	42.5	43.6	64.4%
United Rep. of Tanzania	14.0	16.0	18.7	21.8	25.5	29.9	34.0	38.8	42.3	43.5	44.8	76.0%
Togo	2.2	2.4	2.7	3.2	3.7	4.1	4.8	5.4	5.8	5.9	6.0	64.4%
Tunisia	5.2	5.6	6.4	7.3	8.2	9.0	9.6	10.0	10.3	10.4	10.5	29.4%
Zambia	4.3	4.9	5.8	6.8	7.9	8.9	10.2	11.5	12.4	12.7	12.9	64.5%
Zimbabwe	5.4	6.2	7.3	8.9	10.5	11.7	12.5	12.6	12.5	12.5	12.6	20.1%
Other Africa	70.5	77.5	89.8	100.6	115.9	127.1	147.4	169.8	185.0	190.3	195.8	68.9%
Africa	**377.3**	**419.2**	**481.2**	**553.4**	**633.5**	**718.5**	**810.3**	**910.4**	**975.6**	**998.3**	**1 021.6**	**61.3%**

* Includes Estonia and Slovenia prior to 1990.
** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.
*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

Population

millions

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	67.8	70.6	80.6	92.3	105.3	117.5	129.6	140.6	145.5	147.0	148.7	41.3%
Brunei Darussalam	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	58.3%
Cambodia	..	..	..	..	..	11.2	12.4	13.4	13.8	14.0	14.1	..
Chinese Taipei	14.9	16.1	17.8	19.3	20.3	21.3	22.2	22.7	22.9	23.0	23.2	14.3%
India	560.3	613.5	687.3	765.1	849.5	932.2	1 015.9	1 094.6	1 140.0	1 155.3	1 170.9	37.8%
Indonesia	121.4	134.1	150.8	168.1	184.3	199.4	213.4	227.3	235.0	237.4	239.9	30.1%
DPR of Korea	14.6	16.1	17.2	18.7	20.1	21.8	22.9	23.7	24.1	24.2	24.3	20.9%
Malaysia	11.2	12.3	13.8	15.8	18.2	20.7	23.4	26.1	27.5	27.9	28.4	56.0%
Mongolia	..	..	..	1.9	2.2	2.3	2.4	2.5	2.7	2.7	2.8	25.7%
Myanmar	26.8	29.5	32.9	36.1	39.3	42.1	45.0	46.3	47.3	47.6	48.0	22.1%
Nepal	12.2	13.4	15.0	16.9	19.1	21.6	24.4	27.3	28.9	29.4	30.0	57.0%
Pakistan	61.0	68.5	80.5	95.5	111.8	127.3	144.5	158.6	167.4	170.5	173.6	55.2%
Philippines	36.5	40.9	47.1	54.1	61.6	69.3	77.3	85.5	90.2	91.7	93.3	51.3%
Singapore	2.1	2.3	2.4	2.7	3.0	3.5	4.0	4.3	4.8	5.0	5.1	66.6%
Sri Lanka	12.8	13.8	15.1	16.2	17.3	18.2	18.7	19.8	20.5	20.7	20.9	20.3%
Thailand	38.0	42.4	47.5	52.3	57.1	59.7	63.2	66.7	68.3	68.7	69.1	21.1%
Vietnam	43.7	48.0	53.7	58.9	66.0	72.0	77.6	82.4	85.1	86.0	86.9	31.7%
Other Asia	28.4	30.6	32.7	35.5	40.2	34.4	38.7	43.5	46.7	47.8	49.1	22.0%
Asia	**1 051.9**	**1 152.2**	**1 294.7**	**1 449.7**	**1 615.7**	**1 774.7**	**1 936.0**	**2 085.8**	**2 171.0**	**2 199.5**	**2 228.6**	**37.9%**
People's Rep. of China	841.1	916.4	981.2	1 051.0	1 135.2	1 204.9	1 262.6	1 303.7	1 324.7	1 331.4	1 338.3	17.9%
Hong Kong, China	4.0	4.5	5.1	5.5	5.7	6.2	6.7	6.8	7.0	7.0	7.1	23.9%
China	**845.2**	**920.9**	**986.3**	**1 056.5**	**1 140.9**	**1 211.0**	**1 269.3**	**1 310.5**	**1 331.6**	**1 338.4**	**1 345.4**	**17.9%**
Argentina	24.4	26.1	28.1	30.4	32.6	34.9	36.9	38.7	39.7	40.1	40.4	23.8%
Bolivia	4.3	4.8	5.4	6.0	6.7	7.5	8.3	9.1	9.6	9.8	9.9	49.1%
Brazil	98.4	108.2	121.7	136.2	149.7	161.8	174.4	186.0	191.5	193.2	194.9	30.3%
Colombia	21.9	24.0	26.9	30.0	33.2	36.5	39.8	43.0	45.0	45.7	46.3	39.4%
Costa Rica	1.9	2.0	2.3	2.7	3.1	3.5	3.9	4.3	4.5	4.6	4.7	51.8%
Cuba	8.9	9.4	9.8	10.1	10.6	10.9	11.1	11.3	11.3	11.3	11.3	6.5%
Dominican Republic	4.6	5.1	5.8	6.5	7.2	7.9	8.6	9.3	9.7	9.8	9.9	38.0%
Ecuador	6.2	6.9	8.0	9.1	10.3	11.4	12.3	13.4	14.1	14.3	14.5	41.0%
El Salvador	3.8	4.2	4.7	5.0	5.3	5.7	5.9	6.1	6.1	6.2	6.2	16.1%
Guatemala	5.6	6.2	7.0	8.0	8.9	10.0	11.2	12.7	13.7	14.0	14.4	61.3%
Haiti	4.8	5.1	5.7	6.4	7.1	7.9	8.6	9.3	9.7	9.9	10.0	40.3%
Honduras	2.8	3.1	3.6	4.2	4.9	5.6	6.2	6.9	7.3	7.5	7.6	55.5%
Jamaica	1.9	2.0	2.1	2.3	2.4	2.5	2.6	2.7	2.7	2.7	2.7	13.1%
Netherlands Antilles	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	5.2%
Nicaragua	2.5	2.8	3.2	3.7	4.1	4.6	5.1	5.4	5.6	5.7	5.8	40.5%
Panama	1.6	1.7	2.0	2.2	2.4	2.7	3.0	3.2	3.4	3.5	3.5	45.6%
Paraguay	2.5	2.8	3.2	3.7	4.2	4.8	5.3	5.9	6.2	6.3	6.5	52.1%
Peru	13.6	15.1	17.3	19.5	21.7	23.8	25.9	27.6	28.5	28.8	29.1	34.1%
Trinidad and Tobago	1.0	1.0	1.1	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3	10.4%
Uruguay	2.8	2.8	2.9	3.0	3.1	3.2	3.3	3.3	3.3	3.3	3.4	8.0%
Venezuela	11.0	12.7	15.0	17.5	19.8	22.0	24.3	26.6	27.9	28.4	28.8	46.0%
Other Non-OECD Americas	2.6	2.7	2.8	2.9	3.0	3.2	3.3	3.6	3.7	3.7	3.7	24.8%
Non-OECD Americas	**227.1**	**249.1**	**278.8**	**310.5**	**341.6**	**371.8**	**401.7**	**429.8**	**445.1**	**450.1**	**455.1**	**33.2%**
Bahrain	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.7	1.1	1.2	1.3	156.0%
Islamic Republic of Iran	29.4	32.8	38.6	46.5	54.9	59.8	65.3	69.7	72.3	73.1	74.0	34.8%
Iraq	10.6	12.0	14.1	16.3	18.9	21.6	25.1	28.5	30.7	31.5	32.3	71.0%
Jordan	1.6	1.8	2.2	2.6	3.2	4.2	4.8	5.4	5.8	5.9	6.0	90.8%
Kuwait	0.8	1.1	1.4	1.7	2.1	1.6	1.9	2.3	2.5	2.6	2.7	31.1%
Lebanon	2.5	2.8	2.8	2.9	2.9	3.5	3.7	4.1	4.2	4.2	4.2	43.4%
Oman	0.8	0.9	1.2	1.5	1.9	2.2	2.3	2.4	2.6	2.7	2.8	48.9%
Qatar	0.1	0.2	0.2	0.4	0.5	0.5	0.6	0.8	1.4	1.6	1.8	271.1%
Saudi Arabia	6.0	7.3	9.8	13.2	16.1	18.5	20.0	24.0	26.2	26.8	27.4	70.1%
Syrian Arab Republic	6.6	7.5	8.9	10.6	12.3	14.2	16.0	18.5	19.6	20.0	20.4	65.9%
United Arab Emirates	0.3	0.5	1.0	1.3	1.8	2.3	3.0	4.1	6.2	6.9	7.5	315.3%
Yemen	6.2	6.7	7.9	9.8	11.9	15.1	17.7	20.6	22.6	23.3	24.1	101.3%
Middle East	**65.1**	**73.9**	**88.4**	**107.3**	**127.0**	**144.1**	**161.2**	**181.2**	**195.2**	**200.0**	**204.6**	**61.0%**

CO_2 emissions / TPES

tonnes CO_2 / terajoule

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World *	**60.8**	**60.5**	**59.7**	**57.5**	**57.1**	**56.5**	**56.1**	**56.7**	**57.4**	**56.8**	**56.7**	**-0.8%**
Annex I Parties	..	..	..	..	*59.5*	*57.4*	*57.0*	*56.3*	*55.8*	*55.0*	*54.6*	*-8.2%*
Annex II Parties	*66.0*	*64.2*	*62.3*	*59.5*	*58.4*	*56.6*	*56.5*	*56.2*	*55.5*	*54.4*	*54.4*	*-6.8%*
North America	*64.0*	*62.2*	*60.9*	*60.1*	*59.6*	*58.3*	*59.0*	*58.4*	*57.7*	*56.5*	*57.1*	*-4.2%*
Europe	*69.0*	*66.4*	*64.5*	*58.6*	*55.8*	*53.3*	*51.7*	*51.1*	*50.4*	*49.1*	*48.4*	*-13.4%*
Asia Oceania	*67.1*	*67.2*	*62.4*	*59.8*	*59.8*	*57.7*	*57.6*	*59.5*	*59.0*	*58.6*	*58.1*	*-2.8%*
Annex I EIT	..	..	..	..	*62.5*	*60.6*	*58.9*	*56.6*	*56.6*	*56.9*	*55.0*	*-12.1%*
Non-Annex I Parties	..	..	..	..	*51.5*	*53.9*	*53.6*	*56.1*	*58.1*	*57.5*	*57.5*	*11.7%*
Annex I Kyoto Parties	..	..	..	..	*58.8*	*56.2*	*54.9*	*54.2*	*53.8*	*53.3*	*52.4*	*-10.9%*
Non-OECD Total **	**50.2**	**53.2**	**54.6**	**53.1**	**54.3**	**54.7**	**53.9**	**56.0**	**57.9**	**57.4**	**57.1**	**5.2%**
OECD Total ***	**66.4**	**64.7**	**62.9**	**60.5**	**58.9**	**57.2**	**57.0**	**56.4**	**55.8**	**54.9**	**55.0**	**-6.7%**
Canada	57.4	54.3	53.0	49.8	49.6	48.2	50.7	49.1	49.7	50.1	50.9	2.7%
Chile	57.2	53.1	53.5	48.5	52.9	50.7	49.8	49.0	54.0	53.0	53.8	1.8%
Mexico	53.9	56.0	53.3	55.3	51.6	54.6	57.5	54.1	53.2	54.7	55.9	8.3%
United States	64.6	63.0	61.7	61.2	60.7	59.4	59.9	59.4	58.6	57.2	57.9	-4.7%
OECD Americas	**63.7**	**62.0**	**60.5**	**59.8**	**59.2**	**58.0**	**58.8**	**58.0**	**57.3**	**56.3**	**57.0**	**-3.6%**
Australia	66.7	71.2	71.4	72.5	72.0	73.7	74.8	77.2	74.2	72.8	73.4	2.0%
Israel	60.0	58.0	59.9	77.3	69.8	71.2	72.2	75.8	67.1	70.5	71.0	1.6%
Japan	67.7	67.0	61.1	57.8	57.9	55.2	54.5	56.0	55.7	55.4	55.0	-5.0%
Korea	73.3	75.0	72.1	68.4	58.8	59.2	55.6	53.3	52.8	53.7	53.8	-8.6%
New Zealand	47.5	46.5	43.7	41.9	43.5	42.3	43.3	48.0	46.6	42.5	40.5	-6.8%
OECD Asia Oceania	**67.3**	**67.5**	**63.2**	**61.0**	**59.8**	**58.3**	**57.5**	**58.4**	**57.6**	**57.6**	**57.3**	**-4.3%**
Austria	61.8	59.5	57.4	56.2	54.3	53.0	51.6	52.8	50.3	47.8	48.9	-9.8%
Belgium	70.4	65.2	64.2	55.2	53.4	51.2	48.4	45.8	45.2	42.1	41.8	-21.8%
Czech Republic	79.4	83.5	84.3	84.0	74.8	71.2	71.0	63.6	62.4	62.5	62.0	-17.1%
Denmark	71.0	71.7	78.1	74.9	69.4	71.4	64.9	61.0	60.3	60.8	58.3	-15.9%
Estonia	..	..	..	..	87.0	76.3	74.1	78.0	77.8	73.7	79.3	-9.0%
Finland	52.3	53.8	53.6	44.9	45.8	46.3	40.8	38.5	38.6	39.5	41.3	-9.8%
France	65.1	62.3	57.5	42.2	37.6	35.7	35.7	34.3	33.4	33.1	32.6	-13.3%
Germany	76.6	74.3	70.6	67.8	64.6	61.6	58.5	57.1	57.2	56.3	55.6	-14.0%
Greece	69.2	70.3	72.3	74.3	78.1	79.9	77.1	75.0	74.0	73.2	72.9	-6.7%
Hungary	75.7	73.7	70.5	64.8	55.1	52.9	51.8	48.8	47.9	46.3	45.5	-17.4%
Iceland	37.0	34.7	27.7	21.8	21.5	20.7	16.5	15.0	9.3	9.1	8.5	-60.2%
Ireland	77.2	75.8	75.1	73.0	71.3	72.5	71.1	72.0	69.5	64.7	64.1	-10.0%
Italy	66.4	65.4	65.7	64.2	64.8	61.4	59.3	59.9	59.0	56.4	55.9	-13.7%
Luxembourg	90.7	76.6	80.0	77.4	73.1	61.7	57.9	62.1	60.0	60.5	59.9	-18.0%
Netherlands	60.8	57.0	61.9	60.7	56.7	57.7	56.1	55.3	54.9	53.8	53.5	-5.5%
Norway	42.2	39.4	36.5	32.5	32.2	33.4	30.7	32.4	30.1	31.4	28.8	-10.4%
Poland	79.5	78.4	77.9	80.3	79.3	79.5	78.0	75.7	72.8	72.9	71.8	-9.4%
Portugal	55.0	56.3	56.9	53.7	56.0	57.0	57.5	56.7	52.1	52.6	48.9	-12.8%
Slovak Republic	65.4	62.4	66.6	62.7	63.5	54.9	50.3	48.3	47.3	47.4	46.9	-26.1%
Slovenia	..	..	..	..	52.3	52.4	52.5	51.1	51.7	51.1	50.8	-3.0%
Spain	67.2	65.0	66.2	59.0	54.4	55.1	55.6	57.1	54.5	52.9	50.2	-7.8%
Sweden	54.6	48.6	43.3	29.7	26.7	27.3	26.5	23.3	21.4	21.8	22.2	-17.0%
Switzerland	56.8	51.0	46.8	44.8	40.6	41.3	40.5	41.0	39.1	37.5	39.9	-1.7%
Turkey	50.6	52.9	53.9	57.5	57.5	59.2	62.7	61.2	63.9	62.7	60.4	5.1%
United Kingdom	71.4	69.4	68.7	64.8	63.7	57.1	56.2	57.3	58.8	56.4	57.0	-10.5%
OECD Europe ***	**69.9**	**67.7**	**66.2**	**61.3**	**58.2**	**55.6**	**54.1**	**53.1**	**52.6**	**51.5**	**50.8**	**-12.8%**
European Union - 27	..	..	..	..	*59.1*	*56.1*	*54.3*	*53.4*	*52.8*	*51.6*	*51.0*	*-13.8%*

* The ratio for the world has been calculated to include international marine bunkers and international aviation bunkers.
** Includes Estonia and Slovenia prior to 1990.
*** Excludes Estonia and Slovenia prior to 1990.

CO_2 emissions / TPES

tonnes CO_2 / terajoule

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**50.2**	**53.2**	**54.6**	**53.1**	**54.3**	**54.7**	**53.9**	**56.0**	**57.9**	**57.4**	**57.1**	**5.2%**
Albania	54.3	53.7	59.3	63.4	55.9	33.5	41.9	44.6	44.9	40.5	43.3	-22.6%
Armenia	..	..	..	..	63.5	50.0	40.6	39.3	41.9	39.1	39.5	-37.9%
Azerbaijan	..	..	..	..	59.4	60.4	62.2	56.7	53.1	50.5	49.8	-16.1%
Belarus	..	..	..	..	65.3	59.3	56.8	55.2	54.7	55.6	56.3	-13.8%
Bosnia and Herzegovina	..	..	..	..	80.5	51.7	74.2	74.0	79.9	76.6	74.2	-7.8%
Bulgaria	78.9	74.2	70.5	63.2	62.5	54.9	53.8	55.0	59.1	57.6	58.6	-6.3%
Croatia	..	..	..	..	57.4	53.8	54.4	55.8	55.3	54.4	53.2	-7.2%
Cyprus	72.2	70.8	71.9	72.3	67.4	71.5	70.1	75.3	69.9	70.3	70.6	4.7%
Georgia	..	..	..	..	64.0	51.8	38.3	36.4	37.9	41.3	37.8	-40.8%
Gibraltar	72.1	72.4	73.6	72.8	72.6	72.9	72.9	73.0	73.1	73.0	73.1	0.6%
Kazakhstan	..	..	..	..	76.9	76.6	75.6	73.8	77.5	74.6	73.9	-3.9%
Kosovo **	..	..	..	..	..	..	80.4	82.9	83.1	83.0	83.0	..
Kyrgyzstan	..	..	..	..	71.6	44.3	44.3	45.3	51.9	57.1	57.1	-20.2%
Latvia	..	..	..	..	56.7	46.0	43.9	40.9	42.1	40.5	43.7	-22.9%
Lithuania	..	..	..	..	49.2	38.7	37.6	36.6	36.3	34.5	46.1	-6.4%
FYR of Macedonia	..	..	..	..	82.1	78.1	75.2	72.3	71.7	71.5	67.9	-17.3%
Malta	73.5	73.6	73.9	79.6	78.6	79.2	74.5	73.4	73.3	72.3	70.6	-10.2%
Republic of Moldova	..	..	..	..	73.1	59.4	54.2	52.7	53.4	56.0	56.1	-23.2%
Montenegro **	..	..	..	..	..	..	..	47.2	55.6	45.2	60.6	..
Romania	65.1	64.8	64.5	63.7	64.1	60.0	56.9	58.0	56.0	54.1	51.6	-19.5%
Russian Federation	..	..	..	..	59.2	59.1	58.1	55.6	55.3	56.1	53.8	-9.0%
Serbia **	..	..	..	..	75.8	77.4	76.3	73.1	70.6	72.6	70.5	-7.1%
Tajikistan	..	..	..	..	49.0	26.2	24.1	23.9	28.7	28.8	28.3	-42.4%
Turkmenistan	..	..	..	..	62.2	59.0	59.4	59.2	59.1	59.5	59.1	-5.1%
Ukraine	..	..	..	..	65.3	57.3	52.1	51.1	54.4	52.8	48.8	-25.2%
Uzbekistan	..	..	..	..	61.7	57.0	55.3	54.8	54.3	55.1	54.7	-11.4%
Former Soviet Union ***	62.0	65.3	65.8	61.2	..	..	..	..	..	..	..	..
Former Yugoslavia ***	68.9	70.4	62.1	70.7	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**62.7**	**65.5**	**65.7**	**61.7**	**62.0**	**59.4**	**57.6**	**56.0**	**56.7**	**56.9**	**55.0**	**-11.2%**
Algeria	61.4	60.7	60.6	58.1	56.7	56.2	56.2	58.7	57.2	58.1	58.3	2.8%
Angola	10.3	11.6	14.0	13.8	16.3	14.8	16.2	18.5	25.8	26.8	29.0	78.3%
Benin	6.5	8.8	6.9	7.2	3.6	2.8	17.0	25.3	27.6	28.8	29.5	707.3%
Botswana	..	..	..	42.5	55.6	53.2	54.5	54.9	50.1	50.9	48.6	-12.6%
Cameroon	6.4	8.2	10.8	13.0	12.8	10.8	10.5	10.0	15.9	16.6	16.9	31.8%
Congo	27.1	26.3	26.8	23.7	19.1	14.5	14.5	18.2	25.2	25.6	27.0	41.7%
Dem. Rep. of Congo	9.0	8.2	8.8	7.7	6.0	3.8	2.4	2.7	3.0	3.0	3.1	-48.6%
Côte d'Ivoire	23.2	24.3	22.5	19.6	14.6	15.1	21.7	14.5	15.0	15.3	14.5	-0.4%
Egypt	62.3	62.4	66.0	60.1	57.9	56.3	59.5	58.1	58.3	57.8	57.9	-0.0%
Eritrea	..	..	..	..	..	18.5	20.4	18.8	16.0	15.5	15.8	..
Ethiopia	3.7	3.0	3.1	2.7	3.6	3.5	4.1	5.0	4.3	4.2	3.9	8.7%
Gabon	10.5	13.8	22.2	29.7	18.2	23.4	22.5	27.7	27.9	28.7	29.7	62.7%
Ghana	15.4	15.3	13.5	11.9	12.2	12.2	15.8	18.7	19.6	24.7	24.3	98.7%
Kenya	14.6	13.8	14.5	12.8	12.3	11.1	11.8	10.7	11.6	13.0	13.3	7.9%
Libya	56.8	59.8	64.3	53.9	57.7	53.1	57.2	57.8	58.4	54.2	64.4	11.7%
Morocco	67.2	69.4	68.4	70.5	67.6	72.2	68.6	73.3	69.3	67.6	66.5	-1.6%
Mozambique	10.0	8.4	8.2	5.6	4.4	4.3	4.4	4.3	5.1	5.5	5.9	34.1%
Namibia	..	..	..	..	..	47.1	43.1	45.6	52.2	49.9	49.6	..
Nigeria	3.9	6.7	12.2	12.6	9.9	9.6	11.1	12.4	10.7	9.3	9.7	-1.7%
Senegal	23.3	27.6	31.2	32.3	30.1	31.7	35.9	39.8	39.5	38.6	38.7	28.4%
South Africa	82.4	89.2	76.3	63.2	66.6	63.3	64.8	61.3	62.6	61.0	60.5	-9.1%
Sudan	11.1	10.5	10.6	10.6	12.4	9.1	9.9	14.4	19.6	20.3	20.2	63.7%
United Rep. of Tanzania	4.8	4.7	4.7	4.2	4.2	5.5	4.6	7.2	7.3	6.9	7.1	69.9%
Togo	11.2	9.6	9.8	7.1	10.8	8.8	10.8	9.8	10.3	10.3	10.4	-3.1%
Tunisia	53.1	52.7	57.3	55.0	58.3	58.5	58.9	58.0	54.5	56.1	54.4	-6.7%
Zambia	23.4	26.9	17.8	13.6	11.5	8.4	6.5	6.9	5.0	5.3	5.7	-50.5%
Zimbabwe	31.8	29.0	29.3	30.9	41.1	36.0	30.7	25.5	20.4	21.2	22.6	-45.1%
Other Africa	6.9	7.7	9.5	7.6	8.2	8.5	8.4	8.8	9.2	8.9	8.9	8.3%
Africa	**30.9**	**34.8**	**35.0**	**33.4**	**33.5**	**32.5**	**32.7**	**33.1**	**33.6**	**32.9**	**32.6**	**-2.9%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

CO_2 emissions / TPES

tonnes CO_2 / terajoule

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	13.4	16.5	20.5	21.2	25.4	30.8	32.5	36.6	39.9	41.1	40.8	60.2%
Brunei Darussalam	53.7	45.4	46.5	39.3	45.6	48.6	45.3	52.8	49.3	62.1	59.2	29.9%
Cambodia	..	..	..	..	..	12.3	13.7	18.3	24.0	17.7	17.9	..
Chinese Taipei	74.0	70.9	62.3	51.3	56.6	59.2	61.1	61.4	59.4	58.4	59.1	4.3%
India	30.6	32.4	33.0	38.5	43.9	48.3	50.8	51.6	54.9	55.3	56.1	27.7%
Indonesia	17.1	22.0	29.5	31.9	35.4	39.1	42.0	44.4	46.6	45.9	47.2	33.5%
DPR of Korea	83.1	82.3	83.0	83.8	82.0	81.3	83.1	82.7	81.7	82.0	81.2	-0.9%
Malaysia	49.8	52.3	48.7	51.9	55.0	58.4	57.1	57.2	60.2	57.9	60.8	10.5%
Mongolia	..	..	..	88.5	88.5	88.8	87.8	86.3	84.8	86.1	86.6	-2.2%
Myanmar	13.8	11.4	13.1	12.7	9.1	13.9	17.4	17.0	11.9	11.7	13.7	50.8%
Nepal	1.2	1.9	2.7	2.6	3.6	6.2	9.0	7.9	7.1	8.2	8.5	134.1%
Pakistan	23.3	24.6	25.1	29.0	32.8	35.4	36.6	37.3	39.1	38.9	38.0	15.9%
Philippines	35.9	38.0	35.5	28.6	31.9	40.7	40.4	43.6	42.0	44.4	45.1	41.3%
Singapore	53.7	54.5	59.1	57.6	61.0	53.0	60.9	53.9	55.3	48.4	45.9	-24.8%
Sri Lanka	17.4	15.7	19.6	17.1	16.2	22.2	30.5	35.6	32.6	31.7	32.3	99.2%
Thailand	28.3	29.2	36.5	40.4	45.8	54.2	52.3	52.2	51.1	50.9	50.5	10.3%
Vietnam	29.2	28.7	24.5	25.6	23.0	30.3	36.6	46.0	49.7	50.8	52.6	128.8%
Other Asia	55.3	56.5	52.4	38.5	35.5	32.3	32.7	38.7	39.7	41.6	42.1	18.5%
Asia	**33.0**	**35.0**	**37.3**	**39.7**	**43.2**	**46.5**	**48.5**	**49.7**	**51.6**	**51.6**	**52.2**	**20.9%**
People's Rep. of China	48.8	51.9	56.1	58.8	61.2	68.1	66.3	71.3	73.4	71.1	70.2	14.7%
Hong Kong, China	72.9	71.1	75.0	79.9	90.6	80.7	71.1	76.9	71.4	72.9	71.8	-20.7%
China	**49.0**	**52.0**	**56.2**	**59.0**	**61.5**	**68.2**	**66.3**	**71.3**	**73.4**	**71.1**	**70.2**	**14.2%**
Argentina	58.7	56.8	54.6	51.0	51.8	52.1	54.5	53.8	53.5	53.1	54.5	5.2%
Bolivia	50.9	51.9	41.0	40.6	47.1	44.2	45.6	43.6	48.9	49.0	45.9	-2.6%
Brazil	31.2	36.0	37.8	31.0	33.1	35.6	38.7	35.8	34.8	33.6	34.9	5.4%
Colombia	45.4	44.0	45.7	45.9	44.3	49.4	54.3	50.7	48.4	47.6	45.0	1.4%
Costa Rica	26.5	31.7	34.1	28.6	30.6	44.7	36.3	35.2	34.3	32.9	33.6	9.6%
Cuba	45.4	47.2	48.1	48.7	45.6	48.0	50.3	55.8	56.6	64.6	65.3	43.2%
Dominican Republic	35.2	39.9	43.5	40.4	44.6	46.3	53.3	54.4	55.9	53.3	53.1	19.1%
Ecuador	38.2	45.4	50.4	50.1	52.3	54.3	54.0	52.6	57.4	60.9	59.4	13.5%
El Salvador	19.4	21.3	16.6	16.0	21.6	32.9	31.4	32.3	33.0	35.2	33.4	54.8%
Guatemala	20.0	21.8	26.6	20.3	17.4	26.0	28.7	31.9	29.7	28.5	24.0	38.3%
Haiti	5.9	5.7	7.0	10.0	14.5	12.8	16.7	18.3	20.1	21.8	22.2	53.5%
Honduras	19.2	20.4	21.5	19.8	21.6	29.9	35.5	41.5	40.1	39.3	38.2	76.2%
Jamaica	65.5	66.0	68.2	64.3	61.6	62.2	60.6	66.3	66.3	60.7	62.2	1.1%
Netherlands Antilles	63.0	63.1	53.2	60.9	44.9	51.3	48.9	51.6	49.8	56.2	54.3	20.7%
Nicaragua	28.4	29.4	27.9	22.2	20.9	25.5	30.9	28.9	32.5	32.4	34.0	62.5%
Panama	36.0	44.0	49.6	41.1	40.9	49.3	45.7	56.6	50.6	54.1	53.2	29.9%
Paraguay	9.9	11.2	15.5	15.0	14.9	21.0	20.2	20.8	20.6	22.0	23.4	57.3%
Peru	40.7	42.5	43.6	41.2	47.1	51.6	51.8	50.5	56.6	57.7	51.6	9.6%
Trinidad and Tobago	55.7	60.0	49.5	45.1	45.4	47.7	47.2	48.3	48.4	47.3	47.9	5.6%
Uruguay	51.6	53.3	50.2	37.3	39.8	42.0	40.7	42.8	44.3	43.9	37.0	-7.1%
Venezuela	63.2	59.7	62.0	57.3	57.3	54.5	53.3	52.9	57.3	57.4	56.8	-0.9%
Other Non-OECD Americas	39.5	43.1	40.8	56.4	61.0	61.4	62.5	61.5	61.5	61.2	61.1	0.2%
Non-OECD Americas	**43.1**	**44.1**	**44.9**	**40.4**	**41.7**	**43.6**	**45.4**	**43.9**	**44.0**	**43.7**	**43.7**	**4.8%**
Bahrain	51.1	59.5	63.0	59.7	64.2	56.3	57.5	57.8	57.7	57.6	57.7	-10.3%
Islamic Republic of Iran	59.9	64.1	56.6	65.0	61.6	59.3	61.2	58.5	58.3	57.7	58.3	-5.2%
Iraq	59.9	60.8	66.8	63.7	64.7	67.4	64.7	66.6	61.6	67.6	66.0	2.0%
Jordan	64.9	67.5	67.1	67.7	67.4	67.7	70.5	64.5	62.5	61.7	61.7	-8.4%
Kuwait	54.8	55.6	60.7	63.2	75.3	58.0	62.4	63.4	63.3	63.9	62.5	-17.0%
Lebanon	58.6	62.3	63.6	67.1	66.7	69.6	68.7	68.9	69.7	69.2	68.9	3.3%
Oman	26.7	71.5	46.3	64.3	58.0	57.8	59.6	62.5	54.9	64.0	48.1	-17.0%
Qatar	57.5	56.1	55.1	53.3	54.4	56.3	54.3	53.0	55.3	57.4	51.3	-5.8%
Saudi Arabia	41.3	61.3	76.1	63.7	63.6	56.7	59.6	54.8	60.0	62.2	62.9	-1.1%
Syrian Arab Republic	60.5	70.6	70.3	64.3	64.3	64.7	60.3	63.1	65.0	64.4	63.5	-1.2%
United Arab Emirates	57.8	60.2	63.1	62.0	60.7	60.1	60.2	59.9	59.6	59.1	59.2	-2.4%
Yemen	38.7	60.0	64.6	66.1	61.1	65.3	66.6	68.3	70.6	70.0	72.2	18.1%
Middle East	**55.1**	**62.2**	**64.5**	**63.7**	**63.0**	**59.9**	**60.9**	**58.6**	**59.7**	**60.7**	**60.2**	**-4.4%**

CO_2 emissions / GDP using exchange rates

kilogrammes CO_2 / US dollar using 2005 prices

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World *	**0.88**	**0.84**	**0.80**	**0.73**	**0.70**	**0.65**	**0.59**	**0.60**	**0.59**	**0.59**	**0.59**	**-14.6%**
Annex I Parties	*..*	*..*	*..*	*..*	*0.56*	*0.49*	*0.44*	*0.40*	*0.38*	*0.37*	*0.37*	*-34.4%*
Annex II Parties	*0.68*	*0.62*	*0.56*	*0.47*	*0.43*	*0.40*	*0.37*	*0.35*	*0.32*	*0.31*	*0.31*	*-27.4%*
North America	*0.97*	*0.89*	*0.80*	*0.66*	*0.61*	*0.57*	*0.51*	*0.46*	*0.43*	*0.41*	*0.42*	*-31.8%*
Europe	*0.51*	*0.46*	*0.43*	*0.37*	*0.32*	*0.29*	*0.26*	*0.25*	*0.22*	*0.22*	*0.22*	*-31.8%*
Asia Oceania	*0.47*	*0.46*	*0.39*	*0.33*	*0.31*	*0.31*	*0.31*	*0.30*	*0.28*	*0.28*	*0.28*	*-10.5%*
Annex I EIT	*..*	*..*	*..*	*..*	*2.43*	*2.35*	*1.90*	*1.50*	*1.29*	*1.27*	*1.29*	*-47.0%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*1.22*	*1.20*	*1.08*	*1.13*	*1.11*	*1.11*	*1.10*	*-10.5%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*0.53*	*0.45*	*0.39*	*0.37*	*0.34*	*0.33*	*0.34*	*-36.4%*
Non-OECD Total **	**1.59**	**1.61**	**1.58**	**1.62**	**1.69**	**1.55**	**1.35**	**1.34**	**1.28**	**1.27**	**1.24**	**-26.3%**
OECD Total ***	**0.70**	**0.64**	**0.59**	**0.50**	**0.45**	**0.43**	**0.39**	**0.36**	**0.34**	**0.33**	**0.33**	**-26.5%**
Canada	0.85	0.80	0.75	0.62	0.58	0.57	0.53	0.49	0.46	0.45	0.45	-22.8%
Chile	0.71	0.67	0.59	0.52	0.60	0.50	0.55	0.49	0.51	0.50	0.50	-16.2%
Mexico	0.39	0.42	0.46	0.50	0.48	0.50	0.45	0.46	0.43	0.46	0.45	-6.3%
United States	0.98	0.90	0.80	0.67	0.61	0.57	0.51	0.46	0.43	0.41	0.41	-32.5%
OECD Americas	**0.94**	**0.86**	**0.78**	**0.65**	**0.60**	**0.57**	**0.51**	**0.46**	**0.43**	**0.42**	**0.42**	**-30.4%**
Australia	0.55	0.62	0.62	0.57	0.58	0.54	0.53	0.48	0.46	0.45	0.44	-23.9%
Israel	0.46	0.42	0.42	0.45	0.49	0.49	0.46	0.44	0.41	0.41	0.41	-15.8%
Japan	0.47	0.44	0.37	0.30	0.28	0.28	0.28	0.27	0.25	0.25	0.25	-11.0%
Korea	0.78	0.80	0.87	0.70	0.64	0.68	0.65	0.56	0.53	0.54	0.55	-13.0%
New Zealand	0.28	0.29	0.29	0.29	0.34	0.32	0.33	0.30	0.29	0.26	0.25	-24.2%
OECD Asia Oceania	**0.48**	**0.47**	**0.42**	**0.35**	**0.34**	**0.35**	**0.35**	**0.34**	**0.32**	**0.32**	**0.32**	**-4.6%**
Austria	0.38	0.34	0.32	0.29	0.26	0.25	0.22	0.24	0.21	0.20	0.21	-19.2%
Belgium	0.68	0.59	0.55	0.42	0.39	0.38	0.34	0.30	0.28	0.26	0.27	-31.0%
Czech Republic	2.14	1.89	1.85	1.84	1.52	1.27	1.15	0.92	0.77	0.76	0.77	-49.4%
Denmark	0.44	0.39	0.41	0.35	0.27	0.28	0.21	0.19	0.18	0.18	0.18	-31.8%
Estonia	..	..	..	..	3.57	2.26	1.49	1.21	1.12	1.08	1.33	-62.7%
Finland	0.54	0.50	0.53	0.41	0.39	0.41	0.32	0.28	0.26	0.28	0.31	-21.0%
France	0.46	0.40	0.36	0.26	0.22	0.21	0.19	0.18	0.17	0.16	0.16	-25.3%
Germany	0.72	0.65	0.60	0.54	0.43	0.35	0.31	0.29	0.27	0.26	0.26	-39.7%
Greece	0.25	0.29	0.31	0.37	0.45	0.46	0.44	0.40	0.36	0.36	0.35	-22.8%
Hungary	1.18	1.08	1.07	0.95	0.76	0.74	0.60	0.51	0.46	0.45	0.45	-40.8%
Iceland	0.29	0.28	0.22	0.18	0.18	0.19	0.16	0.13	0.11	0.12	0.12	-35.9%
Ireland	0.58	0.46	0.45	0.40	0.36	0.31	0.26	0.21	0.20	0.19	0.19	-47.2%
Italy	0.37	0.35	0.31	0.28	0.27	0.26	0.25	0.26	0.24	0.22	0.23	-17.5%
Luxembourg	1.63	1.14	1.00	0.74	0.54	0.35	0.26	0.30	0.25	0.25	0.26	-52.5%
Netherlands	0.48	0.46	0.47	0.41	0.36	0.35	0.29	0.29	0.26	0.26	0.27	-23.3%
Norway	0.24	0.20	0.19	0.16	0.15	0.14	0.12	0.12	0.12	0.12	0.12	-17.1%
Poland	2.11	1.94	2.28	2.29	1.90	1.65	1.11	0.96	0.82	0.78	0.80	-58.0%
Portugal	0.22	0.23	0.24	0.24	0.29	0.32	0.32	0.33	0.27	0.27	0.25	-14.1%
Slovak Republic	1.64	1.62	1.83	1.67	1.62	1.28	0.99	0.80	0.60	0.58	0.58	-64.1%
Slovenia	..	..	..	..	0.50	0.55	0.47	0.44	0.40	0.39	0.39	-21.8%
Spain	0.30	0.32	0.34	0.30	0.28	0.30	0.29	0.30	0.26	0.24	0.23	-19.2%
Sweden	0.47	0.40	0.35	0.25	0.20	0.21	0.16	0.14	0.11	0.11	0.12	-40.5%
Switzerland	0.17	0.16	0.16	0.15	0.13	0.13	0.12	0.12	0.11	0.11	0.11	-19.2%
Turkey	0.36	0.41	0.44	0.46	0.47	0.48	0.52	0.45	0.48	0.50	0.47	0.1%
United Kingdom	0.65	0.56	0.50	0.43	0.37	0.32	0.26	0.23	0.21	0.20	0.21	-44.1%
OECD Europe ***	**0.57**	**0.52**	**0.50**	**0.43**	**0.37**	**0.34**	**0.30**	**0.28**	**0.26**	**0.25**	**0.25**	**-32.7%**
European Union - 27	*..*	*..*	*..*	*..*	*0.40*	*0.36*	*0.31*	*0.29*	*0.26*	*0.25*	*0.25*	*-36.9%*

* The ratio for the world has been calculated to include international marine bunkers and international aviation bunkers.
** Includes Estonia and Slovenia prior to 1990.
*** Excludes Estonia and Slovenia prior to 1990.

CO_2 emissions / GDP using exchange rates

kilogrammes CO_2 / US dollar using 2005 prices

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**1.59**	**1.61**	**1.58**	**1.62**	**1.69**	**1.55**	**1.35**	**1.34**	**1.28**	**1.27**	**1.24**	**-26.3%**
Albania	1.30	1.19	1.54	1.32	1.11	0.38	0.48	0.49	0.39	0.34	0.35	-68.5%
Armenia	..	..	..	..	5.04	1.59	1.24	0.84	0.78	0.74	0.68	-86.4%
Azerbaijan	..	..	..	..	5.44	6.45	4.23	2.48	1.20	0.92	0.87	-84.0%
Belarus	..	..	..	..	5.25	3.97	2.79	2.05	1.62	1.56	1.52	-71.0%
Bosnia and Herzegovina	..	..	..	..	10.26	1.30	1.60	1.45	1.55	1.55	1.58	-84.6%
Bulgaria	5.87	4.95	4.26	3.50	2.99	2.43	1.90	1.59	1.41	1.28	1.33	-55.6%
Croatia	..	..	..	..	0.51	0.52	0.49	0.46	0.42	0.42	0.41	-20.9%
Cyprus	0.76	0.61	0.49	0.40	0.40	0.43	0.43	0.41	0.39	0.39	0.38	-5.4%
Georgia	..	..	..	..	2.77	2.38	1.02	0.68	0.59	0.69	0.60	-78.4%
Gibraltar	0.22	0.20	0.21	0.19	0.25	0.42	0.43	0.44	0.44	0.48	0.50	99.0%
Kazakhstan	..	..	..	..	4.71	5.43	3.24	2.75	3.20	2.75	3.01	-36.1%
Kosovo **	..	..	..	..	..	..	1.88	1.72	1.63	1.77	1.75	..
Kyrgyzstan	..	..	..	..	7.32	2.85	2.18	2.05	1.99	2.34	2.31	-68.5%
Latvia	..	..	..	..	1.30	1.08	0.63	0.47	0.42	0.46	0.52	-59.9%
Lithuania	..	..	..	..	1.34	0.99	0.63	0.52	0.45	0.46	0.49	-63.5%
FYR of Macedonia	..	..	..	..	1.40	1.71	1.52	1.47	1.29	1.21	1.16	-17.1%
Malta	0.73	0.48	0.42	0.45	0.67	0.53	0.37	0.45	0.38	0.38	0.37	-44.5%
Republic of Moldova	..	..	..	..	5.06	4.57	2.68	2.27	1.83	1.76	1.75	-65.5%
Montenegro **	..	..	..	..	..	..	..	0.62	0.66	0.45	0.75	..
Romania	3.02	2.45	2.13	1.78	1.88	1.46	1.15	0.95	0.75	0.70	0.66	-64.8%
Russian Federation	..	..	..	..	2.58	3.01	2.65	1.98	1.69	1.75	1.75	-32.4%
Serbia **	..	..	..	..	1.48	2.04	1.98	1.94	1.74	1.68	1.65	11.9%
Tajikistan	..	..	..	..	2.91	1.71	1.52	1.01	1.04	0.92	0.86	-70.5%
Turkmenistan	..	..	..	..	9.29	11.04	9.45	5.56	4.72	3.91	3.93	-57.7%
Ukraine	..	..	..	..	5.02	5.97	4.90	3.55	3.04	2.86	2.94	-41.4%
Uzbekistan	..	..	..	..	10.68	11.16	10.69	7.53	6.27	5.23	4.66	-56.3%
Former Soviet Union ***	3.09	3.18	3.10	2.92	..	..	..	..	..	..	..	..
Former Yugoslavia ***	0.98	0.94	0.82	1.12	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**2.93**	**2.96**	**2.83**	**2.68**	**2.91**	**3.07**	**2.56**	**1.96**	**1.70**	**1.68**	**1.70**	**-41.5%**
Algeria	0.35	0.36	0.55	0.66	0.77	0.82	0.79	0.78	0.82	0.88	0.85	10.2%
Angola	0.12	0.15	0.20	0.19	0.23	0.29	0.27	0.24	0.25	0.28	0.31	33.1%
Benin	0.23	0.33	0.23	0.22	0.11	0.08	0.40	0.62	0.77	0.82	0.86	651.3%
Botswana	..	..	..	0.60	0.65	0.60	0.53	0.43	0.39	0.39	0.39	-39.8%
Cameroon	0.15	0.16	0.19	0.18	0.22	0.23	0.20	0.18	0.23	0.26	0.26	18.3%
Congo	0.37	0.28	0.26	0.17	0.14	0.11	0.10	0.14	0.20	0.21	0.21	48.0%
Dem. Rep. of Congo	0.26	0.25	0.33	0.31	0.29	0.29	0.29	0.32	0.33	0.33	0.33	15.9%
Côte d'Ivoire	0.30	0.30	0.28	0.25	0.20	0.23	0.37	0.36	0.38	0.34	0.32	56.8%
Egypt	1.28	1.41	1.44	1.61	1.58	1.42	1.34	1.70	1.59	1.50	1.47	-7.3%
Eritrea	..	..	..	..	..	0.83	0.63	0.55	0.46	0.45	0.47	..
Ethiopia	0.25	0.22	0.25	0.27	0.32	0.33	0.36	0.36	0.34	0.31	0.27	-17.4%
Gabon	0.16	0.12	0.23	0.27	0.13	0.17	0.17	0.25	0.25	0.27	0.27	100.8%
Ghana	0.43	0.55	0.51	0.50	0.49	0.49	0.61	0.60	0.56	0.66	0.64	30.6%
Kenya	0.65	0.54	0.51	0.47	0.42	0.40	0.43	0.38	0.40	0.46	0.46	9.8%
Libya	0.09	0.26	0.34	0.58	0.77	1.03	1.10	0.97	0.92	0.95	0.95	22.3%
Morocco	0.42	0.51	0.55	0.55	0.53	0.67	0.63	0.67	0.63	0.59	0.61	14.5%
Mozambique	0.99	0.95	0.92	0.76	0.42	0.38	0.30	0.23	0.25	0.26	0.27	-36.7%
Namibia	..	..	..	..	..	0.36	0.31	0.34	0.42	0.39	0.37	..
Nigeria	0.14	0.25	0.47	0.66	0.46	0.43	0.50	0.49	0.37	0.29	0.30	-35.7%
Senegal	0.36	0.43	0.51	0.46	0.42	0.44	0.52	0.53	0.52	0.53	0.53	27.6%
South Africa	1.42	1.59	1.42	1.45	1.48	1.54	1.45	1.33	1.36	1.31	1.20	-19.0%
Sudan	0.48	0.39	0.39	0.43	0.46	0.29	0.26	0.33	0.34	0.36	0.35	-23.0%
United Rep. of Tanzania	0.39	0.32	0.29	0.27	0.23	0.31	0.26	0.36	0.33	0.30	0.30	32.5%
Togo	0.37	0.29	0.26	0.22	0.37	0.37	0.50	0.46	0.48	0.48	0.48	28.4%
Tunisia	0.66	0.63	0.68	0.67	0.74	0.72	0.69	0.63	0.57	0.54	0.54	-26.3%
Zambia	0.82	0.94	0.70	0.57	0.49	0.41	0.30	0.29	0.19	0.19	0.20	-59.7%
Zimbabwe	1.94	1.66	1.71	1.67	2.23	1.95	1.53	1.86	1.84	1.84	1.83	-17.9%
Other Africa	0.23	0.26	0.33	0.29	0.31	0.37	0.33	0.29	0.28	0.28	0.28	-11.6%
Africa	**0.67**	**0.77**	**0.77**	**0.86**	**0.87**	**0.90**	**0.86**	**0.83**	**0.80**	**0.78**	**0.74**	**-14.8%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

CO_2 emissions / GDP using exchange rates

kilogrammes CO_2 / US dollar using 2005 prices

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	0.18	0.28	0.36	0.37	0.47	0.57	0.55	0.61	0.64	0.66	0.65	38.8%
Brunei Darussalam	0.10	0.28	0.32	0.43	0.49	0.58	0.54	0.53	0.77	0.85	0.82	68.5%
Cambodia	..	..	..	..	..	0.52	0.49	0.42	0.43	0.44	0.43	..
Chinese Taipei	1.01	0.91	0.91	0.65	0.68	0.67	0.71	0.72	0.64	0.62	0.61	-11.6%
India	1.30	1.38	1.39	1.57	1.66	1.73	1.63	1.40	1.37	1.36	1.30	-21.6%
Indonesia	0.62	0.69	0.85	0.83	0.97	0.98	1.20	1.17	1.07	1.07	1.09	11.9%
DPR of Korea	8.51	6.17	4.92	3.68	2.79	2.33	2.41	2.49	2.36	2.17	2.29	-18.0%
Malaysia	0.83	0.79	0.79	0.85	0.90	0.96	1.03	1.10	1.13	1.06	1.08	19.5%
Mongolia	..	..	..	7.53	6.85	6.24	4.78	3.76	3.41	3.61	3.44	-49.8%
Myanmar	2.38	1.87	1.78	1.60	1.23	1.57	1.43	0.88	0.45	0.38	0.39	-68.3%
Nepal	0.09	0.13	0.19	0.16	0.21	0.32	0.44	0.37	0.31	0.35	0.36	73.6%
Pakistan	0.82	0.89	0.82	0.89	1.00	1.09	1.13	1.07	1.07	1.06	1.00	-0.5%
Philippines	0.74	0.74	0.63	0.58	0.62	0.83	0.82	0.69	0.58	0.58	0.58	-5.3%
Singapore	0.56	0.56	0.55	0.50	0.60	0.57	0.49	0.41	0.37	0.38	0.37	-37.8%
Sri Lanka	0.52	0.43	0.46	0.35	0.31	0.35	0.53	0.55	0.41	0.39	0.40	29.5%
Thailand	0.72	0.74	0.81	0.77	0.91	1.04	1.15	1.23	1.15	1.17	1.18	30.7%
Vietnam	1.69	1.73	1.45	1.22	0.97	1.06	1.19	1.51	1.54	1.64	1.76	81.3%
Other Asia	0.56	0.60	0.84	0.47	0.43	0.31	0.35	0.36	0.32	0.34	0.34	-19.4%
Asia	**1.12**	**1.13**	**1.11**	**1.12**	**1.14**	**1.14**	**1.16**	**1.10**	**1.06**	**1.06**	**1.04**	**-9.3%**
People's Rep. of China	6.31	6.66	6.50	4.74	4.21	3.19	2.14	2.24	2.04	1.96	1.88	-55.3%
Hong Kong, China	0.41	0.36	0.28	0.32	0.33	0.28	0.27	0.23	0.20	0.23	0.19	-42.1%
China	**5.43**	**5.66**	**5.30**	**4.03**	**3.59**	**2.84**	**1.97**	**2.10**	**1.93**	**1.86**	**1.79**	**-50.2%**
Argentina	0.85	0.79	0.77	0.81	0.94	0.81	0.84	0.82	0.75	0.71	0.67	-28.5%
Bolivia	0.54	0.64	0.75	0.84	0.91	0.99	0.87	0.99	1.09	1.11	1.18	29.4%
Brazil	0.36	0.37	0.35	0.31	0.32	0.35	0.39	0.37	0.35	0.33	0.35	9.3%
Colombia	0.64	0.56	0.51	0.52	0.48	0.49	0.48	0.39	0.34	0.35	0.33	-30.5%
Costa Rica	0.27	0.29	0.28	0.26	0.26	0.34	0.27	0.29	0.27	0.26	0.26	-0.4%
Cuba	1.11	1.08	1.17	0.82	0.88	0.83	0.81	0.59	0.47	0.60	0.55	-37.7%
Dominican Republic	0.49	0.53	0.50	0.45	0.48	0.56	0.61	0.51	0.45	0.41	0.39	-19.8%
Ecuador	0.35	0.42	0.55	0.59	0.56	0.61	0.65	0.66	0.63	0.69	0.68	21.7%
El Salvador	0.17	0.20	0.17	0.20	0.23	0.35	0.34	0.36	0.33	0.34	0.32	38.9%
Guatemala	0.26	0.28	0.29	0.24	0.20	0.30	0.36	0.39	0.32	0.35	0.32	54.6%
Haiti	0.12	0.12	0.14	0.18	0.22	0.24	0.33	0.48	0.53	0.52	0.49	123.7%
Honduras	0.41	0.42	0.38	0.34	0.38	0.53	0.57	0.71	0.68	0.65	0.63	64.4%
Jamaica	0.76	0.96	1.00	0.70	0.85	0.81	0.96	0.94	1.02	0.74	0.71	-15.6%
Netherlands Antilles	13.67	8.49	6.36	3.13	1.60	1.47	1.73	1.68	1.58	1.91	1.43	-10.9%
Nicaragua	0.43	0.43	0.52	0.51	0.61	0.77	0.84	0.83	0.74	0.76	0.77	25.1%
Panama	0.52	0.56	0.44	0.34	0.33	0.41	0.39	0.44	0.32	0.36	0.38	12.3%
Paraguay	0.30	0.28	0.32	0.31	0.35	0.52	0.49	0.46	0.43	0.49	0.48	38.9%
Peru	0.45	0.44	0.43	0.38	0.44	0.41	0.41	0.36	0.35	0.37	0.37	-14.8%
Trinidad and Tobago	1.02	0.85	0.79	1.08	1.43	1.44	1.94	2.12	2.02	2.14	2.28	59.9%
Uruguay	0.57	0.55	0.45	0.31	0.30	0.30	0.31	0.31	0.36	0.36	0.27	-9.9%
Venezuela	0.70	0.74	0.96	1.04	1.01	0.96	0.99	1.02	0.92	0.95	1.05	4.1%
Other Non-OECD Americas	0.62	0.82	0.58	0.50	0.52	0.53	0.49	0.48	0.46	0.50	0.50	-2.7%
Non-OECD Americas	**0.56**	**0.53**	**0.52**	**0.49**	**0.50**	**0.51**	**0.54**	**0.52**	**0.48**	**0.48**	**0.48**	**-3.8%**
Bahrain	1.82	1.73	1.48	2.23	2.00	1.43	1.41	1.35	1.35	1.34	1.33	-33.5%
Islamic Republic of Iran	0.62	0.75	1.09	1.46	1.76	2.09	2.15	2.20	2.22	2.25	2.21	25.4%
Iraq	0.12	0.15	0.17	0.36	0.99	4.70	1.65	2.39	1.98	2.39	2.69	172.8%
Jordan	0.59	0.96	0.93	1.25	1.65	1.54	1.55	1.43	1.17	1.19	1.11	-32.6%
Kuwait	0.26	0.33	0.66	1.17	0.79	0.73	0.90	0.87	0.79	0.91	0.97	23.7%
Lebanon	0.32	0.40	0.55	0.39	0.57	0.76	0.78	0.66	0.61	0.68	0.62	8.2%
Oman	0.06	0.13	0.32	0.40	0.62	0.67	0.78	0.91	0.93	1.01	0.97	57.3%
Qatar	0.15	0.32	0.43	0.81	0.95	1.14	0.82	0.87	0.61	0.64	0.63	-33.5%
Saudi Arabia	0.17	0.15	0.46	0.72	0.79	0.90	0.96	1.06	1.12	1.19	1.24	56.1%
Syrian Arab Republic	1.27	1.12	1.18	1.64	2.04	1.62	1.75	1.90	1.87	1.61	1.58	-22.6%
United Arab Emirates	0.20	0.16	0.23	0.46	0.59	0.66	0.62	0.60	0.69	0.72	0.73	24.0%
Yemen	0.63	0.65	0.73	0.71	0.81	0.90	0.97	1.13	1.14	1.12	1.04	29.0%
Middle East	**0.30**	**0.33**	**0.48**	**0.80**	**1.00**	**1.23**	**1.18**	**1.24**	**1.23**	**1.29**	**1.29**	**28.8%**

CO_2 emissions / GDP using purchasing power parities

kilogrammes CO_2 / US dollar using 2005 prices

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World *	**0.74**	**0.70**	**0.66**	**0.60**	**0.58**	**0.54**	**0.49**	**0.47**	**0.45**	**0.44**	**0.44**	**-23.6%**
Annex I Parties	*..*	*..*	*..*	*..*	*0.55*	*0.50*	*0.44*	*0.40*	*0.37*	*0.36*	*0.36*	*-33.8%*
Annex II Parties	*0.73*	*0.67*	*0.60*	*0.51*	*0.46*	*0.43*	*0.40*	*0.37*	*0.34*	*0.33*	*0.33*	*-27.8%*
North America	*0.97*	*0.89*	*0.80*	*0.66*	*0.61*	*0.57*	*0.51*	*0.46*	*0.43*	*0.41*	*0.42*	*-31.8%*
Europe	*0.57*	*0.51*	*0.48*	*0.41*	*0.35*	*0.32*	*0.29*	*0.27*	*0.25*	*0.24*	*0.24*	*-31.8%*
Asia Oceania	*0.55*	*0.53*	*0.46*	*0.38*	*0.36*	*0.36*	*0.36*	*0.35*	*0.32*	*0.32*	*0.32*	*-11.1%*
Annex I EIT	*..*	*..*	*..*	*..*	*1.14*	*1.15*	*0.94*	*0.74*	*0.63*	*0.62*	*0.63*	*-44.9%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*0.59*	*0.58*	*0.52*	*0.53*	*0.51*	*0.51*	*0.50*	*-15.5%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*0.52*	*0.46*	*0.41*	*0.37*	*0.34*	*0.34*	*0.34*	*-35.3%*
Non-OECD Total **	**0.71**	**0.73**	**0.72**	**0.72**	**0.75**	**0.70**	**0.60**	**0.59**	**0.55**	**0.54**	**0.53**	**-29.2%**
OECD Total ***	**0.72**	**0.66**	**0.60**	**0.52**	**0.46**	**0.44**	**0.40**	**0.37**	**0.34**	**0.33**	**0.34**	**-27.8%**
Canada	0.86	0.80	0.75	0.62	0.58	0.57	0.53	0.49	0.46	0.45	0.45	-22.8%
Chile	0.42	0.40	0.35	0.31	0.36	0.30	0.33	0.29	0.30	0.30	0.30	-16.2%
Mexico	0.25	0.27	0.30	0.33	0.32	0.33	0.30	0.30	0.28	0.30	0.30	-6.3%
United States	0.98	0.90	0.80	0.67	0.61	0.57	0.51	0.46	0.43	0.41	0.41	-32.5%
OECD Americas	**0.91**	**0.84**	**0.75**	**0.63**	**0.58**	**0.55**	**0.49**	**0.45**	**0.41**	**0.40**	**0.40**	**-30.6%**
Australia	0.59	0.66	0.66	0.61	0.61	0.57	0.56	0.51	0.49	0.48	0.46	-23.9%
Israel	0.38	0.35	0.34	0.37	0.41	0.41	0.38	0.36	0.34	0.34	0.34	-15.8%
Japan	0.55	0.52	0.43	0.35	0.33	0.33	0.33	0.32	0.29	0.29	0.29	-11.0%
Korea	0.60	0.62	0.67	0.54	0.49	0.52	0.50	0.43	0.40	0.41	0.43	-13.1%
New Zealand	0.30	0.31	0.31	0.32	0.36	0.35	0.36	0.32	0.31	0.28	0.28	-24.2%
OECD Asia Oceania	**0.55**	**0.53**	**0.47**	**0.39**	**0.38**	**0.39**	**0.38**	**0.36**	**0.34**	**0.34**	**0.34**	**-8.7%**
Austria	0.42	0.38	0.36	0.32	0.29	0.27	0.24	0.27	0.23	0.22	0.23	-19.2%
Belgium	0.77	0.66	0.61	0.47	0.43	0.43	0.38	0.33	0.31	0.29	0.30	-31.0%
Czech Republic	1.28	1.13	1.10	1.10	0.91	0.76	0.68	0.55	0.46	0.46	0.46	-49.4%
Denmark	0.63	0.56	0.59	0.50	0.39	0.40	0.30	0.27	0.26	0.26	0.26	-31.8%
Estonia	..	..	..	..	2.23	1.41	0.93	0.76	0.70	0.67	0.83	-62.7%
Finland	0.66	0.61	0.65	0.50	0.47	0.50	0.39	0.34	0.32	0.34	0.37	-21.0%
France	0.53	0.45	0.41	0.30	0.25	0.24	0.22	0.21	0.19	0.19	0.19	-25.3%
Germany	0.77	0.70	0.65	0.58	0.46	0.38	0.33	0.32	0.29	0.28	0.28	-39.7%
Greece	0.22	0.26	0.28	0.33	0.40	0.41	0.39	0.35	0.32	0.32	0.31	-22.8%
Hungary	0.76	0.69	0.69	0.61	0.49	0.47	0.39	0.33	0.30	0.29	0.29	-40.8%
Iceland	0.46	0.44	0.35	0.29	0.29	0.29	0.25	0.21	0.18	0.19	0.18	-35.9%
Ireland	0.73	0.57	0.56	0.51	0.45	0.39	0.32	0.27	0.25	0.24	0.24	-47.2%
Italy	0.39	0.37	0.34	0.30	0.30	0.29	0.27	0.28	0.26	0.24	0.24	-17.5%
Luxembourg	1.93	1.35	1.19	0.87	0.64	0.41	0.30	0.36	0.29	0.30	0.30	-52.5%
Netherlands	0.54	0.51	0.53	0.46	0.40	0.39	0.32	0.32	0.29	0.29	0.30	-23.3%
Norway	0.33	0.28	0.26	0.22	0.21	0.20	0.17	0.17	0.16	0.16	0.17	-17.1%
Poland	1.22	1.12	1.32	1.32	1.10	0.95	0.64	0.56	0.48	0.45	0.46	-58.0%
Portugal	0.18	0.20	0.20	0.20	0.24	0.27	0.27	0.28	0.23	0.23	0.21	-14.1%
Slovak Republic	0.90	0.89	1.01	0.92	0.89	0.70	0.55	0.44	0.33	0.32	0.32	-64.1%
Slovenia	..	..	..	..	0.38	0.42	0.36	0.33	0.30	0.30	0.30	-21.8%
Spain	0.28	0.30	0.33	0.28	0.27	0.28	0.28	0.29	0.25	0.23	0.22	-19.1%
Sweden	0.59	0.50	0.43	0.32	0.25	0.26	0.20	0.17	0.14	0.14	0.15	-40.5%
Switzerland	0.24	0.22	0.22	0.21	0.18	0.18	0.17	0.17	0.15	0.15	0.15	-19.2%
Turkey	0.22	0.25	0.27	0.28	0.29	0.30	0.32	0.28	0.30	0.31	0.29	0.1%
United Kingdom	0.76	0.65	0.58	0.50	0.43	0.37	0.31	0.27	0.25	0.24	0.24	-44.1%
OECD Europe ***	**0.61**	**0.55**	**0.52**	**0.46**	**0.39**	**0.35**	**0.31**	**0.29**	**0.27**	**0.26**	**0.26**	**-33.6%**
European Union - 27	*..*	*..*	*..*	*..*	*0.42*	*0.37*	*0.32*	*0.30*	*0.27*	*0.26*	*0.26*	*-37.2%*

* The ratio for the world has been calculated to include international marine bunkers and international aviation bunkers.
** Includes Estonia and Slovenia prior to 1990.
*** Excludes Estonia and Slovenia prior to 1990.

CO_2 emissions / GDP using purchasing power parities

kilogrammes CO_2 / US dollar using 2005 prices

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**0.71**	**0.73**	**0.72**	**0.72**	**0.75**	**0.70**	**0.60**	**0.59**	**0.55**	**0.54**	**0.53**	**-29.2%**
Albania	0.57	0.52	0.67	0.57	0.49	0.17	0.21	0.21	0.17	0.15	0.15	-68.5%
Armenia	..	..	..	..	1.96	0.62	0.48	0.33	0.30	0.29	0.27	-86.4%
Azerbaijan	..	..	..	..	1.91	2.26	1.48	0.87	0.42	0.32	0.31	-84.0%
Belarus	..	..	..	..	1.90	1.44	1.01	0.74	0.59	0.57	0.55	-71.0%
Bosnia and Herzegovina	..	..	..	..	4.68	0.59	0.73	0.66	0.71	0.71	0.72	-84.6%
Bulgaria	2.23	1.88	1.62	1.33	1.14	0.92	0.72	0.60	0.54	0.49	0.51	-55.6%
Croatia	..	..	..	..	0.34	0.34	0.32	0.30	0.27	0.27	0.27	-20.9%
Cyprus	0.70	0.56	0.45	0.37	0.37	0.40	0.40	0.38	0.36	0.36	0.35	-5.4%
Georgia	..	..	..	..	1.13	0.97	0.42	0.28	0.24	0.28	0.24	-78.4%
Gibraltar	0.25	0.23	0.25	0.22	0.29	0.48	0.49	0.51	0.51	0.55	0.58	99.0%
Kazakhstan	..	..	..	..	2.04	2.35	1.40	1.19	1.39	1.19	1.30	-36.1%
Kosovo **	..	..	..	..	..	..	0.75	0.69	0.65	0.71	0.70	..
Kyrgyzstan	..	..	..	..	2.03	0.79	0.60	0.57	0.55	0.65	0.64	-68.5%
Latvia	..	..	..	..	0.69	0.58	0.34	0.25	0.22	0.25	0.28	-59.9%
Lithuania	..	..	..	..	0.72	0.53	0.34	0.28	0.24	0.25	0.26	-63.5%
FYR of Macedonia	..	..	..	..	0.52	0.64	0.56	0.55	0.48	0.45	0.43	-17.2%
Malta	0.52	0.34	0.30	0.32	0.47	0.37	0.26	0.32	0.27	0.27	0.26	-44.5%
Republic of Moldova	..	..	..	..	1.78	1.61	0.94	0.80	0.64	0.62	0.62	-65.5%
Montenegro **	..	..	..	..	..	..	..	0.27	0.29	0.20	0.33	..
Romania	1.48	1.19	1.04	0.87	0.92	0.71	0.56	0.46	0.37	0.34	0.32	-64.8%
Russian Federation	..	..	..	..	1.16	1.35	1.19	0.89	0.76	0.79	0.79	-32.4%
Serbia **	..	..	..	..	0.59	0.82	0.80	0.77	0.69	0.67	0.66	11.5%
Tajikistan	..	..	..	..	0.69	0.41	0.36	0.24	0.25	0.22	0.20	-70.5%
Turkmenistan	..	..	..	..	3.33	3.96	3.39	1.99	1.69	1.40	1.41	-57.7%
Ukraine	..	..	..	..	1.64	1.96	1.61	1.16	1.00	0.94	0.96	-41.4%
Uzbekistan	..	..	..	..	2.92	3.05	2.92	2.06	1.71	1.43	1.27	-56.3%
Former Soviet Union ***	1.31	1.35	1.32	1.24	..	..	..	..	..	..	..	..
Former Yugoslavia ***	0.54	0.53	0.46	0.62	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**1.28**	**1.29**	**1.24**	**1.17**	**1.26**	**1.35**	**1.13**	**0.86**	**0.75**	**0.74**	**0.74**	**-40.9%**
Algeria	0.15	0.16	0.24	0.29	0.34	0.36	0.34	0.34	0.35	0.38	0.37	10.1%
Angola	0.06	0.08	0.10	0.10	0.12	0.15	0.14	0.12	0.13	0.14	0.16	33.1%
Benin	0.10	0.14	0.10	0.09	0.05	0.03	0.17	0.26	0.32	0.34	0.36	651.1%
Botswana	..	..	..	0.29	0.31	0.28	0.25	0.20	0.18	0.18	0.18	-39.8%
Cameroon	0.07	0.08	0.09	0.09	0.11	0.11	0.10	0.08	0.11	0.12	0.12	18.3%
Congo	0.19	0.15	0.13	0.09	0.07	0.05	0.05	0.07	0.10	0.11	0.11	48.2%
Dem. Rep. of Congo	0.12	0.11	0.15	0.14	0.13	0.13	0.13	0.14	0.15	0.15	0.15	15.9%
Côte d'Ivoire	0.16	0.17	0.15	0.13	0.11	0.12	0.20	0.19	0.21	0.19	0.17	56.9%
Egypt	0.34	0.38	0.39	0.43	0.43	0.38	0.36	0.46	0.43	0.40	0.39	-7.3%
Eritrea	..	..	..	..	..	0.34	0.26	0.22	0.19	0.19	0.19	..
Ethiopia	0.06	0.06	0.06	0.07	0.08	0.09	0.09	0.09	0.09	0.08	0.07	-17.4%
Gabon	0.08	0.06	0.11	0.13	0.06	0.08	0.08	0.12	0.12	0.13	0.13	100.9%
Ghana	0.18	0.23	0.21	0.20	0.20	0.20	0.25	0.25	0.23	0.27	0.26	30.7%
Kenya	0.25	0.21	0.20	0.18	0.17	0.16	0.17	0.15	0.16	0.18	0.18	9.7%
Libya	0.05	0.14	0.18	0.31	0.42	0.56	0.60	0.53	0.50	0.52	0.52	22.4%
Morocco	0.23	0.28	0.30	0.30	0.29	0.37	0.35	0.37	0.34	0.32	0.33	14.5%
Mozambique	0.47	0.45	0.43	0.36	0.20	0.18	0.14	0.11	0.12	0.12	0.13	-36.7%
Namibia	..	..	..	..	..	0.24	0.21	0.23	0.28	0.26	0.25	..
Nigeria	0.07	0.11	0.22	0.30	0.21	0.20	0.23	0.23	0.17	0.13	0.14	-35.7%
Senegal	0.17	0.20	0.25	0.22	0.20	0.21	0.25	0.26	0.25	0.25	0.25	27.7%
South Africa	0.87	0.97	0.86	0.89	0.90	0.94	0.88	0.81	0.83	0.80	0.73	-19.0%
Sudan	0.21	0.17	0.17	0.19	0.20	0.13	0.12	0.15	0.15	0.16	0.16	-23.0%
United Rep. of Tanzania	0.14	0.11	0.10	0.09	0.08	0.11	0.09	0.13	0.12	0.11	0.11	32.5%
Togo	0.17	0.13	0.12	0.10	0.17	0.17	0.23	0.21	0.22	0.22	0.22	28.4%
Tunisia	0.29	0.28	0.30	0.30	0.33	0.32	0.31	0.28	0.25	0.24	0.24	-26.3%
Zambia	0.44	0.51	0.38	0.31	0.27	0.22	0.16	0.16	0.10	0.10	0.11	-59.6%
Zimbabwe	2.87	2.45	2.53	2.47	3.30	2.88	2.26	2.74	2.72	2.72	2.71	-17.9%
Other Africa	0.10	0.11	0.14	0.12	0.13	0.15	0.14	0.12	0.12	0.12	0.12	-12.3%
Africa	**0.32**	**0.37**	**0.37**	**0.40**	**0.41**	**0.42**	**0.40**	**0.38**	**0.37**	**0.35**	**0.34**	**-17.6%**

* Includes Estonia and Slovenia prior to 1990.
** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.
*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

CO_2 emissions / GDP using purchasing power parities

kilogrammes CO_2 / US dollar using 2005 prices

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	0.07	0.10	0.13	0.13	0.17	0.21	0.20	0.22	0.24	0.24	0.24	38.8%
Brunei Darussalam	0.05	0.15	0.17	0.23	0.26	0.32	0.29	0.29	0.42	0.46	0.45	68.5%
Cambodia	..	..	..	..	..	0.16	0.15	0.13	0.13	0.14	0.14	..
Chinese Taipei	0.61	0.55	0.55	0.39	0.41	0.40	0.43	0.43	0.38	0.37	0.36	-11.6%
India	0.43	0.46	0.46	0.52	0.55	0.57	0.54	0.46	0.45	0.45	0.43	-21.6%
Indonesia	0.25	0.28	0.35	0.34	0.39	0.40	0.49	0.48	0.43	0.43	0.44	11.9%
DPR of Korea	2.27	1.64	1.31	0.98	0.74	0.62	0.64	0.66	0.63	0.58	0.61	-18.0%
Malaysia	0.38	0.36	0.36	0.39	0.41	0.44	0.47	0.50	0.52	0.48	0.49	19.5%
Mongolia	..	..	..	2.61	2.37	2.16	1.66	1.30	1.18	1.25	1.19	-49.8%
Myanmar	0.06	0.05	0.04	0.04	0.03	0.04	0.03	0.02	0.01	0.01	0.01	-68.4%
Nepal	0.03	0.04	0.06	0.05	0.07	0.10	0.14	0.12	0.10	0.11	0.11	73.7%
Pakistan	0.26	0.29	0.26	0.29	0.32	0.35	0.37	0.35	0.34	0.34	0.32	-0.5%
Philippines	0.29	0.29	0.25	0.23	0.24	0.33	0.32	0.27	0.23	0.23	0.23	-5.3%
Singapore	0.36	0.36	0.35	0.32	0.38	0.36	0.31	0.26	0.24	0.24	0.24	-37.8%
Sri Lanka	0.18	0.15	0.16	0.12	0.11	0.12	0.19	0.19	0.14	0.14	0.14	29.5%
Thailand	0.29	0.29	0.32	0.30	0.36	0.41	0.46	0.49	0.46	0.46	0.47	30.7%
Vietnam	0.50	0.51	0.43	0.36	0.29	0.31	0.36	0.45	0.46	0.49	0.52	81.3%
Other Asia	0.24	0.28	0.43	0.23	0.24	0.17	0.19	0.19	0.18	0.18	0.18	-25.8%
Asia	**0.39**	**0.40**	**0.40**	**0.40**	**0.43**	**0.43**	**0.44**	**0.40**	**0.38**	**0.38**	**0.37**	**-13.9%**
People's Rep. of China	2.65	2.80	2.73	1.99	1.77	1.34	0.90	0.94	0.86	0.82	0.79	-55.3%
Hong Kong, China	0.30	0.27	0.21	0.24	0.24	0.21	0.20	0.17	0.15	0.17	0.14	-42.1%
China	**2.44**	**2.55**	**2.43**	**1.82**	**1.62**	**1.26**	**0.86**	**0.91**	**0.83**	**0.80**	**0.77**	**-52.4%**
Argentina	0.37	0.35	0.34	0.35	0.41	0.35	0.37	0.36	0.33	0.31	0.29	-28.5%
Bolivia	0.15	0.18	0.21	0.23	0.25	0.28	0.24	0.27	0.30	0.31	0.33	29.4%
Brazil	0.20	0.21	0.20	0.17	0.18	0.19	0.22	0.20	0.20	0.19	0.20	9.3%
Colombia	0.30	0.26	0.24	0.24	0.22	0.23	0.22	0.18	0.16	0.16	0.15	-30.5%
Costa Rica	0.14	0.15	0.15	0.13	0.14	0.18	0.14	0.15	0.14	0.14	0.14	-0.4%
Cuba	0.98	0.95	1.03	0.72	0.77	0.73	0.72	0.52	0.41	0.53	0.48	-37.7%
Dominican Republic	0.28	0.31	0.29	0.26	0.28	0.32	0.35	0.30	0.26	0.23	0.22	-19.8%
Ecuador	0.15	0.18	0.23	0.25	0.24	0.26	0.27	0.28	0.26	0.29	0.29	21.7%
El Salvador	0.08	0.10	0.09	0.10	0.11	0.18	0.17	0.18	0.16	0.17	0.16	38.9%
Guatemala	0.14	0.15	0.15	0.12	0.11	0.16	0.19	0.20	0.17	0.19	0.17	54.5%
Haiti	0.05	0.05	0.06	0.08	0.10	0.10	0.14	0.21	0.23	0.23	0.21	123.7%
Honduras	0.18	0.18	0.16	0.15	0.17	0.23	0.25	0.31	0.29	0.28	0.27	64.4%
Jamaica	0.46	0.58	0.60	0.42	0.51	0.49	0.57	0.56	0.61	0.44	0.43	-15.6%
Netherlands Antilles	15.22	9.47	7.09	3.49	1.78	1.64	1.93	1.87	1.76	2.13	1.59	-10.9%
Nicaragua	0.17	0.17	0.20	0.20	0.24	0.29	0.32	0.32	0.29	0.29	0.29	25.1%
Panama	0.27	0.29	0.23	0.18	0.17	0.21	0.21	0.23	0.17	0.19	0.20	12.3%
Paraguay	0.10	0.09	0.10	0.10	0.11	0.17	0.16	0.15	0.14	0.16	0.16	38.9%
Peru	0.20	0.20	0.20	0.17	0.20	0.19	0.18	0.16	0.16	0.17	0.17	-14.8%
Trinidad and Tobago	0.62	0.52	0.48	0.65	0.86	0.87	1.17	1.28	1.22	1.30	1.38	59.9%
Uruguay	0.31	0.30	0.24	0.17	0.17	0.16	0.17	0.17	0.20	0.19	0.15	-9.9%
Venezuela	0.38	0.41	0.53	0.57	0.56	0.53	0.55	0.56	0.51	0.52	0.58	4.1%
Other Non-OECD Americas	0.53	0.72	0.51	0.44	0.46	0.47	0.43	0.43	0.41	0.45	0.45	-3.7%
Non-OECD Americas	**0.29**	**0.28**	**0.27**	**0.26**	**0.27**	**0.26**	**0.28**	**0.27**	**0.25**	**0.25**	**0.25**	**-5.1%**
Bahrain	1.20	1.15	0.98	1.47	1.33	0.95	0.93	0.89	0.89	0.89	0.88	-33.5%
Islamic Republic of Iran	0.18	0.22	0.33	0.44	0.53	0.62	0.64	0.66	0.66	0.67	0.66	25.4%
Iraq	0.05	0.06	0.06	0.14	0.37	1.78	0.63	0.91	0.75	0.91	1.02	172.8%
Jordan	0.32	0.52	0.50	0.67	0.89	0.83	0.83	0.77	0.63	0.64	0.60	-32.6%
Kuwait	0.19	0.24	0.48	0.85	0.57	0.53	0.66	0.63	0.58	0.67	0.71	23.6%
Lebanon	0.18	0.23	0.31	0.22	0.32	0.43	0.44	0.37	0.34	0.38	0.35	8.1%
Oman	0.04	0.08	0.19	0.24	0.37	0.40	0.47	0.55	0.56	0.61	0.59	57.3%
Qatar	0.11	0.24	0.33	0.61	0.72	0.86	0.62	0.66	0.46	0.48	0.48	-33.5%
Saudi Arabia	0.11	0.09	0.30	0.47	0.51	0.58	0.62	0.68	0.72	0.76	0.80	56.1%
Syrian Arab Republic	0.48	0.42	0.45	0.62	0.77	0.61	0.66	0.72	0.71	0.61	0.60	-22.6%
United Arab Emirates	0.14	0.11	0.15	0.30	0.39	0.44	0.41	0.40	0.46	0.48	0.48	24.0%
Yemen	0.23	0.23	0.27	0.26	0.29	0.33	0.35	0.41	0.41	0.41	0.38	29.0%
Middle East	**0.14**	**0.15**	**0.23**	**0.38**	**0.50**	**0.62**	**0.59**	**0.63**	**0.63**	**0.65**	**0.66**	**32.4%**

CO_2 emissions / population

tonnes CO_2 / capita

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
World *	**3.74**	**3.86**	**4.07**	**3.85**	**3.98**	**3.85**	**3.87**	**4.22**	**4.42**	**4.29**	**4.44**	**11.4%**
Annex I Parties	*..*	*..*	*..*	*..*	*11.83*	*10.91*	*11.17*	*11.23*	*10.90*	*10.12*	*10.41*	*-12.0%*
Annex II Parties	*12.20*	*12.18*	*12.64*	*11.82*	*12.26*	*12.33*	*12.90*	*12.82*	*12.16*	*11.28*	*11.56*	*-5.7%*
North America	*20.16*	*19.82*	*20.17*	*18.72*	*19.08*	*18.94*	*19.90*	*19.27*	*18.15*	*16.74*	*17.16*	*-10.1%*
Europe	*8.63*	*8.56*	*9.11*	*8.36*	*8.36*	*8.16*	*8.26*	*8.35*	*7.92*	*7.30*	*7.43*	*-11.1%*
Asia Oceania	*7.57*	*8.18*	*8.19*	*7.98*	*9.35*	*9.90*	*10.35*	*10.65*	*10.24*	*9.81*	*10.09*	*7.9%*
Annex I EIT	*..*	*..*	*..*	*..*	*12.38*	*8.83*	*8.14*	*8.49*	*8.85*	*8.22*	*8.60*	*-30.6%*
Non-Annex I Parties	*..*	*..*	*..*	*..*	*1.58*	*1.78*	*1.84*	*2.33*	*2.69*	*2.73*	*2.85*	*80.7%*
Annex I Kyoto Parties	*..*	*..*	*..*	*..*	*10.21*	*8.99*	*8.92*	*9.15*	*8.97*	*8.37*	*8.61*	*-15.7%*
Non-OECD Total **	**1.46**	**1.72**	**1.97**	**2.01**	**2.19**	**2.07**	**2.04**	**2.51**	**2.86**	**2.88**	**2.99**	**36.7%**
OECD Total ***	**10.47**	**10.48**	**10.93**	**10.24**	**10.49**	**10.51**	**10.97**	**10.92**	**10.50**	**9.81**	**10.10**	**-3.7%**
Canada	15.46	16.31	17.42	15.57	15.63	15.90	17.38	17.35	16.52	15.58	15.73	0.6%
Chile	2.13	1.63	1.90	1.60	2.36	2.70	3.41	3.58	4.09	3.86	4.08	73.2%
Mexico	1.95	2.45	3.23	3.42	3.26	3.25	3.55	3.71	3.79	3.72	3.85	18.1%
United States	20.66	20.19	20.47	19.06	19.46	19.28	20.18	19.48	18.33	16.86	17.31	-11.0%
OECD Americas	**16.41**	**15.98**	**16.17**	**14.91**	**15.03**	**14.80**	**15.54**	**15.10**	**14.32**	**13.26**	**13.61**	**-9.5%**
Australia	10.92	12.89	14.05	13.90	15.14	15.69	17.58	17.97	17.75	17.33	17.00	12.3%
Israel	4.66	4.90	5.03	5.77	7.17	8.34	8.76	8.44	8.76	8.49	8.93	24.5%
Japan	7.23	7.66	7.52	7.25	8.61	9.14	9.33	9.55	9.04	8.59	8.97	4.2%
Korea	1.58	2.18	3.26	3.76	5.35	7.95	9.31	9.75	10.32	10.57	11.52	115.4%
New Zealand	4.80	5.52	5.23	6.00	6.94	7.14	7.99	8.17	7.94	7.18	7.04	1.4%
OECD Asia Oceania	**6.26**	**6.85**	**7.06**	**7.00**	**8.40**	**9.41**	**10.06**	**10.37**	**10.21**	**9.94**	**10.38**	**23.6%**
Austria	6.49	6.62	7.37	7.18	7.35	7.47	7.70	9.08	8.47	7.60	8.27	12.5%
Belgium	12.09	11.82	12.75	10.34	10.83	11.37	11.58	10.75	10.36	9.33	9.78	-9.7%
Czech Republic	15.35	15.17	16.06	16.75	14.97	11.97	11.86	11.69	11.25	10.50	10.89	-27.3%
Denmark	11.09	10.37	12.21	11.83	9.81	11.09	9.49	8.91	8.82	8.46	8.48	-13.6%
Estonia	..	..	..	..	22.75	11.11	10.66	12.52	13.21	10.94	13.79	-39.4%
Finland	8.62	9.42	11.54	9.91	10.91	10.97	10.64	10.53	10.73	10.30	11.73	7.5%
France	8.24	7.99	8.37	6.37	6.06	5.96	6.21	6.17	5.77	5.45	5.52	-8.9%
Germany	12.49	12.40	13.48	13.06	11.97	10.63	10.04	9.81	9.74	9.12	9.32	-22.2%
Greece	2.80	3.75	4.62	5.41	6.78	7.13	8.01	8.56	8.39	8.00	7.45	9.9%
Hungary	5.82	6.72	7.82	7.64	6.41	5.55	5.31	5.59	5.28	4.81	4.89	-23.6%
Iceland	6.79	7.37	7.62	6.71	7.37	7.30	7.60	7.36	6.57	6.44	6.04	-17.9%
Ireland	7.29	6.64	7.62	7.45	8.50	8.97	10.74	10.49	9.80	8.73	8.64	1.6%
Italy	5.42	5.76	6.38	6.14	7.01	7.20	7.48	7.86	7.27	6.47	6.59	-6.0%
Luxembourg	45.11	33.69	32.75	27.03	27.34	19.92	18.49	24.54	21.64	20.15	20.98	-23.3%
Netherlands	9.82	10.31	11.78	10.63	10.43	11.06	10.81	11.19	11.12	10.66	11.26	8.0%
Norway	6.02	6.01	6.85	6.54	6.67	7.53	7.47	7.86	7.87	7.67	8.01	20.1%
Poland	8.74	9.94	11.61	11.28	9.00	8.65	7.60	7.68	7.83	7.52	7.99	-11.2%
Portugal	1.66	1.97	2.41	2.44	3.93	4.81	5.81	5.95	5.01	5.00	4.53	15.2%
Slovak Republic	8.57	9.25	11.10	10.54	10.71	7.61	6.92	7.07	6.70	6.12	6.45	-39.8%
Slovenia	..	..	..	..	6.26	6.69	7.08	7.79	8.28	7.43	7.48	19.4%
Spain	3.49	4.39	4.98	4.54	5.26	5.91	7.05	7.82	6.96	6.15	5.82	10.7%
Sweden	10.18	9.69	8.84	7.04	6.16	6.52	5.95	5.58	4.82	4.45	5.07	-17.7%
Switzerland	6.14	5.73	6.14	6.34	6.09	5.88	5.89	5.95	5.68	5.43	5.63	-7.5%
Turkey	1.14	1.48	1.60	1.88	2.30	2.55	3.12	3.15	3.71	3.57	3.65	58.5%
United Kingdom	11.15	10.31	10.14	9.63	9.60	8.90	8.90	8.85	8.35	7.53	7.78	-19.0%
OECD Europe ***	**8.11**	**8.15**	**8.74**	**8.10**	**7.90**	**7.57**	**7.58**	**7.65**	**7.39**	**6.84**	**6.99**	**-11.4%**
European Union - 27	*..*	*..*	*..*	*..*	*8.56*	*8.03*	*7.93*	*8.08*	*7.75*	*7.14*	*7.29*	*-14.8%*

* The ratio for the world has been calculated to include international marine bunkers and international aviation bunkers.
** Includes Estonia and Slovenia prior to 1990.
*** Excludes Estonia and Slovenia prior to 1990.

CO_2 emissions / population

tonnes CO_2 / capita

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Non-OECD Total *	**1.46**	**1.72**	**1.97**	**2.01**	**2.19**	**2.07**	**2.04**	**2.51**	**2.86**	**2.88**	**2.99**	**36.7%**
Albania	1.78	1.86	2.85	2.44	1.90	0.59	1.02	1.31	1.23	1.11	1.18	-38.3%
Armenia	..	..	..	..	5.77	1.06	1.11	1.34	1.71	1.38	1.31	-77.4%
Azerbaijan	..	..	..	..	9.08	4.19	3.70	3.91	3.37	2.76	2.73	-70.0%
Belarus	..	..	..	..	12.22	6.03	5.86	6.35	6.72	6.56	6.88	-43.7%
Bosnia and Herzegovina	..	..	..	..	5.49	0.97	3.66	4.13	5.28	5.14	5.29	-3.6%
Bulgaria	7.36	8.28	9.46	9.07	8.58	6.34	5.22	5.94	6.43	5.56	5.81	-32.3%
Croatia	..	..	..	..	4.52	3.39	4.00	4.67	4.73	4.47	4.30	-4.8%
Cyprus	2.86	3.39	5.07	5.13	6.62	8.03	9.09	9.34	9.59	9.37	8.99	35.9%
Georgia	..	..	..	..	6.92	1.71	1.04	0.99	1.09	1.21	1.11	-84.0%
Gibraltar	3.78	3.76	4.14	4.17	6.35	11.14	13.46	14.57	15.56	15.95	16.86	165.4%
Kazakhstan	..	..	..	..	14.46	10.59	7.59	10.37	14.54	12.42	14.23	-1.6%
Kosovo **	..	..	..	..	..	..	2.93	3.65	4.10	4.56	4.66	..
Kyrgyzstan	..	..	..	..	5.08	0.96	0.91	0.98	1.12	1.35	1.30	-74.4%
Latvia	..	..	..	..	7.00	3.53	2.88	3.29	3.49	3.18	3.60	-48.6%
Lithuania	..	..	..	..	8.95	3.90	3.20	3.97	4.26	3.73	4.02	-55.1%
FYR of Macedonia	..	..	..	..	4.46	4.17	4.18	4.31	4.40	4.09	3.99	-10.7%
Malta	2.00	1.97	2.71	3.34	6.35	6.22	5.40	6.70	6.23	5.94	5.99	-5.6%
Republic of Moldova	..	..	..	..	8.17	2.97	1.56	1.89	1.78	1.61	1.72	-79.0%
Montenegro **	..	..	..	..	..	..	..	2.23	3.05	1.97	3.31	..
Romania	5.61	6.62	7.93	7.63	7.20	5.16	3.84	4.34	4.31	3.67	3.52	-51.0%
Russian Federation	..	..	..	..	14.69	10.63	10.29	10.59	11.22	10.72	11.16	-24.1%
Serbia **	..	..	..	..	6.11	4.23	5.22	6.60	6.79	6.33	6.31	3.4%
Tajikistan	..	..	..	..	2.06	0.42	0.35	0.36	0.44	0.41	0.40	-80.7%
Turkmenistan	..	..	..	..	12.48	8.10	7.86	9.50	11.12	9.64	10.45	-16.3%
Ukraine	..	..	..	..	13.26	7.63	5.94	6.49	6.70	5.39	5.81	-56.2%
Uzbekistan	..	..	..	..	5.84	4.46	4.77	4.12	4.20	3.73	3.56	-39.1%
Former Soviet Union ***	8.14	10.09	11.50	11.51	..	..	..	..	..	..	..	..
Former Yugoslavia ***	3.12	3.60	4.04	5.43	..	..	..	..	..	..	..	..
Non-OECD Europe and Eurasia *	**7.54**	**9.28**	**10.60**	**10.68**	**11.64**	**7.75**	**7.10**	**7.51**	**8.04**	**7.38**	**7.71**	**-33.7%**
Algeria	0.63	0.88	1.51	1.96	2.08	2.01	2.08	2.42	2.61	2.84	2.78	33.4%
Angola	0.27	0.30	0.35	0.32	0.39	0.33	0.36	0.44	0.71	0.76	0.87	124.5%
Benin	0.10	0.14	0.11	0.11	0.05	0.04	0.22	0.35	0.45	0.48	0.51	856.8%
Botswana	..	..	..	1.33	2.12	2.10	2.38	2.36	2.31	2.17	2.29	8.0%
Cameroon	0.10	0.13	0.18	0.23	0.22	0.18	0.18	0.17	0.23	0.25	0.26	16.9%
Congo	0.42	0.39	0.39	0.36	0.26	0.17	0.16	0.23	0.35	0.39	0.41	58.6%
Dem. Rep. of Congo	0.12	0.11	0.12	0.10	0.08	0.05	0.03	0.04	0.05	0.04	0.05	-42.8%
Côte d'Ivoire	0.42	0.45	0.40	0.29	0.21	0.22	0.37	0.32	0.34	0.31	0.29	39.9%
Egypt	0.55	0.64	0.93	1.28	1.38	1.34	1.50	2.06	2.24	2.17	2.19	58.7%
Eritrea	..	..	..	..	..	0.24	0.17	0.13	0.09	0.09	0.09	..
Ethiopia	0.04	0.03	0.04	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.06	50.8%
Gabon	0.87	1.26	1.87	2.13	0.97	1.22	1.12	1.57	1.61	1.68	1.76	81.5%
Ghana	0.22	0.24	0.21	0.17	0.18	0.19	0.27	0.30	0.32	0.38	0.39	112.3%
Kenya	0.28	0.26	0.27	0.24	0.23	0.20	0.22	0.20	0.22	0.26	0.27	14.4%
Libya	1.79	3.72	6.06	5.84	6.31	7.35	7.59	7.36	7.64	7.96	8.12	28.7%
Morocco	0.44	0.57	0.71	0.74	0.79	0.97	1.02	1.32	1.39	1.35	1.44	81.5%
Mozambique	0.30	0.22	0.19	0.11	0.08	0.07	0.07	0.07	0.09	0.10	0.11	33.8%
Namibia	..	..	..	..	..	1.06	0.93	1.19	1.61	1.47	1.46	..
Nigeria	0.10	0.18	0.35	0.38	0.30	0.28	0.34	0.40	0.33	0.27	0.29	-3.1%
Senegal	0.29	0.34	0.38	0.34	0.29	0.30	0.38	0.43	0.43	0.44	0.44	49.9%
South Africa	6.93	8.15	7.57	7.31	7.21	7.02	6.74	6.97	7.93	7.48	6.94	-3.7%
Sudan	0.22	0.19	0.18	0.18	0.21	0.15	0.16	0.24	0.30	0.32	0.31	51.4%
United Rep. of Tanzania	0.11	0.09	0.09	0.07	0.07	0.08	0.08	0.13	0.14	0.13	0.13	99.0%
Togo	0.16	0.13	0.14	0.09	0.16	0.14	0.20	0.18	0.19	0.19	0.19	25.4%
Tunisia	0.71	0.85	1.23	1.32	1.48	1.59	1.88	2.01	2.08	2.04	2.08	40.4%
Zambia	0.80	0.90	0.58	0.41	0.33	0.23	0.17	0.18	0.13	0.14	0.15	-54.7%
Zimbabwe	1.34	1.17	1.09	1.08	1.53	1.27	1.02	0.82	0.64	0.67	0.72	-52.8%
Other Africa	0.11	0.12	0.15	0.12	0.12	0.13	0.13	0.14	0.15	0.14	0.14	14.6%
Africa	**0.66**	**0.77**	**0.84**	**0.86**	**0.86**	**0.83**	**0.84**	**0.91**	**0.96**	**0.93**	**0.91**	**5.9%**

* Includes Estonia and Slovenia prior to 1990.

** Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

*** Prior to 1990, data for individual countries are not available separately; FSU includes Estonia and Former Yugoslavia includes Slovenia.

CO_2 emissions / population

tonnes CO_2 / capita

	1971	1975	1980	1985	1990	1995	2000	2005	2008	2009	2010	% change 90-10
Bangladesh	0.05	0.07	0.09	0.10	0.13	0.17	0.20	0.26	0.32	0.34	0.36	176.4%
Brunei Darussalam	3.04	8.97	13.93	13.40	13.34	16.21	14.22	14.03	19.46	20.72	20.58	54.2%
Cambodia	..	..	..	..	..	0.13	0.16	0.20	0.26	0.26	0.27	..
Chinese Taipei	2.08	2.63	4.08	3.69	5.64	7.43	9.85	11.57	11.47	10.91	11.66	106.7%
India	0.36	0.39	0.41	0.54	0.69	0.83	0.96	1.06	1.26	1.35	1.39	102.5%
Indonesia	0.21	0.28	0.46	0.52	0.79	1.08	1.28	1.48	1.55	1.61	1.71	116.2%
DPR of Korea	4.61	4.77	6.12	6.75	5.66	3.44	3.00	3.11	2.86	2.72	2.59	-54.3%
Malaysia	1.14	1.31	1.76	2.14	2.73	3.99	4.81	5.83	6.69	6.06	6.51	138.9%
Mongolia	..	..	..	6.02	5.77	4.36	3.66	3.72	4.20	4.32	4.31	-25.3%
Myanmar	0.17	0.14	0.16	0.16	0.10	0.16	0.21	0.23	0.16	0.15	0.17	61.7%
Nepal	0.02	0.02	0.03	0.03	0.05	0.08	0.13	0.11	0.10	0.12	0.12	163.3%
Pakistan	0.27	0.31	0.32	0.41	0.52	0.62	0.67	0.74	0.80	0.80	0.78	48.0%
Philippines	0.63	0.71	0.71	0.53	0.62	0.83	0.87	0.83	0.78	0.77	0.82	32.1%
Singapore	2.91	3.74	5.26	5.96	9.65	11.84	11.85	11.87	11.40	11.16	12.39	28.5%
Sri Lanka	0.22	0.20	0.25	0.22	0.22	0.30	0.57	0.68	0.60	0.58	0.64	196.3%
Thailand	0.43	0.50	0.71	0.80	1.41	2.36	2.50	3.25	3.37	3.33	3.59	154.9%
Vietnam	0.37	0.35	0.28	0.29	0.26	0.39	0.57	0.97	1.20	1.32	1.50	476.0%
Other Asia	0.30	0.33	0.51	0.29	0.25	0.27	0.29	0.35	0.37	0.41	0.43	67.4%
Asia	**0.41**	**0.46**	**0.55**	**0.63**	**0.79**	**0.97**	**1.10**	**1.26**	**1.39**	**1.43**	**1.49**	**88.8%**
People's Rep. of China	0.95	1.15	1.43	1.62	1.95	2.48	2.41	3.88	4.91	5.11	5.39	176.8%
Hong Kong, China	2.27	2.42	2.87	4.03	5.75	5.84	5.98	5.98	6.05	6.51	5.87	2.0%
China	**0.96**	**1.15**	**1.44**	**1.63**	**1.97**	**2.50**	**2.42**	**3.89**	**4.92**	**5.12**	**5.40**	**174.3%**
Argentina	3.40	3.28	3.40	2.91	3.06	3.38	3.76	3.90	4.32	4.14	4.21	37.7%
Bolivia	0.50	0.68	0.78	0.72	0.77	0.92	0.86	1.03	1.26	1.30	1.42	83.1%
Brazil	0.93	1.27	1.48	1.23	1.30	1.49	1.74	1.73	1.89	1.75	1.99	53.2%
Colombia	1.21	1.19	1.26	1.28	1.35	1.57	1.48	1.34	1.32	1.35	1.31	-3.2%
Costa Rica	0.68	0.85	0.93	0.74	0.85	1.27	1.15	1.32	1.46	1.37	1.40	65.7%
Cuba	2.31	2.52	3.08	3.16	3.20	2.04	2.44	2.23	2.21	2.81	2.67	-16.6%
Dominican Republic	0.74	1.00	1.08	0.95	1.07	1.44	2.03	1.89	1.98	1.84	1.87	75.5%
Ecuador	0.60	0.90	1.34	1.33	1.29	1.43	1.47	1.80	1.89	2.05	2.08	61.8%
El Salvador	0.37	0.48	0.38	0.35	0.42	0.81	0.88	1.01	1.01	1.01	0.95	126.3%
Guatemala	0.41	0.49	0.60	0.40	0.36	0.58	0.75	0.83	0.74	0.79	0.72	99.1%
Haiti	0.08	0.08	0.11	0.12	0.13	0.11	0.16	0.21	0.24	0.24	0.21	60.5%
Honduras	0.40	0.42	0.46	0.39	0.44	0.63	0.71	1.01	1.07	0.98	0.96	117.6%
Jamaica	2.91	3.68	3.05	2.01	3.01	3.37	3.75	3.94	4.40	3.06	2.94	-2.1%
Netherlands Antilles	89.64	61.14	50.26	25.01	14.37	14.77	22.38	22.60	22.14	25.33	18.99	32.2%
Nicaragua	0.60	0.66	0.55	0.49	0.44	0.54	0.69	0.74	0.74	0.72	0.77	73.4%
Panama	1.63	1.81	1.50	1.23	1.06	1.54	1.67	2.11	1.94	2.25	2.39	125.8%
Paraguay	0.22	0.25	0.42	0.38	0.45	0.72	0.61	0.58	0.60	0.65	0.73	61.2%
Peru	1.15	1.22	1.19	0.94	0.89	1.00	1.02	1.05	1.25	1.33	1.44	62.9%
Trinidad and Tobago	6.29	5.78	7.36	8.19	9.36	9.73	16.31	25.78	29.46	30.07	31.91	241.0%
Uruguay	1.85	1.93	1.91	1.04	1.21	1.40	1.59	1.60	2.31	2.31	1.92	59.2%
Venezuela	4.71	4.95	6.15	5.45	5.32	5.37	5.21	5.57	6.03	5.93	6.35	19.3%
Other Non-OECD Americas	2.99	4.05	3.69	3.21	4.18	4.26	4.55	4.66	4.85	4.90	4.96	18.7%
Non-OECD Americas	**1.53**	**1.70**	**1.90**	**1.64**	**1.69**	**1.84**	**2.03**	**2.09**	**2.26**	**2.20**	**2.34**	**38.4%**
Bahrain	13.69	20.04	20.65	24.92	23.73	20.80	22.14	25.03	21.24	19.51	18.71	-21.2%
Islamic Republic of Iran	1.42	2.18	2.34	3.15	3.26	4.20	4.82	6.05	6.88	7.03	6.88	111.3%
Iraq	0.98	1.29	1.92	2.26	2.83	4.51	2.80	2.63	2.39	2.92	3.23	14.4%
Jordan	0.85	1.18	1.96	2.81	2.92	2.91	2.99	3.33	3.20	3.26	3.08	5.6%
Kuwait	17.31	14.30	19.30	21.29	13.75	22.18	25.31	30.97	28.99	30.51	31.93	132.2%
Lebanon	1.79	2.04	2.36	2.27	1.85	3.71	3.77	3.57	3.80	4.55	4.40	137.9%
Oman	0.33	0.80	1.89	3.69	5.48	6.61	8.90	11.59	13.85	14.73	14.47	164.2%
Qatar	18.87	30.05	34.67	32.90	29.66	37.25	40.05	45.74	35.65	35.32	36.90	24.4%
Saudi Arabia	2.11	3.06	10.11	9.27	9.86	11.24	12.61	13.88	14.80	15.35	16.25	64.8%
Syrian Arab Republic	0.91	1.20	1.48	1.99	2.28	2.31	2.49	2.97	3.19	2.86	2.82	23.6%
United Arab Emirates	8.97	9.15	18.81	26.38	28.68	29.65	28.22	26.64	23.46	21.54	20.50	-28.5%
Yemen	0.19	0.26	0.43	0.49	0.54	0.62	0.75	0.91	0.93	0.92	0.90	67.3%
Middle East	**1.53**	**2.15**	**3.47**	**4.16**	**4.39**	**5.38**	**5.66**	**6.62**	**7.19**	**7.42**	**7.56**	**72.4%**

Per capita emissions by sector in 2010 *

kg CO_2 / capita

	Total CO_2 emissions from fuel combustion	**Electricity and heat production**	**Other energy industry own use ** **	**Manufacturing industries and construction**	**Transport**	***of which: road***	**Other sectors**	***of which: residential***
World ***	**4 436**	**1 829**	**230**	**906**	**990**	**728**	**481**	**276**
Annex I Parties	*10 412*	*4 295*	*524*	*1 539*	*2 618*	*2 260*	*1 435*	*847*
Annex II Parties	*11 560*	*4 510*	*618*	*1 605*	*3 210*	*2 838*	*1 617*	*906*
North America	*17 156*	*7 043*	*944*	*1 998*	*5 204*	*4 474*	*1 966*	*1 048*
Europe	*7 429*	*2 446*	*391*	*1 137*	*1 972*	*1 848*	*1 483*	*959*
Asia Oceania	*10 092*	*4 363*	*498*	*1 973*	*2 064*	*1 829*	*1 194*	*449*
Annex I EIT	*8 598*	*4 349*	*334*	*1 545*	*1 329*	*942*	*1 041*	*741*
Non-Annex I Parties	*2 849*	*1 256*	*162*	*759*	*413*	*373*	*259*	*143*
Annex I Kyoto Parties	*8 608*	*3 447*	*445*	*1 490*	*1 897*	*1 636*	*1 329*	*805*
Non-OECD Total	**2 992**	**1 349**	**158**	**792**	**417**	**358**	**277**	**161**
OECD Total	**10 096**	**4 007**	**558**	**1 423**	**2 699**	**2 408**	**1 408**	**797**
Canada	15 733	3 357	1 850	2 955	4 975	4 093	2 597	1 139
Chile	4 078	1 448	138	903	1 241	1 092	347	198
Mexico	3 850	1 138	513	506	1 398	1 361	295	175
United States	17 312	7 448	845	1 893	5 229	4 516	1 897	1 038
OECD Americas	**13 611**	**5 477**	**816**	**1 614**	**4 182**	**3 633**	**1 522**	**815**
Australia	17 003	9 005	1 381	2 155	3 646	3 063	816	354
Israel	8 930	5 294	408	453	1 562	1 562	1 213	344
Japan	8 974	3 639	346	1 961	1 748	1 579	1 280	477
Korea	11 521	5 712	742	2 017	1 775	1 673	1 275	674
New Zealand	7 040	1 536	373	1 393	3 098	2 772	639	121
OECD Asia Oceania	**10 381**	**4 710**	**551**	**1 928**	**1 979**	**1 784**	**1 214**	**498**
Austria	8 266	1 970	887	1 523	2 607	2 530	1 280	903
Belgium	9 780	2 092	511	2 257	2 283	2 227	2 637	1 711
Czech Republic	10 886	5 971	226	1 886	1 584	1 511	1 218	756
Denmark	8 478	3 961	405	725	2 320	2 142	1 067	576
Estonia	13 787	11 006	75	613	1 663	1 524	430	139
Finland	11 732	5 819	663	1 889	2 339	2 135	1 023	353
France	5 518	849	252	965	1 907	1 824	1 546	880
Germany	9 315	3 998	321	1 418	1 780	1 724	1 797	1 236
Greece	7 453	3 663	298	724	1 929	1 657	839	586
Hungary	4 895	1 599	164	595	1 162	1 136	1 376	855
Iceland	6 044	16	-	1 494	2 630	2 456	1 903	29
Ireland	8 638	2 910	90	782	2 564	2 492	2 293	1 606
Italy	6 588	2 232	301	883	1 787	1 685	1 386	881
Luxembourg	20 977	2 618	-	2 276	12 804	12 780	3 278	2 058
Netherlands	11 257	3 575	624	2 548	2 007	1 957	2 502	1 235
Norway	8 011	581	2 290	1 541	2 873	2 121	726	122
Poland	7 990	4 129	198	894	1 226	1 198	1 543	978
Portugal	4 527	1 417	222	689	1 729	1 639	469	205
Slovak Republic	6 446	1 603	888	1 434	1 262	1 090	1 260	619
Slovenia	7 478	2 973	7	997	2 487	2 468	1 015	583
Spain	5 824	1 549	383	1 040	2 121	1 848	731	426
Sweden	5 073	1 199	260	975	2 298	2 176	341	44
Switzerland	5 630	361	131	744	2 185	2 148	2 209	1 464
Turkey	3 650	1 377	150	700	604	536	819	562
United Kingdom	7 776	2 873	519	822	1 919	1 781	1 643	1 325
OECD Europe	**6 995**	**2 488**	**341**	**1 068**	**1 712**	**1 605**	**1 386**	**896**
European Union - 27	*7 294*	*2 672*	*345*	*1 090*	*1 795*	*1 691*	*1 391*	*896*

* This table shows per capita emissions for the same sectors which are present throughout this publication. In particular, the emissions from electricity and heat production are shown separately and not reallocated as in the table on pages 105-107.
** Includes emissions from own use in petroleum refining, the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries.
*** World includes international bunkers in the transport sector.

Per capita emissions by sector in 2010

kg CO_2 / capita

	Total CO_2 emissions from fuel combustion	Electricity and heat production	Other energy industry own use	Manufacturing industries and construction	Transport	*of which: road*	Other sectors	*of which: residential*
Non-OECD Total	**2 992**	**1 349**	**158**	**792**	**417**	**358**	**277**	**161**
Albania	1 175	5	27	258	703	691	182	71
Armenia	1 306	204	-	171	405	405	526	288
Azerbaijan	2 726	1 009	262	113	563	502	779	647
Belarus	6 884	3 465	450	1 073	780	645	1 116	838
Bosnia and Herzegovina	5 294	3 495	110	416	858	858	415	150
Bulgaria	5 811	3 879	127	569	1 018	961	218	112
Croatia	4 301	945	419	800	1 348	1 259	789	476
Cyprus	8 995	4 670	-	849	2 750	2 746	726	326
Georgia	1 109	183	39	158	467	453	261	190
Gibraltar	16 858	4 349	-	2 017	10 492	10 492	-	-
Kazakhstan	14 226	4 591	2 890	3 209	790	725	2 745	591
Kosovo	4 665	3 678	-	265	527	526	194	91
Kyrgyzstan	1 301	247	-	351	486	486	217	-
Latvia	3 600	1 053	-	528	1 410	1 299	610	242
Lithuania	4 021	1 127	540	658	1 304	1 215	392	213
FYR of Macedonia	3 985	2 597	2	529	645	634	212	68
Malta	5 990	4 463	-	98	1 282	1 282	146	146
Republic of Moldova	1 716	750	5	70	285	270	605	502
Montenegro	3 311	2 678	-	342	275	-	15	13
Romania	3 524	1 539	259	645	643	595	438	271
Russian Federation	11 156	5 874	446	2 076	1 707	987	1 053	801
Serbia	6 314	4 168	74	758	888	755	426	209
Tajikistan	397	67	-	-	42	42	289	-
Turkmenistan	10 449	3 250	1 584	613	844	475	4 157	-
Ukraine	5 812	2 536	157	1 507	653	465	958	761
Uzbekistan	3 559	1 279	116	606	281	168	1 277	968
Non-OECD Europe and Eurasia	**7 711**	**3 727**	**434**	**1 438**	**1 092**	**730**	**1 019**	**638**
Algeria	2 779	704	314	359	940	836	463	370
Angola	871	121	14	139	393	355	203	67
Benin	509	12	-	16	354	354	126	126
Botswana	2 293	573	-	617	1 001	980	102	39
Cameroon	257	62	22	18	136	129	18	18
Congo	411	20	-	13	351	340	27	27
Dem. Rep. of Congo	46	-	-	16	11	11	19	5
Côte d'Ivoire	294	135	10	25	65	53	59	20
Egypt	2 189	814	183	412	474	437	307	188
Eritrea	94	38	-	4	26	26	25	9
Ethiopia	65	-	-	16	32	32	16	9
Gabon	1 761	470	22	681	397	397	192	92
Ghana	389	89	4	57	201	185	37	22
Kenya	269	51	6	58	116	110	38	24
Libya	8 121	4 405	480	985	1 902	1 901	349	349
Morocco	1 438	501	24	238	331	331	344	130
Mozambique	107	-	-	19	72	66	15	5
Namibia	1 458	128	-	120	772	726	437	-
Nigeria	290	67	37	24	120	98	43	11
Senegal	440	152	3	78	162	154	45	31
South Africa	6 938	4 757	45	990	764	710	382	181
Sudan	314	62	11	53	155	154	33	18
United Rep. of Tanzania	133	33	-	20	68	68	13	12
Togo	195	4	-	14	152	152	24	24
Tunisia	2 081	706	5	488	565	565	316	154
Zambia	150	2	4	60	50	34	33	-
Zimbabwe	722	425	4	91	94	87	108	7
Other Africa	143	41	-	17	63	56	21	12
Africa	**910**	**414**	**39**	**138**	**215**	**199**	**104**	**56**

Per capita emissions by sector in 2010

kg CO_2 / capita

	Total CO_2 emissions from fuel combustion	Electricity and heat production	Other energy industry own use	Manufacturing industries and construction	Transport	*of which: road*	Other sectors	*of which: residential*
Bangladesh	356	169	2	62	56	43	68	38
Brunei Darussalam	20 580	6 938	4 596	5 877	2 920	2 916	248	248
Cambodia	266	57	-	47	136	109	26	26
Chinese Taipei	11 656	6 564	573	2 575	1 529	1 479	415	196
India	1 388	748	52	342	138	124	108	64
Indonesia	1 713	502	122	521	441	387	127	70
DPR of Korea	2 587	414	1	1 633	36	36	503	3
Malaysia	6 514	3 209	370	1 134	1 494	1 484	307	66
Mongolia	4 308	2 938	11	487	500	347	371	317
Myanmar	167	41	15	51	48	37	12	-
Nepal	122	-	-	27	63	63	32	13
Pakistan	776	231	8	245	188	182	104	75
Philippines	820	349	19	136	252	221	64	27
Singapore	12 395	4 463	1 188	5 097	1 580	1 574	66	34
Sri Lanka	640	196	2	60	333	313	50	17
Thailand	3 594	1 184	224	1 125	801	794	261	63
Vietnam	1 501	471	35	506	348	339	141	83
Other Asia	426	134	-	76	163	138	53	17
Asia	**1 494**	**681**	**65**	**396**	**237**	**218**	**116**	**60**
People's Rep. of China	5 393	2 652	206	1 739	380	295	416	226
Hong Kong, China	5 867	3 920	-	813	791	791	344	113
China	**5 395**	**2 659**	**205**	**1 734**	**382**	**298**	**416**	**225**
Argentina	4 213	1 137	422	744	1 023	941	887	533
Bolivia	1 416	293	123	156	683	656	160	119
Brazil	1 989	230	129	585	852	760	194	87
Colombia	1 310	216	145	320	466	446	164	80
Costa Rica	1 403	115	15	214	969	964	90	29
Cuba	2 667	1 563	32	784	125	112	162	53
Dominican Republic	1 869	945	4	163	523	420	235	215
Ecuador	2 081	475	79	287	1 010	849	230	193
El Salvador	948	215	7	217	410	410	99	91
Guatemala	716	175	5	98	391	390	47	46
Haiti	213	32	-	54	107	38	21	21
Honduras	960	294	-	172	389	389	105	23
Jamaica	2 944	1 103	88	87	1 037	523	629	50
Netherlands Antilles	18 995	4 534	4 005	3 466	6 107	6 107	882	882
Nicaragua	771	291	13	104	296	282	68	15
Panama	2 388	634	-	551	991	989	211	139
Paraguay	727	-	-	25	661	654	41	29
Peru	1 442	357	135	296	560	531	95	59
Trinidad and Tobago	31 909	4 428	6 479	18 339	2 327	2 322	335	319
Uruguay	1 920	261	181	242	880	876	356	137
Venezuela	6 348	1 084	1 722	1 654	1 672	1 671	215	183
Other Non-OECD Americas	4 959	2 541	1	395	1 403	1 241	619	307
Non-OECD Americas	**2 341**	**462**	**255**	**588**	**797**	**733**	**240**	**134**
Bahrain	18 713	6 708	3 550	5 384	2 874	2 841	198	198
Islamic Rep. of Iran	6 881	1 778	408	1 297	1 604	1 587	1 794	1 357
Iraq	3 233	1 557	124	255	920	920	378	378
Jordan	3 080	1 382	97	384	853	846	364	213
Kuwait	31 931	17 546	4 455	5 477	4 263	4 263	191	191
Lebanon	4 404	2 634	-	312	1 181	1 181	276	276
Oman	14 474	5 654	2 827	3 065	2 257	2 257	671	169
Qatar	36 900	7 904	11 557	12 062	5 224	5 224	153	153
Saudi Arabia	16 247	6 444	2 710	3 143	3 804	3 726	145	145
Syrian Arab Republic	2 825	1 349	73	431	596	585	376	213
United Arab Emirates	20 500	7 777	274	8 951	3 424	3 424	74	74
Yemen	900	211	137	39	257	257	256	80
Middle East	**7 559**	**2 715**	**786**	**1 577**	**1 651**	**1 633**	**829**	**623**

Per capita emissions with electricity and heat allocated to consuming sectors * in 2010

kg CO_2 / capita

	Total CO_2 emissions from fuel combustion	Other energy industry own use **	Manufacturing industries and construction	Transport	*of which: road*	Other sectors	*of which: residential*
World *	**4 436**	**319**	**1 636**	**1 013**	**728**	**1 468**	**788**
Annex I Parties	*10 412*	*763*	*2 880*	*2 688*	*2 260*	*4 082*	*2 238*
Annex II Parties	*11 560*	*762*	*2 936*	*3 259*	*2 838*	*4 603*	*2 372*
North America	*17 156*	*1 159*	*3 741*	*5 222*	*4 474*	*7 033*	*3 546*
Europe	*7 429*	*485*	*1 986*	*2 019*	*1 848*	*2 940*	*1 680*
Asia Oceania	*10 092*	*583*	*3 421*	*2 143*	*1 829*	*3 945*	*1 748*
Annex I EIT	*8 598*	*861*	*3 056*	*1 465*	*942*	*3 216*	*2 158*
Non-Annex I Parties	*2 849*	*211*	*1 405*	*423*	*373*	*810*	*422*
Annex I Kyoto Parties	*8 608*	*685*	*2 678*	*1 977*	*1 636*	*3 269*	*1 864*
Non-OECD Total	**2 992**	**242**	**1 433**	**436**	**358**	**881**	**498**
OECD Total	**10 096**	**689**	**2 686**	**2 741**	**2 408**	**3 981**	**2 053**
Canada	15 733	2 034	4 096	5 000	4 093	4 603	2 123
Chile	4 078	153	1 842	1 253	1 092	831	443
Mexico	3 850	552	1 115	1 404	1 361	779	436
United States	17 312	1 049	3 649	5 244	4 516	7 370	3 737
OECD Americas	**13 611**	**982**	**3 066**	**4 197**	**3 633**	**5 365**	**2 715**
Australia	17 003	1 798	5 353	3 808	3 063	6 044	2 922
Israel	8 930	449	1 799	1 562	1 562	5 119	1 993
Japan	8 974	398	3 147	1 817	1 579	3 612	1 564
Korea	11 521	855	4 877	1 800	1 673	3 989	1 590
New Zealand	7 040	393	1 941	3 102	2 772	1 603	636
OECD Asia Oceania	**10 381**	**642**	**3 703**	**2 044**	**1 784**	**3 993**	**1 721**
Austria	8 266	920	2 226	2 689	2 530	2 432	1 548
Belgium	9 780	612	3 230	2 321	2 227	3 617	2 158
Czech Republic	10 886	659	3 881	1 730	1 511	4 616	2 679
Denmark	8 478	475	1 327	2 344	2 142	4 331	2 465
Estonia	13 787	602	2 696	1 708	1 524	8 781	5 087
Finland	11 732	732	4 480	2 370	2 135	4 150	2 163
France	5 518	297	1 159	1 927	1 824	2 134	1 148
Germany	9 315	415	2 991	1 879	1 724	4 031	2 384
Greece	7 453	440	1 652	1 941	1 657	3 421	1 811
Hungary	4 895	250	1 023	1 197	1 136	2 424	1 431
Iceland	6 044	-	1 506	2 630	2 456	1 907	31
Ireland	8 638	112	1 570	2 569	2 492	4 387	2 582
Italy	6 588	476	1 882	1 852	1 685	2 378	1 313
Luxembourg	20 977	-	3 622	12 850	12 780	4 505	2 408
Netherlands	11 257	911	3 849	2 051	1 957	4 446	1 947
Norway	8 011	2 318	1 749	2 877	2 121	1 067	306
Poland	7 990	625	1 974	1 284	1 198	4 106	2 514
Portugal	4 527	289	1 220	1 741	1 639	1 277	572
Slovak Republic	6 446	959	1 981	1 286	1 090	2 220	1 073
Slovenia	7 478	36	2 263	2 523	2 468	2 656	1 494
Spain	5 824	428	1 522	2 139	1 848	1 734	874
Sweden	5 073	284	1 342	2 312	2 176	1 135	524
Switzerland	5 630	131	862	2 203	2 148	2 435	1 579
Turkey	3 650	166	1 375	609	536	1 500	868
United Kingdom	7 776	598	1 752	1 950	1 781	3 475	2 296
OECD Europe	**6 995**	**445**	**1 932**	**1 757**	**1 605**	**2 861**	**1 636**
European Union - 27	*7 294*	*466*	*1 988*	*1 845*	*1 691*	*2 995*	*1 711*

* Emissions from electricity and heat generation have been allocated to final consuming sectors in proportion to the electricity and heat consumed. The detailed unallocated emissions are shown in the table on pages 102-104.

** Includes emissions from own use in petroleum refining, the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries.

*** World includes international bunkers in the transport sector.

Per capita emissions with electricity and heat allocated to consuming sectors in 2010

kg CO_2 / capita

	Total CO_2 emissions from fuel combustion	**Other energy industry own use**	**Manufacturing industries and construction**	**Transport**	***of which: road***	**Other sectors**	***of which: residential***
Non-OECD Total	**2 992**	**242**	**1 433**	**436**	**358**	**881**	**498**
Albania	1 175	27	259	703	691	186	73
Armenia	1 306	-	219	410	405	677	365
Azerbaijan	2 726	374	361	594	502	1 397	992
Belarus	6 884	714	2 241	838	645	3 090	1 999
Bosnia and Herzegovina	5 294	218	1 511	897	858	2 668	1 769
Bulgaria	5 811	427	1 826	1 056	961	2 502	1 484
Croatia	4 301	437	1 005	1 361	1 259	1 498	894
Cyprus	8 995	7	1 402	2 750	2 746	4 836	1 986
Georgia	1 109	48	212	481	453	369	278
Gibraltar	16 858	-	2 017	10 492	10 492	4 349	-
Kazakhstan	14 226	3 298	5 577	890	725	4 462	1 736
Kosovo	4 665	7	1 281	527	526	2 849	2 102
Kyrgyzstan	1 301	6	450	488	486	357	38
Latvia	3 600	-	666	1 420	1 299	1 514	784
Lithuania	4 021	595	926	1 308	1 215	1 191	703
FYR of Macedonia	3 985	125	1 317	653	634	1 890	1 214
Malta	5 990	-	1 396	1 282	1 282	3 311	1 466
Republic of Moldova	1 716	30	238	291	270	1 157	867
Montenegro	3 311	116	1 603	293	-	1 298	1 034
Romania	3 524	391	1 195	675	595	1 263	841
Russian Federation	11 156	1 240	4 158	1 918	987	3 840	2 630
Serbia	6 314	157	2 034	912	755	3 211	2 288
Tajikistan	397	-	28	42	42	327	14
Turkmenistan	10 449	1 998	1 436	904	475	6 111	480
Ukraine	5 812	441	2 530	726	465	2 115	1 677
Uzbekistan	3 559	143	902	306	168	2 208	1 108
Non-OECD Europe and Eurasia	**7 711**	**878**	**2 771**	**1 210**	**730**	**2 852**	**1 819**
Algeria	2 779	326	621	953	836	878	613
Angola	871	14	177	393	355	287	151
Benin	509	-	18	354	354	136	131
Botswana	2 293	-	867	1 001	980	425	191
Cameroon	257	22	54	136	129	45	31
Congo	411	-	23	351	340	37	37
Dem. Rep. of Congo	46	-	16	11	11	19	5
Côte d'Ivoire	294	10	56	65	53	163	79
Egypt	2 189	183	676	474	437	856	522
Eritrea	94	-	13	26	26	54	26
Ethiopia	65	-	16	32	32	16	9
Gabon	1 761	32	805	399	397	525	331
Ghana	389	4	98	201	185	85	57
Kenya	269	6	87	116	110	60	38
Libya	8 121	480	1 714	1 902	1 901	4 024	1 548
Morocco	1 438	40	422	336	331	641	290
Mozambique	107	-	20	72	66	15	5
Namibia	1 458	-	146	772	726	540	-
Nigeria	290	37	35	120	98	98	49
Senegal	440	3	116	162	154	160	88
South Africa	6 938	289	3 472	841	710	2 336	1 063
Sudan	314	11	61	155	154	87	49
United Rep. of Tanzania	133	1	35	68	68	30	26
Togo	195	-	15	152	152	27	27
Tunisia	2 081	5	751	581	565	744	345
Zambia	150	4	61	50	34	34	1
Zimbabwe	722	4	279	94	87	345	133
Other Africa	143	1	28	63	56	51	27
Africa	**910**	**49**	**310**	**219**	**199**	**332**	**180**

Per capita emissions with electricity and heat allocated to consuming sectors in 2010

kg CO_2 / capita

	Total CO_2 emissions from fuel combustion	**Other energy industry own use**	**Manufacturing industries and construction**	**Transport**	***of which: road***	**Other sectors**	***of which: residential***
Bangladesh	356	2	156	56	43	143	93
Brunei Darussalam	20 580	4 596	7 114	2 920	2 916	5 950	2 711
Cambodia	266	-	57	136	109	72	55
Chinese Taipei	11 656	688	6 242	1 564	1 479	3 162	1 478
India	1 388	52	681	152	124	504	225
Indonesia	1 713	122	695	441	387	456	274
DPR of Korea	2 587	1	1 840	36	36	710	3
Malaysia	6 514	370	2 660	1 500	1 484	1 984	718
Mongolia	4 308	11	1 537	533	347	2 227	1 453
Myanmar	167	15	66	48	37	38	18
Nepal	122	-	27	63	63	32	13
Pakistan	776	8	308	188	182	271	183
Philippines	820	19	253	253	221	295	146
Singapore	12 395	1 188	6 615	1 766	1 574	2 827	779
Sri Lanka	640	2	127	333	313	179	96
Thailand	3 594	224	1 629	801	794	940	327
Vietnam	1 501	35	758	348	339	360	253
Other Asia	426	9	122	163	138	132	44
Asia	**1 494**	**67**	**699**	**244**	**218**	**485**	**234**
People's Rep. of China	5 393	366	3 443	403	295	1 181	647
Hong Kong, China	5 867	-	1 101	791	791	3 975	1 136
China	**5 395**	**363**	**3 428**	**405**	**298**	**1 198**	**650**
Argentina	4 213	422	1 231	1 029	941	1 530	878
Bolivia	1 416	123	238	683	656	371	221
Brazil	1 989	140	687	852	760	310	142
Colombia	1 310	145	387	466	446	313	169
Costa Rica	1 403	15	239	969	964	180	74
Cuba	2 667	32	1 215	154	112	1 266	813
Dominican Republic	1 869	4	548	523	420	795	527
Ecuador	2 081	79	436	1 010	849	556	365
El Salvador	948	7	311	410	410	220	161
Guatemala	716	5	170	391	390	151	103
Haiti	213	-	64	107	38	42	32
Honduras	960	-	245	389	389	326	148
Jamaica	2 944	88	327	1 037	523	1 493	429
Netherlands Antilles	18 995	4 005	5 960	6 107	6 107	2 922	882
Nicaragua	771	13	183	296	282	279	115
Panama	2 388	-	617	991	989	780	342
Paraguay	727	-	25	661	654	41	29
Peru	1 442	135	485	560	531	262	145
Trinidad and Tobago	31 909	6 479	21 008	2 327	2 322	2 094	1 587
Uruguay	1 920	181	315	880	876	544	238
Venezuela	6 348	1 749	2 125	1 676	1 671	799	487
Other Non-OECD Americas	4 959	1	994	1 403	1 241	2 561	1 139
Non-OECD Americas	**2 341**	**267**	**778**	**799**	**733**	**497**	**262**
Bahrain	18 713	3 550	6 162	2 874	2 841	6 128	3 494
Islamic Rep. of Iran	6 881	426	1 894	1 607	1 587	2 955	1 934
Iraq	3 233	124	513	920	920	1 676	1 058
Jordan	3 080	110	731	853	846	1 385	770
Kuwait	31 931	6 912	5 477	4 263	4 263	15 280	10 021
Lebanon	4 404	-	1 004	1 181	1 181	2 219	1 280
Oman	14 474	2 827	3 605	2 257	2 257	5 786	3 112
Qatar	36 900	11 557	14 558	5 224	5 224	5 561	1 944
Saudi Arabia	16 247	3 212	3 797	3 804	3 726	5 434	3 443
Syrian Arab Republic	2 825	73	884	596	585	1 271	831
United Arab Emirates	20 500	274	9 695	3 424	3 424	7 107	3 103
Yemen	900	137	39	257	257	467	221
Middle East	**7 559**	**884**	**2 087**	**1 652**	**1 633**	**2 935**	**1 784**

Electricity output *

terawatt hours

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	% change 90-10
World	**11 819.0**	**13 229.7**	**15 410.5**	**16 704.7**	**17 494.8**	**18 247.5**	**18 944.3**	**19 798.7**	**20 178.1**	**20 087.3**	**21 396.9**	**81.0%**
Annex I Parties	*8 940.9*	*9 360.4*	*10 348.6*	*10 588.4*	*10 835.2*	*11 072.7*	*11 174.6*	*11 363.2*	*11 382.2*	*10 893.6*	*11 361.3*	*27.1%*
Annex II Parties	*7 030.8*	*7 787.6*	*8 725.2*	*8 869.6*	*9 078.5*	*9 275.7*	*9 303.3*	*9 451.4*	*9 441.5*	*9 049.7*	*9 420.0*	*34.0%*
North America	*3 684.9*	*4 118.4*	*4 631.5*	*4 644.2*	*4 747.9*	*4 894.9*	*4 888.4*	*4 962.8*	*4 983.9*	*4 779.3*	*4 962.2*	*34.7%*
Europe	*2 323.9*	*2 500.1*	*2 795.7*	*2 920.0*	*2 983.4*	*3 019.6*	*3 044.1*	*3 076.5*	*3 095.2*	*2 939.2*	*3 060.7*	*31.7%*
Asia Oceania	*1 022.1*	*1 169.2*	*1 298.1*	*1 305.4*	*1 347.1*	*1 361.2*	*1 370.9*	*1 412.2*	*1 362.4*	*1 331.2*	*1 397.1*	*36.7%*
Annex I EIT	*1 851.5*	*1 484.9*	*1 496.5*	*1 576.0*	*1 603.8*	*1 632.8*	*1 692.8*	*1 717.9*	*1 739.9*	*1 646.9*	*1 727.9*	*-6.7%*
Non-Annex I Parties	*2 878.1*	*3 869.3*	*5 061.9*	*6 116.3*	*6 659.7*	*7 174.8*	*7 769.6*	*8 435.5*	*8 796.0*	*9 193.7*	*10 035.6*	*248.7%*
Annex I Kyoto Parties	*5 639.9*	*5 689.3*	*6 169.7*	*6 364.3*	*6 503.0*	*6 608.7*	*6 689.2*	*6 813.6*	*6 803.4*	*6 500.9*	*6 758.7*	*19.8%*
Non-OECD Total	**4 189.7**	**4 684.2**	**5 680.7**	**6 721.7**	**7 241.9**	**7 747.4**	**8 370.6**	**9 018.6**	**9 382.1**	**9 694.5**	**10 542.5**	**151.6%**
OECD Total	**7 629.3**	**8 545.5**	**9 729.8**	**9 982.9**	**10 253.0**	**10 500.2**	**10 573.6**	**10 780.0**	**10 796.1**	**10 392.8**	**10 854.4**	**42.3%**
Canada	482.0	560.0	605.6	589.5	599.9	626.0	613.4	638.9	640.9	613.9	607.8	26.1%
Chile	18.4	28.0	40.1	46.8	51.2	52.5	55.3	58.5	59.7	60.7	60.4	228.9%
Mexico	115.8	152.2	204.2	213.7	232.6	243.8	249.5	257.2	261.9	261.0	271.0	133.9%
United States	3 202.8	3 558.4	4 025.9	4 054.6	4 148.1	4 268.9	4 275.0	4 323.9	4 343.0	4 165.4	4 354.4	36.0%
OECD Americas	**3 819.1**	**4 298.7**	**4 875.7**	**4 904.7**	**5 031.8**	**5 191.2**	**5 193.2**	**5 278.6**	**5 305.5**	**5 101.1**	**5 293.6**	**38.6%**
Australia	154.3	172.8	209.9	226.2	236.3	228.3	232.5	242.9	243.1	244.4	241.5	56.5%
Israel	20.9	30.4	42.7	47.0	47.3	48.6	50.6	53.8	57.0	55.0	58.6	180.2%
Japan	835.5	960.3	1 049.0	1 038.4	1 068.3	1 089.9	1 094.8	1 125.5	1 075.5	1 043.4	1 110.8	32.9%
Korea	105.4	181.1	288.5	343.2	366.6	387.9	402.3	425.9	443.9	451.7	496.7	371.4%
New Zealand	32.3	36.1	39.2	40.8	42.5	43.0	43.6	43.8	43.8	43.5	44.8	38.9%
OECD Asia Oceania	**1 148.3**	**1 380.7**	**1 629.3**	**1 695.7**	**1 761.0**	**1 797.7**	**1 823.7**	**1 891.9**	**1 863.3**	**1 837.9**	**1 952.4**	**70.0%**
Austria	49.3	55.2	59.9	58.1	61.9	64.1	62.1	62.6	64.5	66.3	67.9	37.8%
Belgium	70.3	73.5	82.8	83.6	84.4	85.7	84.3	87.5	83.6	89.8	93.8	33.4%
Czech Republic	62.3	60.6	72.9	82.8	83.8	81.9	83.7	87.8	83.2	81.7	85.3	37.0%
Denmark	26.0	36.8	36.1	46.2	40.4	36.2	45.6	39.3	36.6	36.4	38.8	49.3%
Estonia	17.4	8.8	8.5	10.2	10.3	10.2	9.7	12.2	10.6	8.8	13.0	-25.5%
Finland	54.4	64.0	70.0	84.3	85.8	70.6	82.3	81.2	77.4	72.1	80.7	48.3%
France	417.2	491.1	536.1	561.8	569.1	571.5	569.3	564.1	569.3	530.9	564.3	35.3%
Germany	547.7	532.8	572.3	601.5	608.5	613.4	629.4	629.5	631.2	584.3	622.1	13.6%
Greece	34.8	41.3	53.4	57.9	58.8	59.4	60.2	62.7	62.9	61.1	57.4	65.0%
Hungary	28.4	34.0	35.2	34.1	33.7	35.8	35.9	40.0	40.0	35.9	37.4	31.4%
Iceland	4.5	5.0	7.7	8.5	8.6	8.7	9.9	12.0	16.5	16.8	17.1	278.2%
Ireland	14.2	17.6	23.7	24.9	25.2	25.6	27.1	27.8	29.9	28.0	28.4	99.8%
Italy	213.1	237.4	269.9	286.3	295.8	296.8	307.7	308.2	313.5	288.3	298.8	40.2%
Luxembourg	0.6	0.5	0.4	2.8	3.4	3.3	3.5	3.2	2.7	3.2	3.2	417.9%
Netherlands	71.9	80.9	89.6	96.8	102.4	100.2	98.4	105.2	107.6	113.5	118.1	64.2%
Norway	121.6	122.2	142.5	106.7	110.1	137.2	121.2	136.1	141.2	131.0	124.1	2.0%
Poland	134.4	137.0	143.2	150.0	152.6	155.4	160.8	158.8	154.7	151.1	157.1	16.9%
Portugal	28.4	33.2	43.4	46.5	44.8	46.2	48.6	46.9	45.5	49.5	53.7	89.4%
Slovak Republic	25.5	26.4	30.8	31.0	30.5	31.4	31.3	27.9	28.8	25.9	27.5	7.7%
Slovenia	12.4	12.9	13.6	13.8	15.3	15.1	15.1	15.0	16.4	16.4	16.2	30.6%
Spain	151.2	165.6	222.2	257.9	277.2	288.9	295.5	301.8	311.1	291.8	299.9	98.4%
Sweden	146.0	148.3	145.2	135.4	151.7	158.4	143.3	148.8	149.9	136.6	148.5	1.7%
Switzerland	55.0	62.2	66.1	65.4	63.9	57.8	62.1	66.4	67.0	66.7	66.1	20.1%
Turkey	57.5	86.2	124.9	140.6	150.7	162.0	176.3	191.6	198.4	194.8	211.2	267.0%
United Kingdom	317.8	332.5	374.4	395.5	391.3	395.4	393.4	392.9	384.6	373.1	378.0	19.0%
OECD Europe	**2 661.9**	**2 866.1**	**3 224.8**	**3 382.5**	**3 460.2**	**3 511.3**	**3 556.7**	**3 609.6**	**3 627.2**	**3 453.8**	**3 608.4**	**35.6%**
European Union - 27	*2 567.8*	*2 713.1*	*2 996.7*	*3 187.9*	*3 254.7*	*3 274.9*	*3 319.2*	*3 333.6*	*3 339.6*	*3 172.3*	*3 315.4*	*29.1%*

* Includes electricity from both electricity-only and combined heat and power plants, and from both main activity producer and autoproducer plants.

Electricity output

terawatt hours

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	% change 90-10
Non-OECD Total	**4 189.7**	**4 684.2**	**5 680.7**	**6 721.7**	**7 241.9**	**7 747.4**	**8 370.6**	**9 018.6**	**9 382.1**	**9 694.5**	**10 542.5**	**151.6%**
Albania	3.2	4.4	4.7	5.0	5.6	5.4	5.5	2.9	3.8	5.2	7.6	137.0%
Armenia	10.4	5.6	6.0	5.5	6.0	6.3	5.9	5.9	5.8	5.7	6.5	-37.4%
Azerbaijan	23.2	17.0	18.7	21.3	21.6	21.2	23.6	21.8	21.6	18.9	18.7	-19.4%
Belarus	39.5	24.9	26.1	26.6	31.2	31.0	31.8	31.8	35.0	30.4	34.9	-11.7%
Bosnia and Herzegovina	14.6	4.4	10.4	11.3	12.7	12.6	13.3	11.8	14.8	15.7	17.1	17.0%
Bulgaria	42.1	41.8	40.6	42.3	41.4	44.0	45.5	42.9	44.6	42.4	46.0	9.2%
Croatia	9.2	8.9	10.6	12.6	13.2	12.4	12.3	12.1	12.2	12.7	14.0	52.0%
Cyprus	2.0	2.5	3.4	4.1	4.2	4.4	4.7	4.9	5.1	5.2	5.4	172.5%
Georgia	13.7	8.2	7.4	7.2	6.9	7.3	7.3	8.3	8.5	8.6	10.1	-26.2%
Gibraltar	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	124.1%
Kazakhstan	87.4	66.7	51.3	63.9	66.9	67.8	71.7	76.6	80.3	78.7	82.6	-5.4%
Kosovo *	..	..	3.0	3.6	4.1	4.5	4.4	4.8	5.2	5.0	5.2	..
Kyrgyzstan	15.7	14.3	16.0	15.6	16.3	16.4	17.1	16.2	11.9	11.1	11.4	-27.9%
Latvia	6.6	4.0	4.1	4.0	4.7	4.9	4.9	4.8	5.3	5.6	6.6	-0.3%
Lithuania	28.4	13.5	11.1	18.8	18.8	14.4	12.1	13.5	13.3	14.6	5.0	-82.4%
FYR of Macedonia	5.8	6.1	6.8	6.7	6.7	6.9	7.0	6.5	6.3	6.8	7.3	26.1%
Malta	1.1	1.6	1.9	2.2	2.2	2.2	2.3	2.3	2.3	2.2	2.1	92.1%
Republic of Moldova	16.2	6.1	3.4	3.4	3.6	3.8	3.8	3.8	3.6	3.5	3.6	-78.1%
Montenegro *	..	..	..	..	..	3.2	3.3	2.8	3.3	2.9	4.2	..
Romania	64.3	59.3	51.9	55.1	56.5	59.4	62.7	61.7	65.0	57.7	60.3	-6.3%
Russian Federation	1 082.2	859.0	876.5	914.3	929.9	951.2	993.9	1 013.4	1 038.4	990.0	1 036.1	-4.3%
Serbia *	40.9	34.5	34.1	35.4	37.7	36.5	36.5	36.6	36.8	37.7	37.4	-8.6%
Tajikistan	18.1	14.8	14.2	16.5	16.5	17.1	16.9	17.5	16.1	16.1	16.4	-9.6%
Turkmenistan	14.6	9.8	9.8	10.8	11.9	12.8	13.7	14.9	15.0	16.0	16.7	14.0%
Ukraine	298.6	193.8	171.3	180.2	182.0	185.9	193.2	196.1	192.5	173.6	188.6	-36.8%
Uzbekistan	56.3	47.5	46.9	49.4	50.0	49.2	50.9	49.0	49.4	50.0	51.7	-8.2%
Non-OECD Europe and Eurasia	**1 894.4**	**1 448.7**	**1 430.5**	**1 515.9**	**1 550.9**	**1 581.0**	**1 644.4**	**1 663.0**	**1 696.3**	**1 616.4**	**1 695.5**	**-10.5%**
Algeria	16.1	19.7	25.4	29.6	31.3	33.9	35.2	37.2	40.2	38.2	45.6	182.9%
Angola	0.8	1.0	1.4	2.0	2.2	2.8	3.3	3.2	4.2	4.7	5.3	525.0%
Benin	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.2	614.3%
Botswana	0.9	1.0	0.9	0.7	0.8	0.9	0.9	0.7	0.6	0.6	0.5	-49.6%
Cameroon	2.7	2.8	3.5	3.7	4.1	4.0	5.1	5.2	5.7	5.8	5.9	118.7%
Congo	0.5	0.4	0.3	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.6	13.4%
Dem. Rep. of Congo	5.7	6.2	6.0	6.2	7.1	7.4	7.5	7.9	7.5	7.8	7.9	39.5%
Côte d'Ivoire	2.0	2.9	4.8	5.1	5.5	5.7	5.7	5.6	5.8	5.9	6.0	202.2%
Egypt	42.3	52.0	78.1	95.2	101.3	108.7	115.4	125.1	131.0	139.0	146.8	247.4%
Eritrea	..	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	..
Ethiopia	1.2	1.5	1.7	2.3	2.5	2.8	3.3	3.5	3.8	4.0	5.0	314.3%
Gabon	1.0	1.1	1.3	1.5	1.5	1.6	1.7	1.7	1.8	1.9	1.8	88.9%
Ghana	5.7	6.1	7.2	5.9	6.0	6.8	8.4	7.0	8.3	8.9	8.4	46.2%
Kenya	3.2	4.1	4.2	5.2	5.6	6.0	6.5	6.7	6.8	6.9	7.5	131.9%
Libya	10.2	11.4	15.5	18.9	20.2	22.3	24.0	25.7	28.7	30.4	31.6	210.9%
Morocco	9.6	12.1	12.9	17.4	18.5	19.9	20.4	20.5	20.8	21.4	22.3	131.7%
Mozambique	0.5	0.4	9.7	10.9	11.7	13.3	14.7	16.1	15.1	17.0	16.7	+
Namibia	..	1.2	1.3	1.6	1.6	1.6	1.5	1.7	2.1	1.7	1.5	..
Nigeria	13.5	15.9	14.7	20.2	24.3	23.5	23.1	23.0	21.1	19.8	26.1	94.0%
Senegal	0.9	1.1	1.6	2.1	2.3	2.5	2.4	2.7	2.4	2.9	3.0	215.0%
South Africa	165.4	185.4	207.8	231.2	240.9	242.1	250.9	260.5	255.5	246.8	256.6	55.2%
Sudan	1.5	1.9	2.6	3.4	3.5	3.8	4.5	5.0	5.5	7.2	7.8	417.6%
United Rep. of Tanzania	1.6	1.9	2.5	2.7	2.9	3.6	3.5	4.2	4.4	4.2	4.4	172.7%
Togo	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	-17.7%
Tunisia	5.8	7.7	10.6	11.3	11.9	12.7	13.1	13.7	14.4	15.3	16.1	177.0%
Zambia	8.0	7.9	7.8	8.3	8.5	8.9	9.9	9.8	9.7	10.4	11.3	41.1%
Zimbabwe	9.4	7.8	7.0	8.8	9.7	10.3	8.5	8.5	7.0	7.4	8.1	-13.6%
Other Africa	7.4	8.9	11.9	13.3	14.0	14.3	14.3	15.3	16.0	16.3	16.9	129.4%
Africa	**316.0**	**362.9**	**441.2**	**508.3**	**538.8**	**560.4**	**584.9**	**611.8**	**619.6**	**625.5**	**664.2**	**110.2%**

*Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

Electricity output

terawatt hours

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	% change 90-10
Bangladesh	7.7	10.8	15.8	19.7	24.7	26.5	29.9	31.3	35.0	37.9	42.3	447.7%
Brunei Darussalam	1.2	2.0	2.5	3.2	3.3	3.3	3.3	3.4	3.4	3.6	3.9	229.5%
Cambodia	..	0.2	0.4	0.8	0.8	1.0	1.2	1.5	1.5	1.3	1.0	..
Chinese Taipei	88.4	129.1	180.6	205.2	215.1	223.5	231.6	239.2	234.8	226.4	243.9	176.0%
India	289.4	417.6	561.2	634.0	666.6	698.2	753.3	813.9	841.7	906.8	959.9	231.6%
Indonesia	32.7	59.2	93.3	114.5	120.2	127.4	133.1	142.2	149.4	156.8	169.8	419.7%
DPR of Korea	27.7	23.0	19.4	21.0	22.0	22.9	22.4	21.5	23.2	21.1	21.7	-21.8%
Malaysia	23.0	45.5	69.3	78.5	82.3	82.7	89.8	97.5	97.8	116.4	125.3	444.4%
Mongolia	3.5	2.7	3.0	3.2	3.4	3.5	3.6	3.8	4.1	4.2	4.5	29.1%
Myanmar	2.5	4.1	5.1	5.4	5.6	6.0	6.2	6.4	6.6	7.0	7.5	204.4%
Nepal	0.9	1.2	1.7	2.3	2.4	2.5	2.7	2.8	2.8	3.1	3.2	265.3%
Pakistan	37.7	57.0	68.1	80.8	85.7	93.8	98.4	95.7	91.6	95.4	94.5	150.7%
Philippines	26.3	33.6	45.3	52.9	56.0	56.6	56.8	59.6	60.8	61.9	67.7	157.3%
Singapore	15.7	22.2	31.7	35.3	36.8	38.2	39.4	41.1	41.7	41.8	45.4	188.7%
Sri Lanka	3.2	4.8	7.0	7.7	8.2	9.3	9.5	9.9	9.2	9.9	10.8	241.7%
Thailand	44.2	80.1	96.0	117.0	125.7	132.2	138.7	143.4	147.4	148.4	159.5	261.1%
Vietnam	8.7	14.6	26.6	40.9	46.2	53.7	60.5	67.0	73.4	83.2	94.9	993.2%
Other Asia	8.4	9.0	13.8	16.0	16.3	16.7	18.4	20.3	20.6	20.8	22.2	164.1%
Asia	**621.1**	**916.5**	**1 240.7**	**1 438.5**	**1 521.2**	**1 598.0**	**1 698.8**	**1 800.6**	**1 845.2**	**1 945.9**	**2 078.0**	**234.6%**
People's Rep. of China	621.2	1 007.8	1 356.2	1 908.5	2 201.0	2 499.7	2 864.3	3 276.3	3 458.8	3 695.9	4 173.7	571.9%
Hong Kong, China	28.9	27.9	31.3	35.5	37.1	38.5	38.6	39.0	38.0	38.7	38.3	32.3%
China	**650.1**	**1 035.7**	**1 387.6**	**1 944.0**	**2 238.1**	**2 538.1**	**2 902.9**	**3 315.2**	**3 496.7**	**3 734.7**	**4 212.0**	**547.9%**
Argentina	50.7	67.0	88.9	92.0	100.2	105.5	97.5	103.6	121.6	121.9	125.3	146.9%
Bolivia	2.3	3.0	3.9	4.3	4.5	4.9	5.3	5.7	5.8	6.1	6.9	197.9%
Brazil	222.8	275.6	348.9	364.3	387.5	403.0	419.3	445.1	462.9	466.0	515.7	131.5%
Colombia	36.4	42.7	43.1	46.5	49.7	50.3	53.8	55.2	56.0	57.2	56.8	56.2%
Costa Rica	3.5	4.9	6.9	7.5	8.2	8.3	8.7	9.1	9.5	9.3	9.6	176.4%
Cuba	15.0	12.5	15.0	15.8	15.6	15.3	16.5	17.6	17.7	17.7	17.4	15.8%
Dominican Republic	3.7	5.5	8.5	13.3	11.8	12.6	13.8	14.4	15.2	15.0	15.9	330.3%
Ecuador	6.3	8.4	10.6	11.5	13.5	12.6	14.9	17.1	19.0	18.0	17.7	178.6%
El Salvador	2.2	3.3	3.4	4.4	4.5	4.8	5.7	5.8	6.0	5.8	6.0	169.6%
Guatemala	2.2	3.5	6.0	7.1	7.5	7.8	8.2	8.8	8.7	9.0	8.8	304.0%
Haiti	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.5	0.5	0.7	0.6	-1.7%
Honduras	2.3	2.7	3.7	4.5	4.9	5.6	6.0	6.3	6.5	6.6	6.7	190.4%
Jamaica	2.5	5.8	6.6	7.1	7.2	7.4	7.5	7.8	6.0	5.5	4.2	70.6%
Netherlands Antilles	0.8	1.0	1.1	1.2	1.2	1.2	1.2	1.3	1.2	1.3	1.3	63.2%
Nicaragua	1.5	1.9	2.4	2.8	2.9	3.1	3.1	3.2	3.4	3.5	3.7	151.1%
Panama	2.7	3.5	4.9	5.6	5.8	5.8	6.0	6.5	6.5	7.0	7.5	181.5%
Paraguay	27.2	42.2	53.5	51.8	51.9	51.2	53.8	53.7	55.5	55.0	54.1	98.9%
Peru	13.8	16.1	19.9	22.9	24.3	25.5	27.4	29.9	32.4	32.9	35.9	159.9%
Trinidad and Tobago	3.6	4.3	5.5	6.4	6.4	7.1	6.9	7.7	7.7	7.7	8.5	137.3%
Uruguay	7.4	6.3	7.6	8.6	5.9	7.7	5.6	9.4	8.8	8.9	10.8	45.2%
Venezuela	59.3	73.4	85.3	91.8	98.6	105.5	112.4	114.6	119.3	119.6	118.3	99.4%
Other Non-OECD Americas	22.2	27.8	32.4	35.7	36.4	37.3	37.8	37.8	36.5	36.6	37.4	68.4%
Non-OECD Americas	**489.0**	**612.1**	**758.7**	**805.7**	**849.0**	**883.1**	**911.8**	**961.2**	**1 006.5**	**1 011.4**	**1 069.0**	**118.6%**
Bahrain	3.5	4.6	6.3	7.8	8.4	8.9	9.7	10.9	11.9	12.1	13.2	280.0%
Islamic Republic of Iran	59.1	85.0	121.4	153.9	166.9	178.1	192.7	204.0	214.5	221.4	233.0	294.2%
Iraq	24.0	29.7	31.9	28.3	32.3	30.4	33.8	33.2	36.8	45.6	50.2	109.0%
Jordan	3.6	5.6	7.4	8.0	9.0	9.7	11.1	13.0	13.8	14.3	14.8	306.2%
Kuwait	18.5	23.7	32.3	39.8	41.3	43.7	47.6	48.8	51.7	53.2	57.0	208.6%
Lebanon	1.5	5.3	9.8	12.7	12.5	12.4	11.6	12.1	13.4	13.8	15.7	947.5%
Oman	4.5	6.5	9.1	10.7	11.5	12.6	13.3	14.2	15.8	17.8	19.8	340.3%
Qatar	4.8	6.0	9.1	12.0	13.2	14.4	17.1	19.5	21.6	24.8	28.1	484.1%
Saudi Arabia	69.2	97.8	126.2	153.0	159.9	176.1	181.4	190.5	204.2	217.1	240.1	246.9%
Syrian Arab Republic	11.6	16.6	25.2	29.5	32.1	34.9	37.3	38.6	41.0	43.3	46.4	299.7%
United Arab Emirates	17.1	25.0	39.9	49.5	52.4	60.7	66.8	76.1	86.3	90.6	97.7	472.2%
Yemen	1.7	2.4	3.4	4.1	4.4	4.8	5.4	6.0	6.5	6.7	7.8	366.4%
Middle East	**219.1**	**308.3**	**422.0**	**509.3**	**543.8**	**586.7**	**627.8**	**666.9**	**717.7**	**760.6**	**823.8**	**276.0%**

CO_2 emissions per kWh from electricity generation *

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
World	**525**	**526**	**526**	**537**	**539**	**541**	**544**	**547**	**540**	**534**	**529**	**534**
Annex I Parties	*494*	*472*	*466*	*470*	*461*	*460*	*454*	*460*	*446*	*424*	*422*	*431*
Annex II Parties	*484*	*469*	*466*	*470*	*463*	*458*	*449*	*455*	*439*	*419*	*419*	*426*
North America	*533*	*535*	*545*	*535*	*531*	*526*	*508*	*513*	*499*	*473*	*481*	*484*
Europe	*408*	*365*	*334*	*343*	*335*	*330*	*335*	*334*	*314*	*298*	*290*	*301*
Asia Oceania	*482*	*461*	*468*	*521*	*504*	*497*	*489*	*514*	*505*	*488*	*481*	*491*
Annex I EIT	*527*	*484*	*465*	*476*	*454*	*474*	*484*	*480*	*474*	*446*	*434*	*451*
Non-Annex I Parties	*630*	*658*	*649*	*654*	*668*	*666*	*673*	*665*	*662*	*664*	*651*	*659*
Annex I Kyoto Parties	*442*	*398*	*382*	*401*	*387*	*387*	*391*	*395*	*380*	*362*	*356*	*366*
Non-OECD Total	**577**	**604**	**606**	**623**	**635**	**641**	**652**	**644**	**643**	**642**	**628**	**638**
OECD Total	**497**	**482**	**478**	**479**	**471**	**466**	**458**	**465**	**449**	**433**	**433**	**439**
Canada	205	184	222	228	214	200	202	198	187	176	186	183
Chile	457	267	349	295	322	318	304	408	411	373	410	398
Mexico	549	539	559	571	495	509	482	479	430	455	455	447
United States	582	590	593	579	577	574	552	560	545	517	522	528
OECD Americas	**533**	**533**	**544**	**534**	**528**	**523**	**505**	**510**	**494**	**471**	**479**	**482**
Australia	817	810	853	918	899	859	859	850	847	852	841	847
Israel	827	820	765	805	809	776	774	770	712	694	689	699
Japan	435	412	402	446	429	431	420	454	440	416	416	424
Korea	520	554	529	476	503	487	491	481	487	525	533	515
New Zealand	109	89	165	213	196	237	231	196	215	167	150	177
OECD Asia Oceania	**492**	**481**	**487**	**520**	**512**	**502**	**497**	**514**	**507**	**503**	**501**	**504**
Austria	238	206	170	236	224	218	217	204	187	158	188	177
Belgium	347	361	291	278	285	275	263	254	254	218	220	230
Czech Republic	744	794	728	618	617	614	606	636	621	588	589	599
Denmark	668	587	449	474	403	369	459	425	398	398	360	385
Estonia	932	1 062	1 063	1 011	1 029	1 048	965	1 048	1 084	1 078	1 014	1 059
Finland	188	223	173	303	258	164	265	238	177	190	229	199
France	105	73	75	70	67	79	72	76	72	78	79	77
Germany	607	581	522	512	503	486	483	504	476	467	461	468
Greece	990	946	820	781	780	779	731	752	748	725	718	730
Hungary	496	512	469	502	448	372	373	368	351	313	317	327
Iceland	1	1	0	0	0	0	0	1	1	0	0	0
Ireland	740	727	642	600	575	584	537	510	471	452	458	460
Italy	575	545	498	511	497	486	509	475	452	411	406	423
Luxembourg	2 552	1 738	528	403	393	389	387	381	385	376	410	390
Netherlands	607	546	477	484	467	454	452	455	442	420	415	425
Norway	1	2	1	3	3	2	3	4	3	11	17	10
Poland	988	905	866	849	833	818	821	820	815	799	781	798
Portugal	519	576	486	422	465	521	431	396	394	379	255	343
Slovak Republic	389	364	245	256	233	221	214	220	207	210	197	205
Slovenia	362	326	343	376	345	349	362	375	332	318	325	325
Spain	427	453	430	378	382	397	369	387	327	297	238	287
Sweden	12	22	22	37	23	19	23	17	18	19	30	22
Switzerland	24	23	25	27	28	32	33	30	29	26	27	27
Turkey	568	512	529	451	426	438	452	494	511	496	460	489
United Kingdom	672	529	472	489	491	491	515	506	499	453	457	470
OECD Europe	**447**	**405**	**375**	**379**	**369**	**364**	**370**	**373**	**355**	**340**	**331**	**342**
European Union - 27	*493*	*442*	*401*	*403*	*391*	*387*	*391*	*395*	*374*	*357*	*347*	*359*

* CO_2 emissions from fossil fuels consumed for electricity generation, in both electricity-only and combined heat and power plants, divided by output of electricity generated from fossil fuels, nuclear, hydro (excl. pumped storage), geothermal, solar, wind, tide, wave, ocean and biofuels. Both main activity producers and autoproducers have been included in the calculation.

CO_2 emissions per kWh from electricity generation

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
Non-OECD Total	**577**	**604**	**606**	**623**	**635**	**641**	**652**	**644**	**643**	**642**	**628**	**638**
Albania	163	38	43	33	30	26	26	31	-	1	2	2
Armenia	495	211	238	143	114	131	130	157	159	102	92	118
Azerbaijan	1 147	822	833	653	677	650	671	570	534	499	439	491
Belarus	548	500	472	443	463	459	461	452	465	466	449	460
Bosnia and Herzegovina	713	176	824	883	772	797	852	1 007	830	806	723	786
Bulgaria	761	582	478	532	537	502	490	592	565	537	535	546
Croatia	408	353	337	434	314	331	337	422	367	291	236	298
Cyprus	838	822	838	833	772	788	758	761	759	743	697	733
Georgia	574	510	225	62	89	101	147	161	79	123	69	90
Gibraltar	776	766	760	755	766	761	751	751	757	757	762	758
Kazakhstan	611	560	692	634	584	570	839	658	541	433	403	459
Kosovo *	..	..	1 316	1 424	1 297	1 121	1 127	1 089	1 088	1 286	1 287	1 220
Kyrgyzstan	165	99	72	72	68	58	56	61	57	57	59	58
Latvia	117	137	136	130	97	89	113	107	114	96	120	110
Lithuania	158	65	99	63	68	101	100	88	83	84	337	168
FYR of Macedonia	917	879	797	809	797	791	783	871	905	799	685	797
Malta	1 587	957	819	946	913	1 034	954	1 012	849	850	872	857
Republic of Moldova	723	748	829	753	526	529	506	530	510	526	517	518
Montenegro *	..	..	..	..	..	341	386	352	456	274	405	379
Romania	855	741	579	643	528	493	521	542	512	472	413	466
Russian Federation	406	363	394	412	402	436	445	428	426	402	384	404
Serbia *	892	1 001	885	920	883	764	817	750	772	766	718	752
Tajikistan	68	25	26	17	22	21	21	20	20	17	14	17
Turkmenistan	686	931	872	872	872	872	872	872	927	865	954	915
Ukraine	654	566	400	435	360	397	430	440	447	390	392	410
Uzbekistan	624	572	629	607	588	588	583	609	543	566	550	553
Non-OECD Europe and Eurasia	**507**	**449**	**440**	**455**	**431**	**451**	**476**	**462**	**454**	**424**	**407**	**428**
Algeria	631	633	620	632	632	606	621	597	596	643	548	596
Angola	343	177	499	510	290	273	260	300	330	465	440	412
Benin	1 200	951	601	752	740	709	698	662	679	719	720	706
Botswana	1 791	1 800	1 876	2 029	2 190	2 073	1 927	1 587	1 789	1 953	2 517	2 086
Cameroon	13	10	10	31	28	40	83	162	161	196	207	188
Congo	6	9	-	82	97	103	102	102	108	245	142	165
Dem. Rep. of Congo	4	4	1	1	1	1	2	3	4	3	3	3
Côte d'Ivoire	205	275	379	384	356	457	385	409	449	389	445	428
Egypt	521	443	343	397	489	474	473	450	460	466	450	458
Eritrea	..	1 463	698	694	711	666	679	655	669	672	646	662
Ethiopia	136	42	11	6	6	3	3	44	119	122	7	82
Gabon	270	255	326	315	328	383	348	424	350	357	383	364
Ghana	-	3	66	278	85	147	276	360	215	187	259	221
Kenya	51	73	454	141	217	247	258	248	322	396	274	331
Libya	779	1 131	1 022	978	888	907	879	846	885	872	885	881
Morocco	783	928	831	804	822	804	794	777	775	690	718	728
Mozambique	241	64	5	3	3	1	1	1	0	1	1	1
Namibia	..	37	5	13	1	29	95	100	424	237	197	286
Nigeria	420	371	338	330	362	359	385	385	386	416	405	402
Senegal	889	881	940	626	674	741	751	635	590	645	637	624
South Africa	849	884	893	849	871	851	831	827	948	906	927	927
Sudan	325	465	508	603	607	549	530	503	488	369	344	400
United Rep. of Tanzania	152	284	192	51	121	361	431	248	243	306	329	293
Togo	422	185	561	216	442	352	459	404	206	202	195	201
Tunisia	651	588	574	489	477	469	492	506	494	472	463	476
Zambia	11	7	7	7	6	6	5	3	3	3	3	3
Zimbabwe	714	920	740	515	572	572	658	660	660	660	660	660
Other Africa	374	322	366	438	442	451	496	475	484	477	477	479
Africa	**670**	**690**	**649**	**628**	**649**	**634**	**627**	**616**	**667**	**641**	**637**	**648**

*Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

CO_2 emissions per kWh from electricity generation

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
Bangladesh	554	601	556	574	546	553	574	567	574	585	593	584
Brunei Darussalam	924	880	795	780	782	762	802	703	755	755	717	742
Cambodia	..	805	834	787	806	793	797	805	820	816	804	813
Chinese Taipei	463	533	625	649	644	649	657	653	648	635	624	636
India	812	901	920	892	931	923	922	946	950	945	912	936
Indonesia	679	592	654	716	708	719	736	768	747	745	709	734
DPR of Korea	566	481	584	542	528	522	533	469	481	499	465	482
Malaysia	677	543	495	539	561	618	598	611	653	600	727	660
Mongolia	724	1 293	1 105	968	878	889	843	957	854	859	949	887
Myanmar	510	508	457	484	436	395	374	357	308	199	262	256
Nepal	-	26	12	1	6	7	5	4	4	4	1	3
Pakistan	408	405	479	371	397	380	413	433	451	458	425	445
Philippines	341	463	493	449	448	491	429	443	483	475	481	480
Singapore	908	933	762	592	561	539	528	524	515	485	499	500
Sri Lanka	2	51	448	488	513	476	335	394	420	432	379	410
Thailand	626	605	567	536	543	535	511	546	529	513	513	518
Vietnam	552	301	427	381	438	447	435	426	406	384	432	407
Other Asia	310	256	252	341	379	370	319	300	284	296	296	292
Asia	**663**	**704**	**729**	**707**	**725**	**724**	**723**	**743**	**746**	**740**	**728**	**738**
People's Rep. of China	897	907	869	859	879	864	861	822	803	800	766	790
Hong Kong, China	828	855	712	795	749	755	754	775	757	763	723	748
China	**894**	**906**	**865**	**858**	**877**	**863**	**859**	**822**	**803**	**800**	**766**	**790**
Argentina	394	273	338	275	308	313	366	391	365	363	367	365
Bolivia	307	400	314	318	295	329	326	334	375	393	423	397
Brazil	55	55	88	78	85	84	81	73	90	64	87	81
Colombia	208	205	160	152	117	131	127	127	107	176	176	153
Costa Rica	20	155	8	20	8	28	55	72	63	40	56	53
Cuba	765	858	690	815	820	832	767	750	733	1 063	1 012	936
Dominican Republic	845	876	759	700	704	649	668	675	634	591	589	604
Ecuador	187	314	215	256	291	378	423	328	256	313	389	319
El Salvador	67	391	324	335	312	301	310	315	273	276	223	258
Guatemala	74	296	392	435	323	299	345	369	343	349	286	326
Haiti	408	327	346	320	301	307	305	513	480	547	538	522
Honduras	10	327	281	352	451	411	267	420	409	346	332	362
Jamaica	757	888	824	822	618	572	400	400	491	544	711	582
Netherlands Antilles	717	714	714	714	713	711	710	708	707	707	707	707
Nicaragua	345	473	591	543	536	481	522	533	480	506	460	482
Panama	170	317	231	356	266	275	310	314	271	300	298	289
Paraguay	0	2	-	-	-	-	-	-	-	-	-	-
Peru	184	186	154	152	212	209	183	199	240	253	289	261
Trinidad and Tobago	708	711	685	753	751	759	753	753	704	719	700	707
Uruguay	43	53	57	2	151	103	296	104	307	253	81	214
Venezuela	323	219	191	265	222	208	222	208	203	205	264	224
Other Non-OECD Americas	223	216	215	238	236	229	228	238	253	252	252	252
Non-OECD Americas	**184**	**167**	**174**	**180**	**179**	**179**	**182**	**179**	**185**	**183**	**197**	**188**
Bahrain	1 061	815	868	883	881	873	824	837	651	665	640	652
Islamic Republic of Iran	603	606	574	529	542	541	549	546	582	578	565	575
Iraq	569	1 678	641	1 000	579	573	387	423	672	932	1 003	869
Jordan	815	834	708	680	682	660	626	587	589	581	566	578
Kuwait	887	578	780	721	727	799	786	782	778	870	842	830
Lebanon	1 835	678	737	674	599	591	706	662	715	717	709	714
Oman	762	830	795	853	885	861	885	874	853	842	794	830
Qatar	1 077	1 131	771	779	649	618	617	565	534	494	494	507
Saudi Arabia	831	813	805	737	754	739	749	726	736	757	737	743
Syrian Arab Republic	553	586	567	620	571	607	612	623	627	629	594	617
United Arab Emirates	743	737	728	805	913	844	820	720	729	631	598	653
Yemen	746	946	930	884	874	841	781	679	636	630	655	640
Middle East	**737**	**809**	**701**	**692**	**679**	**676**	**668**	**650**	**673**	**688**	**674**	**679**

CO_2 emissions per kWh from electricity generation using coal/peat *

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
World	**984**	**997**	**974**	**974**	**996**	**989**	**992**	**981**	**976**	**977**	**958**	**971**
Annex I Parties	*955*	*947*	*921*	*928*	*933*	*928*	*932*	*938*	*920*	*920*	*909*	*916*
Annex II Parties	*928*	*944*	*922*	*923*	*930*	*917*	*919*	*926*	*911*	*915*	*911*	*912*
North America	*915*	*950*	*923*	*922*	*927*	*916*	*910*	*923*	*903*	*908*	*908*	*906*
Europe	*927*	*916*	*897*	*888*	*909*	*900*	*925*	*921*	*914*	*909*	*901*	*908*
Asia Oceania	*1 021*	*973*	*964*	*985*	*973*	*945*	*950*	*949*	*942*	*947*	*940*	*943*
Annex I EIT	*1 086*	*958*	*901*	*956*	*948*	*1 009*	*1 010*	*1 001*	*961*	*941*	*875*	*926*
Non-Annex I Parties	*1 076*	*1 108*	*1 070*	*1 040*	*1 077*	*1 063*	*1 057*	*1 022*	*1 028*	*1 022*	*996*	*1 015*
Annex I Kyoto Parties	*996*	*944*	*917*	*932*	*939*	*941*	*955*	*947*	*930*	*931*	*906*	*923*
Non-OECD Total	**1 085**	**1 084**	**1 052**	**1 040**	**1 075**	**1 072**	**1 065**	**1 032**	**1 032**	**1 024**	**990**	**1 015**
OECD Total	**940**	**950**	**927**	**925**	**932**	**918**	**922**	**926**	**914**	**918**	**917**	**916**
Canada	1 010	992	934	915	958	898	921	851	812	928	923	888
Chile	1 033	890	1 005	1 167	850	923	866	875	958	873	887	906
Mexico	921	1 110	1 046	1 011	992	974	963	957	1 001	970	952	974
United States	911	948	922	922	926	917	909	927	908	907	907	907
OECD Americas	**916**	**951**	**924**	**923**	**928**	**917**	**910**	**923**	**904**	**909**	**908**	**907**
Australia	946	933	964	1 070	1 046	997	999	999	997	1 002	1 000	1 000
Israel	882	847	851	838	830	797	834	836	837	832	840	836
Japan	1 100	1 007	961	930	925	911	917	916	906	909	902	906
Korea	2 017	1 250	1 010	958	1 007	990	999	913	908	940	960	936
New Zealand	901	793	1 319	1 113	1 094	1 045	1 076	1 154	1 054	1 118	1 284	1 152
OECD Asia Oceania	**1 081**	**1 003**	**967**	**972**	**974**	**948**	**957**	**935**	**929**	**941**	**942**	**938**
Austria	951	1 061	894	907	982	997	1 010	1 066	1 011	1 050	1 059	1 040
Belgium	1 002	1 038	992	1 092	1 136	1 180	1 259	1 301	1 438	1 131	1 230	1 266
Czech Republic	960	1 061	941	945	957	944	953	973	987	975	994	985
Denmark	705	658	614	693	656	637	693	688	668	657	647	658
Estonia	1 013	1 079	1 128	1 055	1 071	1 105	1 021	1 081	1 141	1 162	1 124	1 143
Finland	636	666	707	768	774	721	761	741	736	685	722	714
France	1 053	1 111	1 020	956	976	966	1 003	1 012	1 036	1 048	949	1 011
Germany	932	936	879	870	900	867	904	907	896	906	889	897
Greece	1 137	1 126	992	998	1 015	1 009	1 019	991	1 009	1 000	1 025	1 012
Hungary	1 168	1 066	1 037	1 114	1 154	1 099	1 046	1 049	1 060	1 075	1 101	1 078
Iceland	-	-	-	-	-	-	-	-	-	-	-	-
Ireland	917	923	898	908	881	874	844	857	812	833	869	838
Italy	963	987	974	967	975	998	1 173	1 008	1 019	963	968	983
Luxembourg	3 170	3 701	-	-	-	-	-	-	-	-	-	-
Netherlands	884	864	842	850	861	857	821	839	842	810	830	827
Norway	1 411	864	1 041	935	1 025	1 060	1 057	1 065	1 118	1 156	2 146	1 473
Poland	1 005	916	882	869	858	858	863	866	873	870	865	869
Portugal	886	854	865	838	843	857	859	849	848	853	873	858
Slovak Republic	954	1 031	947	1 065	974	982	1 000	1 010	990	1 012	1 001	1 001
Slovenia	1 036	836	985	981	986	971	978	993	984	964	953	967
Spain	936	911	917	910	891	886	901	943	901	926	937	921
Sweden	637	525	866	747	820	988	906	827	690	780	796	755
Switzerland	665	..	-	-	-	-	-	-	-	-	-	-
Turkey	1 199	1 132	1 085	1 068	1 045	918	1 017	1 039	1 038	1 023	1 059	1 040
United Kingdom	910	880	927	916	936	941	933	938	931	933	924	929
OECD Europe	**949**	**933**	**911**	**900**	**915**	**903**	**925**	**927**	**925**	**920**	**917**	**921**
European Union - 27	*952*	*938*	*908*	*902*	*917*	*910*	*928*	*928*	*926*	*920*	*915*	*920*

* CO_2 emissions from coal and peat consumed for electricity generation, in both electricity-only and combined heat and power (CHP) plants, divided by output of electricity generated from coal. Both main activity producers and autoproducers have been included in the calculation. This indicator is not available when electricity output is very small or where inputs to electricity generation do not match electricity output.

CO_2 emissions per kWh from electricity generation using coal/peat

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
Non-OECD Total	**1 085**	**1 084**	**1 052**	**1 040**	**1 075**	**1 072**	**1 065**	**1 032**	**1 032**	**1 024**	**990**	**1 015**
Albania	-	-	-	-	-	-	-	-	-	-	-	-
Armenia	-	-	-	-	-	-	-	-	-	-	-	-
Azerbaijan	-	-	-	-	-	-	-	-	-	-	-	-
Belarus	-	-	-	1 432	1 433	1 484	1 732	1 260	1 886	1 386	1 014	1 429
Bosnia and Herzegovina	896	977	1 615	1 479	1 463	1 532	1 532	1 535	1 235	1 346	1 368	1 316
Bulgaria	1 237	1 138	1 033	1 082	1 110	1 133	1 112	1 070	1 041	1 040	1 055	1 045
Croatia	1 086	1 037	894	859	913	896	863	862	858	882	866	868
Cyprus	-	-	-	-	-	-	-	-	-	-	-	-
Georgia	-	-	-	-	-	-	-	-	-	-	-	-
Gibraltar	-	-	-	-	-	-	-	-	-	-	-	-
Kazakhstan	632	610	773	716	666	611	1 008	731	584	446	429	486
Kosovo *	..	..	1 341	1 448	1 336	1 151	1 154	1 112	1 106	1 319	1 330	1 252
Kyrgyzstan	576	678	814	1 029	866	593	593	586	897	634	1 122	884
Latvia	855	1 241	1 504	1 053	-	-	-	..	..	..	..	..
Lithuania	-	-	-	-	-	-	945	1 013	1 113	-	-	1 113
FYR of Macedonia	964	1 010	970	1 016	1 023	1 007	1 036	1 053	1 050	989	1 033	1 024
Malta	1 167	1 382	-	-	-	-	-	-	-	-	-	-
Republic of Moldova	878	816	1 178	1 163	-	-	-	-	-	-	-	-
Montenegro *	..	..	..	..	..	1 102	1 052	1 135	1 162	1 160	1 328	1 217
Romania	1 045	1 242	1 032	1 042	1 068	1 066	1 053	1 097	1 089	1 089	1 060	1 079
Russian Federation	1 115	761	792	914	908	1 068	1 088	1 045	914	919	720	851
Serbia *	1 213	1 573	1 386	1 295	1 273	1 176	1 189	1 049	1 053	1 061	1 051	1 055
Tajikistan	-	-	-	-	-	-	-	-	-	-	-	-
Turkmenistan	-	-	-	-	-	-	-	-	-	-	-	-
Ukraine	1 183	1 257	1 070	1 149	1 119	1 203	1 115	1 121	1 124	952	975	1 017
Uzbekistan	1 817	1 582	1 566	1 565	1 565	1 567	1 565	1 566	1 565	1 565	1 565	1 565
Non-OECD Europe and Eurasia	**1 065**	**945**	**921**	**986**	**968**	**1 037**	**1 094**	**1 026**	**939**	**897**	**809**	**882**
Algeria	-	-	-	-	-	-	-	-	-	-	-	-
Angola	-	-	-	-	-	-	-	-	-	-	-	-
Benin	-	-	-	-	-	-	-	-	-	-	-	-
Botswana	1 885	1 815	1 900	2 068	2 268	2 081	1 933	1 591	1 789	1 953	2 517	2 086
Cameroon	-	-	-	-	-	-	-	-	-	-	-	-
Congo	-	-	-	-	-	-	-	-	-	-	-	-
Dem. Rep. of Congo	-	-	-	-	-	-	-	-	-	-	-	-
Côte d'Ivoire	-	-	-	-	-	-	-	-	-	-	-	-
Egypt	-	-	-	-	-	-	-	-	-	-	-	-
Eritrea	..	-	-	-	-	-	-	-	-	-	-	-
Ethiopia	-	-	-	-	-	-	-	-	-	-	-	-
Gabon	-	-	-	-	-	-	-	-	-	-	-	-
Ghana	-	-	-	-	-	-	-	-	-	-	-	-
Kenya	-	-	-	-	-	-	-	-	-	-	-	-
Libya	-	-	-	-	-	-	-	-	-	-	-	-
Morocco	1 242	1 020	938	914	910	920	929	940	964	928	968	953
Mozambique	883	-	-	-	-	-	-	-	-	-	-	-
Namibia	..	1 346	1 262	1 403	..	1 503	1 388	1 339	1 333	1 336	1 331	1 333
Nigeria	1 656	-	-	-	-	-	-	-	-	-	-	-
Senegal	-	-	-	-	-	-	-	-	-	-	-	-
South Africa	900	944	960	902	928	900	878	870	1 005	963	982	983
Sudan	-	-	-	-	-	-	-	-	-	-	-	-
United Rep. of Tanzania	-	1 116	1 107	1 114	1 113	1 111	1 106	1 112	1 127	1 140	1 143	1 137
Togo	-	-	-	-	-	-	-	-	-	-	-	-
Tunisia	-	-	-	-	-	-	-	-	-	-	-	-
Zambia	1 703	1 718	1 636	1 575	1 527	1 575	1 636	2 290	2 290	2 290	2 290	2 290
Zimbabwe	1 338	1 287	1 383	1 311	1 321	1 321	1 321	1 321	1 321	1 322	1 322	1 322
Other Africa	956	956	955	955	955	956	955	956	956	956	955	955
Africa	**923**	**962**	**970**	**913**	**938**	**913**	**892**	**883**	**1 010**	**969**	**990**	**990**

*Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

CO_2 emissions per kWh from electricity generation using coal/peat

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
Bangladesh	-	-	-	-	-	1 405	1 391	1 390	1 390	1 390	1 390	1 390
Brunei Darussalam	-	-	-	-	-	-	-	-	-	-	-	-
Cambodia	..	-	-	-	-	-	-	-	-	1 070	1 027	1 048
Chinese Taipei	983	853	941	921	919	925	934	931	945	928	926	933
India	1 125	1 177	1 206	1 167	1 230	1 250	1 253	1 299	1 247	1 237	1 195	1 226
Indonesia	938	941	974	1 025	983	1 023	998	1 051	1 078	1 069	1 084	1 077
DPR of Korea	1 294	1 253	1 217	1 208	1 208	1 208	1 208	1 208	1 208	1 208	1 208	1 208
Malaysia	1 077	1 077	754	1 076	1 076	1 076	1 076	1 076	1 196	1 077	1 182	1 152
Mongolia	683	1 294	1 103	962	869	883	835	951	844	851	943	879
Myanmar	1 196	-	-	1 034	1 034	1 036	1 035	1 035	1 032	1 032	1 034	1 033
Nepal	-	-	-	-	-	-	-	-	-	-	-	-
Pakistan	1 836	1 581	1 491	1 920	2 053	2 316	2 616	2 636	2 137	2 363	2 392	2 298
Philippines	1 020	1 436	960	933	897	1 138	1 021	989	1 221	1 138	920	1 093
Singapore	-	-	-	-	-	-	-	-	-	-	-	-
Sri Lanka	-	-	-	-	-	-	-	-	-	-	-	-
Thailand	957	984	965	990	989	974	800	975	938	923	932	931
Vietnam	1 790	1 415	1 479	958	1 402	988	988	988	987	987	988	987
Other Asia	-	-	980	980	981	983	981	982	981	980	980	980
Asia	**1 101**	**1 123**	**1 131**	**1 100**	**1 141**	**1 157**	**1 151**	**1 189**	**1 173**	**1 160**	**1 132**	**1 155**
People's Rep. of China	1 164	1 165	1 067	1 046	1 091	1 066	1 049	997	1 002	1 001	967	990
Hong Kong, China	832	856	869	890	881	881	888	891	898	888	885	890
China	**1 144**	**1 154**	**1 063**	**1 043**	**1 087**	**1 064**	**1 047**	**996**	**1 001**	**999**	**967**	**989**
Argentina	3 655	2 026	1 246	1 709	1 420	1 372	1 229	1 155	1 146	1 139	1 111	1 132
Bolivia	-	-	-	-	-	-	-	-	-	-	-	-
Brazil	1 691	1 565	1 507	1 637	1 450	1 505	1 617	1 571	1 413	1 456	1 563	1 477
Colombia	1 170	1 155	1 101	1 208	1 137	1 150	1 068	952	1 055	1 109	1 105	1 089
Costa Rica	-	-	-	-	-	-	-	-	-	-	-	-
Cuba	-	-	-	-	-	-	-	-	-	-	-	-
Dominican Republic	946	952	955	954	954	954	953	954	953	954	953	953
Ecuador	-	-	-	-	-	-	-	-	-	-	-	-
El Salvador	-	-	-	-	-	-	-	-	-	-	-	-
Guatemala	-	-	954	954	954	953	953	953	954	954	953	954
Haiti	-	-	-	-	-	-	-	-	-	-	-	-
Honduras	-	-	-	-	-	-	-	-	-	-	-	-
Jamaica	-	-	-	-	-	-	-	-	-	-	-	-
Netherlands Antilles	-	-	-	-	-	-	-	-	-	-	-	-
Nicaragua	-	-	-	-	-	-	-	-	-	-	-	-
Panama	-	-	-	-	-	-	-	-	-	-	-	-
Paraguay	-	-	-	-	-	-	-	-	-	-	-	-
Peru	-	-	1 112	1 112	1 112	1 112	1 112	1 113	1 112	1 279	1 252	1 214
Trinidad and Tobago	-	-	-	-	-	-	-	-	-	-	-	-
Uruguay	-	-	-	-	-	-	-	-	-	-	-	-
Venezuela	-	-	-	-	-	-	-	-	-	-	-	-
Other Non-OECD Americas	-	-	-	-	-	-	-	-	-	-	-	-
Non-OECD Americas	**1 617**	**1 480**	**1 388**	**1 404**	**1 313**	**1 358**	**1 371**	**1 300**	**1 252**	**1 267**	**1 323**	**1 280**
Bahrain	-	-	-	-	-	-	-	-	-	-	-	-
Islamic Republic of Iran	601	605	..	..	..	..	..	..	..	..	..	..
Iraq	-	-	-	-	-	-	-	-	-	-	-	-
Jordan	-	-	-	-	-	-	-	-	-	-	-	-
Kuwait	-	-	-	-	-	-	-	-	-	-	-	-
Lebanon	-	-	-	-	-	-	-	-	-	-	-	-
Oman	-	-	-	-	-	-	-	-	-	-	-	-
Qatar	-	-	-	-	-	-	-	-	-	-	-	-
Saudi Arabia	-	-	-	-	-	-	-	-	-	-	-	-
Syrian Arab Republic	-	-	-	-	-	-	-	-	-	-	-	-
United Arab Emirates	-	-	-	-	-	-	-	-	-	-	-	-
Yemen	-	-	-	-	-	-	-	-	-	-	-	-
Middle East	**601**	**605**	**..**	**..**	**..**	**..**	**..**	**..**	**..**	**..**	**..**	**..**

CO_2 emissions per kWh from electricity generation using oil *

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
World	**731**	**732**	**737**	**748**	**745**	**760**	**754**	**743**	**755**	**787**	**796**	**779**
Annex I Parties	*675*	*629*	*694*	*682*	*694*	*707*	*688*	*686*	*679*	*666*	*654*	*666*
Annex II Parties	*658*	*636*	*688*	*676*	*687*	*701*	*683*	*680*	*671*	*656*	*643*	*657*
North America	*678*	*570*	*797*	*756*	*773*	*761*	*809*	*769*	*757*	*711*	*727*	*732*
Europe	*674*	*656*	*644*	*643*	*655*	*720*	*671*	*721*	*722*	*708*	*704*	*711*
Asia Oceania	*634*	*655*	*636*	*618*	*612*	*619*	*602*	*607*	*596*	*574*	*554*	*575*
Annex I EIT	*716*	*586*	*709*	*724*	*732*	*715*	*686*	*698*	*707*	*695*	*719*	*707*
Non-Annex I Parties	*819*	*838*	*768*	*799*	*779*	*795*	*788*	*772*	*790*	*833*	*844*	*822*
Annex I Kyoto Parties	*673*	*640*	*650*	*648*	*651*	*677*	*657*	*667*	*668*	*655*	*636*	*653*
Non-OECD Total	**792**	**811**	**777**	**798**	**796**	**808**	**798**	**787**	**809**	**848**	**859**	**839**
OECD Total	**674**	**662**	**696**	**693**	**686**	**705**	**687**	**679**	**665**	**661**	**657**	**661**
Canada	721	641	627	723	685	705	998	965	1 006	770	833	870
Chile	849	1 550	938	1 142	1 110	1 088	1 073	686	618	651	672	647
Mexico	781	770	780	991	744	780	754	761	731	758	755	748
United States	671	559	819	762	787	767	786	744	719	698	711	709
OECD Americas	**710**	**657**	**791**	**819**	**768**	**771**	**793**	**758**	**730**	**723**	**734**	**729**
Australia	832	898	912	749	929	886	880	891	897	912	881	896
Israel	772	777	578	695	888	848	866	844	704	797	857	786
Japan	631	652	632	616	608	614	595	602	587	560	543	563
Korea	765	714	560	495	529	589	610	570	544	569	575	563
New Zealand	..	857	-	781	911	781	679	-	734	625	-	679
OECD Asia Oceania	**648**	**669**	**618**	**600**	**607**	**623**	**613**	**608**	**594**	**576**	**562**	**578**
Austria	749	586	510	552	555	530	534	569	600	589	529	573
Belgium	458	439	741	825	828	752	742	720	575	669	537	594
Czech Republic	848	573	1 044	912	744	719	710	965	1 134	1 191	975	1 100
Denmark	610	665	694	508	504	492	494	518	501	509	667	559
Estonia	371	..	588	776	762	832	748	886	904	763	818	828
Finland	459	425	493	600	563	568	602	562	460	478	430	456
France	603	506	547	551	627	869	788	809	805	950	766	841
Germany	817	522	641	690	453	954	555	670	641	648	583	624
Greece	746	737	731	749	721	714	695	731	753	763	769	762
Hungary	734	751	688	741	910	913	977	935	861	701	860	807
Iceland	520	694	624	520	781	624	781	..	..	..	..	..
Ireland	756	736	696	792	766	741	758	653	655	727	703	695
Italy	672	663	704	690	723	710	745	778	782	718	823	774
Luxembourg	1 021	1 226	-	..	..	-	-	-	..	-	-	..
Netherlands	695	729	646	493	498	488	527	505	504	461	513	493
Norway	..	-	406	322	370	356	359	485	431	397	331	386
Poland	820	650	608	586	605	519	523	506	503	488	463	484
Portugal	707	737	635	660	648	648	623	615	632	607	559	600
Slovak Republic	380	519	477	440	395	408	422	407	435	614	674	574
Slovenia	480	1 375	689	621	612	634	607	811	811	687	1 049	849
Spain	805	795	630	645	660	696	603	723	718	671	674	688
Sweden	308	321	359	350	404	392	393	395	382	672	385	480
Switzerland	718	714	365	352	346	398	405	412	387	389	430	402
Turkey	899	951	870	688	711	681	758	686	723	796	779	766
United Kingdom	660	672	468	745	696	682	623	694	726	813	738	759
OECD Europe	**675**	**666**	**658**	**646**	**657**	**713**	**670**	**713**	**715**	**706**	**698**	**706**
European Union - 27	*704*	*661*	*652*	*654*	*662*	*722*	*676*	*722*	*719*	*706*	*701*	*709*

* CO_2 emissions from oil consumed for electricity generation, in both electricity-only and combined heat and power plants, divided by output of electricity generated from oil. Both main activity producers and autoproducers have been included in the calculation. This indicator is not available when electricity output is very small or where inputs to electricity generation do not match electricity output.

CO_2 emissions per kWh from electricity generation using oil

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
Non-OECD Total	**792**	**811**	**777**	**798**	**796**	**808**	**798**	**787**	**809**	**848**	**859**	**839**
Albania	884	622	1 361	1 439	1 187	2 023	1 523	1 240	-	..	..	..
Armenia	578	306	-	-	-	-	-	-	-	-	-	-
Azerbaijan	722	828	885	885	1 058	1 006	1 080	882	858	860	575	764
Belarus	687	696	653	560	638	584	582	610	638	586	611	612
Bosnia and Herzegovina	947	1 977	1 085	1 051	1 044	1 043	1 041	1 041	1 021	864	809	898
Bulgaria	469	622	707	786	663	742	711	749	770	699	806	758
Croatia	760	647	752	732	716	684	680	693	669	650	548	622
Cyprus	838	822	838	833	772	789	758	761	761	750	714	742
Georgia	..	..	..	..	..	..	..	..	..	..	..	..
Gibraltar	776	766	760	755	766	761	751	751	757	757	762	758
Kazakhstan	1 217	1 033	919	919	918	916	890	889	913	919	919	917
Kosovo *	..	..	1 143	1 074	1 074	1 034	963	901	846	824	844	838
Kyrgyzstan	-	-	-	-	-	-	-	-	-	-	-	-
Latvia	527	521	734	515	550	436	948	693	515	696	969	727
Lithuania	511	593	544	778	776	783	814	603	525	521	518	522
FYR of Macedonia	1 189	912	780	994	1 277	1 312	782	802	873	834	977	895
Malta	2 119	932	819	946	913	1 034	954	1 012	849	850	872	857
Republic of Moldova	926	1 990	2 918	2 791	717	763	765	-	697	682	687	689
Montenegro *	..	..	..	..	..	-	-	-	-	-	-	-
Romania	1 272	647	603	611	619	595	580	627	670	638	582	630
Russian Federation	634	515	733	759	770	761	715	729	753	755	837	781
Serbia *	902	914	914	915	917	780	1 080	703	823	1 028	767	873
Tajikistan	-	-	-	-	-	-	-	-	-	-	-	-
Turkmenistan	-	-	-	-	-	-	-	-	-	-	-	-
Ukraine	856	805	630	739	810	966	989	965	966	946	587	833
Uzbekistan	3 012	795	777	777	777	778	778	778	778	780	783	780
Non-OECD Europe and Eurasia	**778**	**656**	**777**	**786**	**810**	**816**	**797**	**796**	**777**	**745**	**784**	**769**
Algeria	1 050	1 178	863	864	869	948	961	916	914	936	998	949
Angola	..	..	1 353	1 349	1 341	1 339	1 341	1 342	1 342	1 343	1 344	1 343
Benin	1 200	951	616	771	749	716	716	671	688	725	724	712
Botswana	1 091	1 054	1 051	1 085	1 055	1 026	1 026	1 026	-	-	-	-
Cameroon	852	893	919	733	600	698	739	705	739	711	858	769
Congo	1 058	1 587	-	-	-	-	-	-	-	1 092	1 050	1 071
Dem. Rep. of Congo	1 012	1 219	1 058	907	794	907	1 058	907	747	1 058	1 058	954
Côte d'Ivoire	616	692	970	1 042	718	933	968	1 037	1 047	857	857	920
Egypt	952	808	280	325	966	810	743	621	632	606	529	589
Eritrea	..	1 463	702	696	713	668	684	659	674	676	650	667
Ethiopia	1 164	641	828	794	882	794	953	960	959	1 094	1 127	1 060
Gabon	895	803	777	677	681	699	709	689	659	660	659	659
Ghana	-	836	772	823	745	860	827	772	842	812	1 583	1 079
Kenya	712	715	896	896	898	898	897	899	899	899	899	899
Libya	779	1 290	1 144	1 067	943	1 003	1 078	1 077	1 087	1 087	1 087	1 087
Morocco	773	932	741	797	915	872	832	740	768	732	820	773
Mozambique	504	907	1 058	840	814	907	794	1 058	-	-	-	-
Namibia	..	833	-	..	-	666	740	740	666	740	740	716
Nigeria	772	729	725	727	726	725	725	725	724	725	726	725
Senegal	941	980	1 045	845	876	917	871	709	678	733	723	711
South Africa	-	819	-	-	-	-	-	753	748	771	751	757
Sudan	884	972	942	922	891	819	760	708	665	665	673	668
United Rep. of Tanzania	3 135	1 495	1 488	1 459	1 499	924	919	891	924	1 001	1 078	1 001
Togo	1 058	1 058	1 309	732	799	589	798	842	847	847	819	837
Tunisia	831	921	907	817	764	781	741	731	718	727	..	722
Zambia	1 091	917	922	896	896	847	690	859	967	803	850	873
Zimbabwe	-	-	1 539	2 963	1 965	2 117	2 117	2 117	2 117	2 117	2 117	2 117
Other Africa	673	574	621	740	764	763	760	738	753	724	724	734
Africa	**850**	**935**	**664**	**758**	**902**	**875**	**853**	**780**	**799**	**785**	**774**	**786**

*Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

CO_2 emissions per kWh from electricity generation using oil

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
Bangladesh	1 101	1 004	1 078	1 079	1 013	1 091	1 091	1 117	1 117	1 118	1 118	1 118
Brunei Darussalam	866	847	690	762	766	766	819	770	770	772	752	765
Cambodia	..	805	836	842	848	845	843	842	856	851	839	849
Chinese Taipei	692	696	688	749	790	804	782	829	825	918	879	874
India	1 129	1 105	1 176	1 070	1 128	1 068	1 221	1 232	1 355	1 464	1 312	1 377
Indonesia	817	889	786	787	727	740	714	792	739	749	764	751
DPR of Korea	1 308	1 379	1 379	1 379	1 379	1 379	1 378	1 380	1 380	1 379	1 380	1 380
Malaysia	861	831	846	840	838	817	813	829	981	776	625	794
Mongolia	820	765	893	936	957	1 013	1 023	1 004	1 012	1 027	1 032	1 024
Myanmar	741	894	868	819	770	840	794	840	794	847	770	803
Nepal	-	827	755	850	971	1 062	1 042	1 129	1 129	1 042	1 129	1 100
Pakistan	890	757	755	675	795	692	749	719	731	762	766	753
Philippines	563	656	685	730	721	751	723	664	722	695	662	693
Singapore	909	1 151	834	835	835	830	833	844	836	837	836	837
Sri Lanka	1 231	696	826	855	803	758	657	657	763	716	798	759
Thailand	786	740	748	724	714	728	738	763	728	761	715	734
Vietnam	924	900	914	894	1 374	1 044	1 015	998	1 241	1 008	920	1 056
Other Asia	686	563	624	723	781	797	774	837	863	868	868	866
Asia	**812**	**808**	**826**	**837**	**842**	**818**	**825**	**855**	**874**	**901**	**887**	**887**
People's Rep. of China	817	817	863	866	831	826	828	834	858	836	1 043	913
Hong Kong, China	619	825	788	769	742	798	805	829	836	983	1 055	958
China	**815**	**818**	**863**	**866**	**830**	**826**	**828**	**834**	**858**	**838**	**1 044**	**913**
Argentina	1 093	632	1 013	1 132	922	808	767	764	750	746	733	743
Bolivia	941	948	953	947	947	943	938	943	940	946	945	944
Brazil	827	825	805	739	714	762	722	714	692	677	719	696
Colombia	890	891	864	874	877	877	874	871	871	893	894	886
Costa Rica	807	916	965	928	959	852	900	896	888	820	833	847
Cuba	853	915	766	905	922	913	838	819	809	1 204	1 130	1 048
Dominican Republic	940	995	834	751	806	768	766	794	684	643	685	671
Ecuador	873	810	761	739	729	978	1 165	920	751	744	926	807
El Salvador	984	927	773	784	688	719	727	719	719	633	639	664
Guatemala	888	881	780	824	830	849	816	803	806	797	797	800
Haiti	1 980	669	716	611	573	587	582	764	766	767	770	768
Honduras	556	845	737	578	646	619	423	670	661	627	616	634
Jamaica	819	923	852	839	635	591	415	413	511	569	759	613
Netherlands Antilles	717	714	714	714	713	711	710	708	707	707	707	707
Nicaragua	892	868	751	745	742	736	746	751	745	732	730	736
Panama	1 157	1 027	781	727	782	769	796	735	721	693	692	702
Paraguay	898	926	-	-	-	-	-	-	-	-	-	-
Peru	802	965	881	841	812	1 142	934	1 425	1 131	1 000	981	1 037
Trinidad and Tobago	..	..	..	..	..	..	..	..	..	..	661	661
Uruguay	844	826	860	1 435	820	824	843	807	786	811	751	783
Venezuela	895	1 200	890	915	936	907	998	930	886	872	947	902
Other Non-OECD Americas	240	229	211	229	229	222	221	232	247	249	249	248
Non-OECD Americas	**681**	**665**	**634**	**651**	**638**	**645**	**636**	**634**	**637**	**672**	**695**	**668**
Bahrain	-	-	-	-	-	-	1 312	1 314	1 231	-	-	1 231
Islamic Republic of Iran	907	910	912	907	906	908	904	906	906	906	904	905
Iraq	550	1 607	558	962	558	980	619	672	1 237	2 065	2 380	1 894
Jordan	855	860	717	686	753	730	699	675	683	659	559	634
Kuwait	1 197	665	917	820	845	917	942	939	977	1 008	949	978
Lebanon	2 753	784	773	756	658	645	751	696	736	756	772	755
Oman	1 056	1 056	1 056	1 055	1 055	1 056	1 055	1 056	1 055	1 055	1 015	1 042
Qatar	-	-	-	-	-	-	-	-	-	-	-	-
Saudi Arabia	834	831	876	803	872	840	828	776	795	832	823	817
Syrian Arab Republic	789	777	730	849	759	802	789	758	740	762	750	751
United Arab Emirates	971	968	953	1 052	1 194	1 194	1 194	1 194	1 195	1 053	1 195	1 147
Yemen	746	946	930	884	874	841	781	679	636	630	692	653
Middle East	**845**	**991**	**813**	**844**	**802**	**861**	**842**	**813**	**857**	**934**	**939**	**910**

CO_2 emissions per kWh from electricity generation using natural gas *

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
World	**490**	**503**	**480**	**466**	**463**	**464**	**458**	**453**	**451**	**449**	**451**	**450**
Annex I Parties	*448*	*472*	*449*	*434*	*430*	*430*	*418*	*419*	*416*	*413*	*415*	*415*
Annex II Parties	*509*	*488*	*442*	*422*	*419*	*415*	*400*	*402*	*397*	*396*	*399*	*398*
North America	*546*	*536*	*483*	*451*	*452*	*449*	*414*	*419*	*412*	*406*	*410*	*409*
Europe	*454*	*397*	*379*	*367*	*358*	*356*	*360*	*356*	*357*	*360*	*365*	*361*
Asia Oceania	*475*	*467*	*446*	*452*	*452*	*448*	*449*	*452*	*450*	*446*	*441*	*446*
Annex I EIT	*378*	*435*	*481*	*480*	*474*	*485*	*487*	*485*	*490*	*484*	*479*	*484*
Non-Annex I Parties	*649*	*585*	*551*	*525*	*522*	*524*	*528*	*514*	*509*	*505*	*504*	*506*
Annex I Kyoto Parties	*408*	*432*	*434*	*430*	*421*	*421*	*424*	*422*	*422*	*420*	*423*	*422*
Non-OECD Total	**475**	**520**	**533**	**524**	**520**	**526**	**531**	**519**	**518**	**514**	**511**	**514**
OECD Total	**510**	**488**	**439**	**417**	**415**	**412**	**399**	**401**	**396**	**395**	**398**	**396**
Canada	403	405	455	484	439	446	436	449	489	460	499	483
Chile	777	574	370	361	407	465	414	463	501	450	383	445
Mexico	555	513	489	415	419	420	428	420	417	400	419	412
United States	549	541	484	449	452	449	413	417	408	403	405	405
OECD Americas	**546**	**535**	**481**	**445**	**447**	**446**	**415**	**419**	**412**	**405**	**411**	**409**
Australia	565	558	584	606	572	528	528	528	528	519	542	529
Israel	-	516	541	673	526	559	481	499	440	433	442	438
Japan	466	459	436	435	438	441	443	445	442	438	430	437
Korea	496	436	379	354	372	369	370	372	367	364	370	367
New Zealand	507	510	463	435	433	428	415	415	397	401	414	404
OECD Asia Oceania	**476**	**465**	**439**	**440**	**440**	**435**	**434**	**437**	**433**	**431**	**426**	**430**
Austria	437	493	395	337	328	329	333	335	328	319	305	317
Belgium	513	436	385	369	368	372	335	331	332	339	332	334
Czech Republic	251	414	465	417	501	459	434	347	422	449	405	426
Denmark	292	271	286	289	290	282	288	278	276	281	260	272
Estonia	253	252	252	254	253	245	238	245	239	237	273	249
Finland	270	331	242	278	258	239	267	243	243	236	236	238
France	337	335	288	264	247	264	314	318	322	463	520	435
Germany	464	446	370	325	306	309	298	299	315	311	346	324
Greece	459	435	505	434	416	459	416	416	423	385	490	432
Hungary	561	544	457	446	402	396	399	405	393	360	365	373
Iceland	-	-	-	-	-	-	-	-	-	-	-	-
Ireland	499	480	460	421	407	412	409	413	392	395	398	395
Italy	475	466	431	420	401	393	382	380	376	374	374	374
Luxembourg	662	633	642	397	393	393	394	391	399	387	417	401
Netherlands	444	353	310	324	322	321	337	329	333	331	330	331
Norway	-	302	302	301	301	302	301	341	312	302	343	319
Poland	527	444	507	506	507	346	360	354	346	339	320	335
Portugal	-	-	372	375	359	357	353	352	355	361	359	358
Slovak Republic	813	837	490	320	329	316	295	305	310	339	385	345
Slovenia	..	345	273	370	307	291	268	332	345	395	378	373
Spain	423	469	311	316	324	319	356	339	349	353	358	353
Sweden	217	218	249	223	217	218	219	215	216	209	209	211
Switzerland	269	242	240	248	245	248	260	257	261	261	253	258
Turkey	488	419	356	354	365	374	356	362	364	371	376	371
United Kingdom	521	426	396	394	392	393	400	388	387	390	384	387
OECD Europe	**461**	**405**	**379**	**368**	**361**	**359**	**360**	**357**	**358**	**361**	**366**	**362**
European Union - 27	*487*	*416*	*385*	*374*	*362*	*359*	*361*	*358*	*359*	*360*	*365*	*361*

* CO_2 emissions from natural gas consumed for electricity generation, in both electricity-only and combined heat and power plants, divided by output of electricity generated from natural gas. Both main activity producers and autoproducers have been included in the calculation. This indicator is not available when electricity output is very small or where inputs to electricity generation do not match electricity output.

CO_2 emissions per kWh from electricity generation using natural gas

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
Non-OECD Total	**475**	**520**	**533**	**524**	**520**	**526**	**531**	**519**	**518**	**514**	**511**	**514**
Albania	-	-	-	-	-	-	-	-	-	-	-	-
Armenia	600	359	526	516	375	454	525	620	609	504	416	510
Azerbaijan	-	490	682	583	599	599	599	578	570	560	538	556
Belarus	421	424	460	438	454	455	455	451	460	439	445	448
Bosnia and Herzegovina	-	-	-	-	-	-	-	-	-	630	632	631
Bulgaria	645	638	571	429	297	270	288	391	322	299	238	286
Croatia	461	562	491	414	417	403	422	460	416	417	367	400
Cyprus	-	-	-	-	-	-	-	-	-	-	-	-
Georgia	521	854	887	566	565	520	508	847	476	766	727	656
Gibraltar	-	-	-	-	-	-	-	-	-	-	-	-
Kazakhstan	381	559	1 009	780	602	778	574	574	574	574	574	574
Kosovo *	..	..	-	-	-	-	-	-	-	-	-	-
Kyrgyzstan	383	383	383	384	383	384	383	385	498	498	498	498
Latvia	306	372	314	290	286	280	254	250	281	254	258	264
Lithuania	350	..	461	370	367	376	379	386	402	401	424	409
FYR of Macedonia	-	-	..	..	..	..	..	-	-	613	487	550
Malta	-	-	-	-	-	-	-	-	-	-	-	-
Republic of Moldova	515	562	791	727	534	537	516	535	521	532	520	524
Montenegro *	..	..	..	..	..	-	-	-	-	-	-	-
Romania	704	514	506	606	489	471	428	428	462	369	332	388
Russian Federation	357	429	487	487	487	503	503	499	505	499	494	499
Serbia *	402	579	580	567	567	307	438	490	463	..	..	463
Tajikistan	..	..	..	..	..	..	..	..	..	..	415	415
Turkmenistan	720	931	872	872	872	872	872	872	928	866	954	916
Ukraine	383	400	422	442	386	393	417	411	397	364	375	379
Uzbekistan	467	565	644	644	644	644	644	643	644	642	642	643
Non-OECD Europe and Eurasia	**406**	**455**	**511**	**507**	**499**	**513**	**513**	**511**	**516**	**512**	**506**	**512**
Algeria	613	621	614	632	631	609	618	594	594	643	540	593
Angola	-	-	-	-	-	-	-	-	-	-	-	-
Benin	-	-	-	-	-	-	-	-	-	-	-	-
Botswana	-	-	-	-	-	-	-	-	-	-	-	-
Cameroon	-	-	-	-	-	-	-	538	538	538	538	538
Congo	-	-	-	573	576	573	572	575	576	574	572	574
Dem. Rep. of Congo	-	-	-	-	-	-	574	573	573	573	573	573
Côte d'Ivoire	-	736	598	600	536	627	539	617	687	625	625	646
Egypt	490	490	490	490	490	490	490	490	490	490	490	490
Eritrea	..	-	-	-	-	-	-	-	-	-	-	-
Ethiopia	-	-	-	-	-	-	-	-	-	-	-	-
Gabon	1 038	876	929	926	964	1 013	1 007	1 043	719	720	720	720
Ghana	-	-	-	-	-	-	-	-	-	-	-	-
Kenya	-	-	-	-	-	-	-	-	-	-	-	-
Libya	-	591	591	632	662	662	591	562	595	562	595	584
Morocco	-	-	-	-	-	397	394	409	350	403	570	441
Mozambique	-	652	778	1 674	775	724	684	573	502	711	600	605
Namibia	..	-	-	-	-	-	-	-	-	-	-	-
Nigeria	584	502	543	502	502	502	502	502	502	502	502	502
Senegal	591	604	628	512	517	519	516	513	513	680	681	625
South Africa	-	-	-	-	-	-	-	-	-	-	-	-
Sudan	-	-	-	-	-	-	-	-	-	-	-	-
United Rep. of Tanzania	-	-	-	-	484	569	602	579	563	798	748	703
Togo	-	-	-	-	-	-	-	-	-	-	-	-
Tunisia	559	533	536	495	481	470	477	483	485	469	468	474
Zambia	-	-	-	-	-	-	-	-	-	-	-	-
Zimbabwe	-	-	-	-	-	-	-	-	-	-	-	-
Other Africa	-	-	-	451	452	451	453	453	453	453	453	453
Africa	**554**	**539**	**542**	**532**	**528**	**526**	**525**	**521**	**524**	**530**	**514**	**523**

*Serbia includes Kosovo from 1990 to 1999 and Montenegro from 1990 to 2004.

CO_2 emissions per kWh from electricity generation using natural gas

grammes CO_2 / kilowatt hour

	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	Average 08-10
Bangladesh	602	586	555	573	545	546	561	555	554	568	578	567
Brunei Darussalam	924	881	796	780	782	762	802	702	754	755	716	742
Cambodia	..	-	-	-	-	-	-	-	-	-	-	-
Chinese Taipei	504	508	464	434	426	429	429	424	429	422	423	425
India	812	539	386	387	393	391	377	364	359	432	517	436
Indonesia	670	509	519	500	587	503	606	546	542	572	504	540
DPR of Korea	-	-	-	-	-	-	-	-	-	-	-	-
Malaysia	574	503	499	429	427	502	484	463	494	437	536	489
Mongolia	-	-	-	-	-	-	-	-	-	-	-	-
Myanmar	1 041	843	686	725	725	725	725	725	725	725	725	725
Nepal	-	-	-	-	-	-	-	-	-	-	-	-
Pakistan	662	594	550	536	526	537	536	573	586	562	557	568
Philippines	-	854	..	349	356	345	330	338	341	349	329	339
Singapore	-	447	446	446	446	446	446	446	446	410	410	422
Sri Lanka	-	-	-	-	-	-	-	-	-	-	-	-
Thailand	503	468	483	479	470	465	465	459	450	446	444	447
Vietnam	..	514	591	522	404	434	444	431	428	418	409	418
Other Asia	-	502	502	502	502	502	502	502	502	502	502	502
Asia	**632**	**524**	**483**	**461**	**458**	**463**	**463**	**451**	**455**	**457**	**480**	**464**
People's Rep. of China	539	545	519	520	520	519	519	518	518	518	518	518
Hong Kong, China	-	859	468	457	451	454	454	454	454	454	454	454
China	**539**	**552**	**485**	**482**	**479**	**488**	**490**	**502**	**500**	**506**	**507**	**504**
Argentina	614	437	514	474	450	460	693	588	476	506	483	488
Bolivia	581	696	642	593	566	552	550	560	624	632	632	629
Brazil	513	740	488	437	472	473	451	450	440	438	424	434
Colombia	646	646	534	502	492	496	485	544	462	464	464	464
Costa Rica	-	-	-	-	-	-	-	-	-	-	-	-
Cuba	502	502	502	502	502	502	502	502	502	502	502	502
Dominican Republic	-	-	-	502	502	502	502	502	502	502	452	485
Ecuador	-	-	-	452	452	452	452	452	452	452	452	452
El Salvador	-	-	-	-	-	-	-	-	-	-	-	-
Guatemala	-	-	-	-	-	-	-	-	-	-	-	-
Haiti	-	-	-	-	-	-	-	-	-	-	-	-
Honduras	-	-	-	-	-	-	-	-	-	-	-	-
Jamaica	-	-	-	-	-	-	-	-	-	-	-	-
Netherlands Antilles	-	-	-	-	-	-	-	-	-	-	-	-
Nicaragua	-	-	-	-	-	-	-	-	-	-	-	-
Panama	-	-	-	-	-	-	-	-	-	-	-	-
Paraguay	-	-	-	-	-	-	-	-	-	-	-	-
Peru	671	670	670	648	610	548	534	462	472	550	597	540
Trinidad and Tobago	714	716	688	725	754	708	742	735	705	715	700	707
Uruguay	-	-	-	-	578	469	536	578	466	505	499	490
Venezuela	841	675	644	652	638	658	654	631	625	607	606	613
Other Non-OECD Americas	448	448	452	452	452	452	452	452	452	452	452	452
Non-OECD Americas	**702**	**568**	**551**	**520**	**506**	**510**	**603**	**565**	**501**	**526**	**508**	**512**
Bahrain	1 061	815	868	883	881	873	797	826	650	665	640	652
Islamic Republic of Iran	505	525	492	499	502	520	514	505	513	510	502	508
Iraq	-	-	-	-	-	331	331	331	331	331	331	331
Jordan	548	681	671	666	622	610	600	566	571	574	573	573
Kuwait	502	502	502	418	419	446	446	446	418	529	529	492
Lebanon	-	-	-	-	-	-	-	-	-	451	452	452
Oman	696	776	741	809	847	819	848	834	809	796	745	783
Qatar	1 077	1 131	771	779	649	618	617	565	534	494	494	507
Saudi Arabia	827	792	723	683	665	661	679	676	673	665	636	658
Syrian Arab Republic	543	543	543	543	543	543	543	543	543	543	543	543
United Arab Emirates	735	730	721	798	906	836	812	711	721	624	589	645
Yemen	-	-	-	-	-	-	-	-	-	-	551	551
Middle East	**718**	**695**	**633**	**631**	**638**	**626**	**620**	**599**	**590**	**568**	**552**	**570**

7. GLOBAL TOTAL

World

Figure 1. CO_2 emissions by fuel

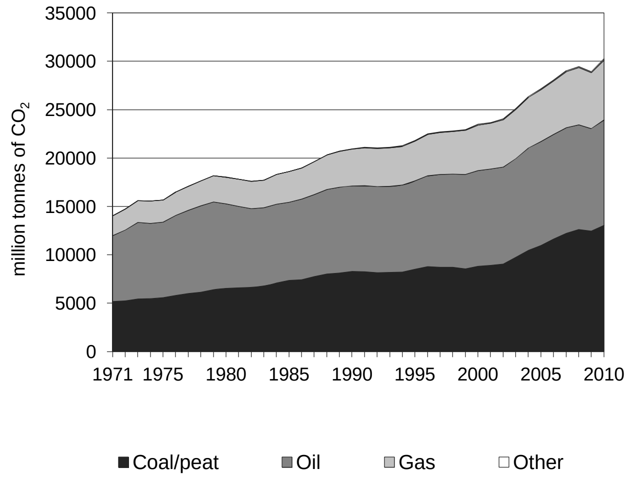


Figure 2. CO_2 emissions by sector

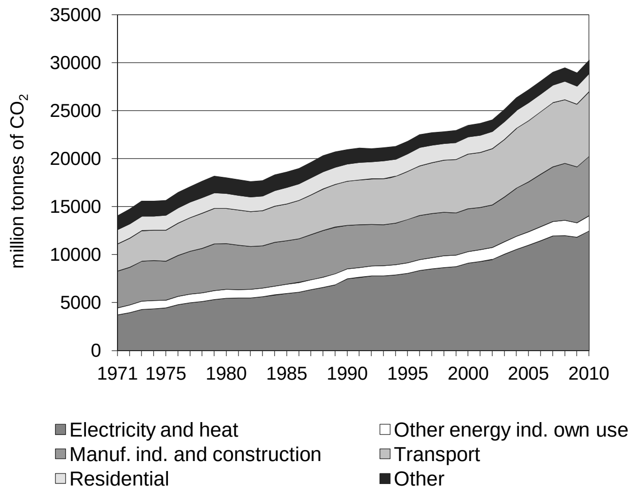


Figure 3. CO_2 emissions by sector

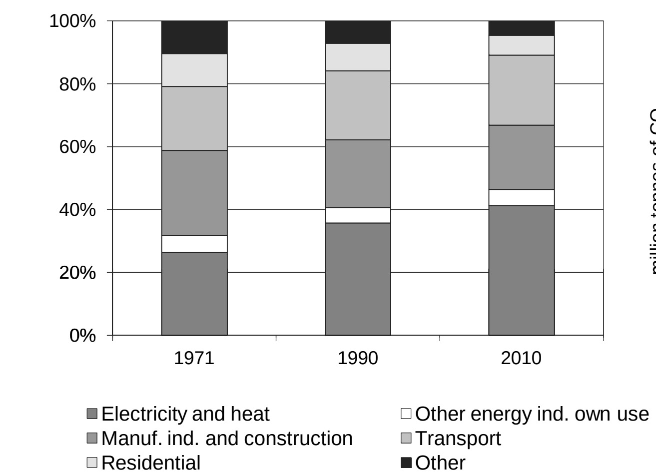


Figure 4. Reference vs Sectoral Approach

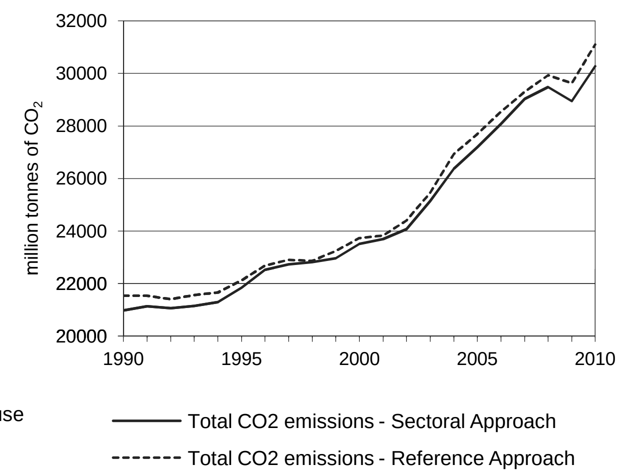


Figure 5. Electricity generation by fuel

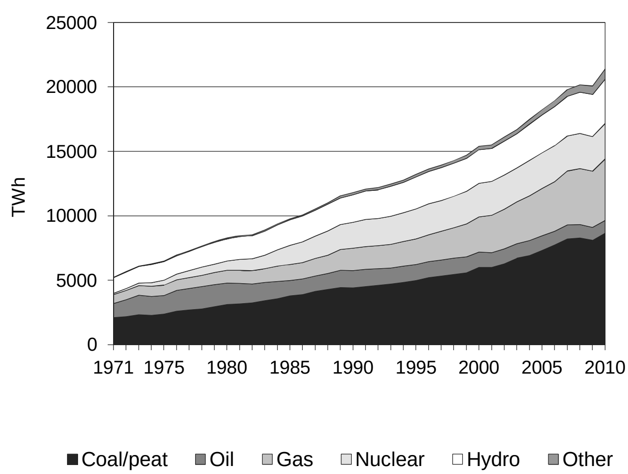
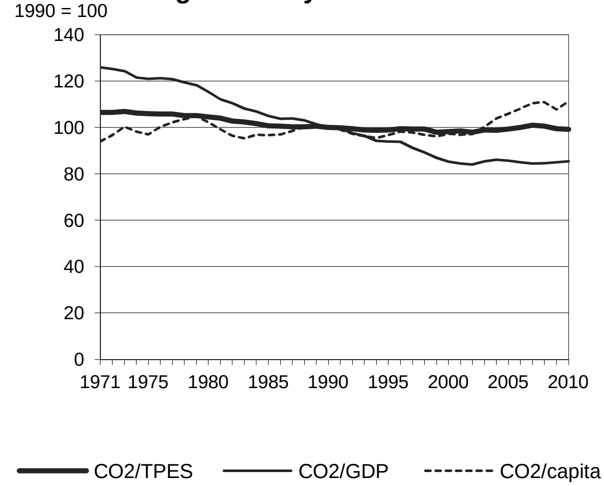


Figure 6. Key indicators



World

Key indicators

	1990	1995	2000	2005	2008	2009	2010	% change 90-10
CO_2 Sectoral Approach ($MtCO_2$)	20 973.9	21 843.8	23 509.1	27 187.4	29 483.0	28 946.7	30 276.1	44.4%
CO_2 Reference Approach ($MtCO_2$)	21 532.3	22 124.5	23 728.9	27 688.1	29 937.2	29 627.8	31 102.3	44.4%
TPES (PJ)	367 298	386 656	419 055	479 455	513 426	509 603	534 434	45.5%
TPES (Mtoe)	8 772.8	9 235.1	10 008.9	11 451.6	12 263.0	12 171.7	12 764.7	45.5%
GDP (billion 2005 USD)	30 153.2	33 419.1	39 638.9	45 617.3	50 115.6	48 950.1	50 942.5	68.9%
GDP PPP (billion 2005 USD)	36 208.9	40 251.1	48 313.0	57 729.2	65 647.3	65 162.6	68 431.1	89.0%
Population (millions)	5 266.2	5 675.7	6 070.7	6 447.3	6 673.0	6 748.7	6 825.4	29.6%
CO_2 / TPES (tCO_2 per TJ)	57.1	56.5	56.1	56.7	57.4	56.8	56.7	-0.8%
CO_2 / GDP ($kgCO_2$ per 2005 USD)	0.70	0.65	0.59	0.60	0.59	0.59	0.59	-14.6%
CO_2 / GDP PPP ($kgCO_2$ per 2005 USD)	0.58	0.54	0.49	0.47	0.45	0.44	0.44	-23.6%
CO_2 / population (tCO_2 per capita)	3.98	3.85	3.87	4.22	4.42	4.29	4.44	11.4%

Ratios are based on the Sectoral Approach.

2010 CO_2 emissions by sector

million tonnes of CO_2	Coal/peat	Oil	Natural gas	Other *	Total	% change 90-10
Sectoral Approach **	**13 065.9**	**10 890.5**	**6 179.1**	**140.6**	**30 276.1**	**44.4%**
Main activity producer elec. and heat	8 449.2	702.2	2 169.2	40.9	11 361.4	71.5%
Unallocated autoproducers	489.4	156.9	411.3	61.5	1 119.1	26.3%
Other energy industry own use	291.3	650.4	628.2	0.9	1 570.8	55.4%
Manufacturing industries and construction	3 299.0	1 524.9	1 330.0	32.5	6 186.4	36.6%
Transport **	13.1	6 550.7	192.1	-	6 755.8	47.0%
of which: road	-	*4 921.6*	*50.6*	-	*4 972.1*	51.1%
Other	524.0	1 305.4	1 448.3	4.9	3 282.6	-1.3%
of which: residential	*301.0*	*595.3*	*984.1*	*0.0*	*1 880.4*	3.2%
Reference Approach **	**13 700.9**	**11 007.0**	**6 253.8**	**140.6**	**31 102.3**	**44.4%**
Diff. due to losses and/or transformation	308.2	99.0	81.3	0.0	488.6	
Statistical differences	326.8	17.4	- 6.6	- 0.0	337.6	
Memo: international marine bunkers	-	*643.7*	-	-	*643.7*	*77.6%*
Memo: international aviation bunkers	-	*455.3*	-	-	*455.3*	*78.3%*

* Other includes industrial waste and non-renewable municipal waste.
** World includes international marine bunkers and international aviation bunkers.

Key sources for CO_2 emissions from fuel combustion in 2010

IPCC source category	CO_2 emissions ($MtCO_2$)	% change 90-10	Level assessment (%) ***	Cumulative total (%)
Main activity prod. elec. and heat - coal/peat	8 449.2	85.5%	19.1	19.1
Road - oil	4 921.6	49.8%	11.1	30.2
Manufacturing industries - coal/peat	3 299.0	50.4%	7.4	37.6
Main activity prod. elec. and heat - gas	2 169.2	110.4%	4.9	42.5
Other transport - oil	1 629.1	44.3%	3.7	46.2
Manufacturing industries - oil	1 524.9	12.9%	3.4	49.7
Manufacturing industries - gas	1 330.0	35.9%	3.0	52.7
Residential - gas	984.1	53.6%	2.2	54.9
Non-specified other - oil	710.0	-2.0%	1.6	56.5
Main activity prod. elec. and heat - oil	702.2	-32.2%	1.6	58.1
Other energy industry own use - oil	650.4	16.8%	1.5	59.5
Memo: total CO_2 from fuel combustion	*30 276.1*	*44.4%*	*68.4*	*68.4*

*** Percent calculated using the total GHG estimate for CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 excluding CO_2 emissions/removals from land use change and forestry.

Energy Data Manager / Statistician

Possible Staff Vacancies

International Energy Agency, Paris, France

The IEA

The International Energy Agency, based in Paris, acts as energy policy advisor to 28 member countries in their effort to ensure reliable, affordable and clean energy for their citizens. Founded during the oil crisis of 1973-74, the IEA's initial role was to co-ordinate measures in times of oil supply emergencies. As energy markets have changed, so has the IEA. Its mandate has broadened to incorporate the "Three E's" of balanced energy policy making: energy security, economic development and environmental protection. Current work focuses on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world, especially major consumers and producers of energy like China, India, Russia and the OPEC countries.

The Energy Data Centre, with a staff of around 30 people, provides a dynamic environment for young people just finishing their studies or with one to two years of work experience.

Job description

The data managers/statisticians compile, verify and disseminate information on all aspects of energy including production, transformation and consumption of all fuels, renewables, the emergency reporting system, energy efficiency indicators, CO_2 emissions, and energy prices and taxes. The data managers are responsible for receiving, reviewing and inputting data submissions from Member countries and other sources into large computerised databases. They check for completeness, correct calculations, internal consistency, accuracy and consistency with definitions. Often this entails proactively investigating and helping to resolve anomalies in collaboration with national administrations of Member and Non-Member countries. The data managers/statisticians also play a key role in helping to design and implement computer macros used in the preparation of their energy statistics publication(s).

Principal Qualifications

- University degree in a topic relevant to energy, computer programming or statistics. We currently have staff with degrees in Mathematics, Statistics, Information Technology, Economics, Engineering, Physics, Chemistry, Environmental Studies, Hydrology, Public Administration and Business.
- Experience in the basic use of databases and computer software. Good computer programming skills in Visual Basic.
- Ability to work accurately, pay attention to detail and work to deadlines. Ability to deal simultaneously with a wide variety of tasks and to organise work efficiently.
- Good communication skills; ability to work well in a team and in a multicultural environment, particularly in liaising with contacts in national administrations and industry.
- Very good knowledge of one of the two official languages of the Organisation (English or French). Knowledge of other languages would be an advantage.
- Some knowledge of energy industry operations and terminology would also be an advantage, but is not required.

Nationals of any OECD Member country are eligible for appointment. Basic salaries start at 3 080 Euros per month. The possibilities for advancement are good for candidates with appropriate qualifications and experience. Tentative enquiries about future vacancies are welcomed from men and women with relevant qualifications and experience. Applications in French or English, accompanied by a curriculum vitae, should be sent to:

Personnel and Finance Division
International Energy Agency
9 rue de la Fédération
75739 Paris Cedex 15, France
Email: recruitment@iea.org

On-Line Data Services

Users can instantly access not only all the data published in this book, but also all the time series used for preparing this publication and all the other statistics publications of the IEA. The data are available on-line, either through annual subscription or pay-per-view access. More information on this service can be found on our website: http://data.iea.org

Ten Annual Publications

Energy Statistics of OECD Countries, 2012 Edition

No other publication offers such in-depth statistical coverage. It is intended for anyone involved in analytical or policy work related to energy issues. It contains data on energy supply and consumption in original units for coal, oil, natural gas, biofuels/waste and products derived from these primary fuels, as well as for electricity and heat. Complete data are available for 2009 and 2010 and supply estimates are available for the most recent year (*i.e.* 2011). Historical tables summarise data on production, trade and final consumption. Each issue includes definitions of products and flows and explanatory notes on the individual country data.

Published July 2012 - Price €120

Energy Balances of OECD Countries, 2012 Edition

A companion volume to *Energy Statistics of OECD Countries*, this publication presents standardised energy balances expressed in million tonnes of oil equivalent. Energy supply and consumption data are divided by main fuel: coal, oil, natural gas, nuclear, hydro, geothermal/solar, biofuels/waste, electricity and heat. This allows for easy comparison of the contributions each fuel makes to the economy and their interrelationships through the conversion of one fuel to another. All of this is essential for estimating total energy supply, forecasting, energy conservation, and analysing the potential for interfuel substitution. Complete data are available for 2009 and 2010 and supply estimates are available for the most recent year (*i.e.* 2011). Historical tables summarise key energy and economic indicators as well as data on production, trade and final consumption. Each issue includes definitions of products and flows and explanatory notes on the individual country data as well as conversion factors from original units to tonnes of oil equivalent.

Published July 2012 - Price €120

Energy Statistics of Non-OECD Countries, 2012 Edition

This publication offers the same in-depth statistical coverage as the homonymous publication covering OECD countries. It includes data in original units for more than 100 individual countries and nine main regions. The consistency of OECD and non-OECD countries' detailed statistics provides an accurate picture of the global energy situation for 2009 and 2010. For a description of the content, please see *Energy Statistics of OECD Countries* above.

Published August 2012 - Price €120

Energy Balances of Non-OECD Countries, 2012 Edition

A companion volume to the publication *Energy Statistics of Non-OECD Countries*, this publication presents energy balances in thousand tonnes of oil equivalent and key economic and energy indicators for more than 100 individual countries and nine main regions. It offers the same statistical coverage as the homonymous publication covering OECD countries, and thus provides an accurate picture of the global energy situation for 2009 and 2010. For a description of the content, please see *Energy Balances of OECD Countries* above.

Published August 2012 - Price €120

Electricity Information 2012

This reference document provides essential statistics on electricity and heat for each OECD member country by bringing together information on production, installed capacity, input energy mix to electricity and heat production, input fuel prices, consumption, end-user electricity prices and electricity trades.

Published August 2012 - Price €150

Coal Information 2012

This well-established publication provides detailed information on past and current evolution of the world coal market. It presents country-specific statistics for OECD member countries and selected non-OECD countries on coal production, demand, trade and prices. This publication represents a key reference tool for all those involved in the coal supply or consumption stream, as well as institutions and governments involved in market and policy analysis of the world coal market.

Published August 2012 - Price €165

Natural Gas Information 2012

A detailed reference work on gas supply and demand, covering not only OECD countries but also the rest of the world. Contains essential information on LNG and pipeline trade, gas reserves, storage capacity and prices. The main part of the book, however, concentrates on OECD countries, showing a detailed gas supply and demand balance for each individual country and for the three OECD regions, as well as a breakdown of gas consumption by end-user. Import and export data are reported by source and destination.

Published August 2012 - Price €165

Oil Information 2012

A comprehensive reference book on current developments in oil supply and demand. The first part of this publication contains key data on world production, trade, prices and consumption of major oil product groups, with time series back to the early 1970s. The second part gives a more detailed and comprehensive picture of oil supply, demand, trade, production and consumption by end-user for each OECD country individually and for OECD regions. Trade data are reported extensively by origin and destination.

Published August 2012 - Price €165

Renewables Information 2012

This reference document brings together in one volume essential statistics on renewables and waste energy sources. It presents a detailed and comprehensive picture of developments for renewable and waste energy sources for each of the OECD member countries, encompassing energy indicators, generating capacity, electricity and heat production from renewable and waste sources, as well as production and consumption of renewable and waste products.

Published August 2012 - Price €110

CO_2 Emissions from Fuel Combustion, 2012 Edition

In order for nations to tackle the problem of climate change, they need accurate greenhouse gas emissions data. This publication provides a basis for comparative analysis of CO_2 emissions from fossil fuel combustion, a major source of anthropogenic emissions. The data in this book are designed to assist in understanding the evolution of the emissions of CO_2 from 1971 to 2010 for more than 140 countries and regions by sector and by fuel. Emissions were calculated using IEA energy databases and the default methods and emissions factors from the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*.

Published November 2012 - Price €165

Two Quarterlies

Oil, Gas, Coal and Electricity, Quarterly Statistics

This publication provides up-to-date, detailed quarterly statistics on oil, coal, natural gas and electricity for OECD countries. Oil statistics cover production, trade, refinery intake and output, stock changes and consumption for crude oil, NGL and nine selected oil product groups. Statistics for electricity, natural gas and coal show supply and trade. Import and export data are reported by origin and destination. Moreover, oil as well as hard coal and brown coal production are reported on a worldwide basis.

Published Quarterly - Price €120, annual subscription €380

Energy Prices and Taxes

This publication responds to the needs of the energy industry and OECD governments for up-to-date information on prices and taxes in national and international energy markets. In contains crude oil import prices by crude stream, industry prices and consumer prices. The end-user prices for OECD member countries cover main petroleum products, gas, coal and electricity. Every issue includes full notes on sources and methods and a description of price mechanisms in each country. Time series availability varies with each data series.

Published Quarterly - Price €120, annual subscription €380

Electronic Editions

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To complement its publications, the Energy Data Centre produces CD-ROMs containing the complete databases which are used for preparing the statistics publications. State-of-the-art software allows you to access and manipulate all these data in a very user-friendly manner and includes graphic facilities. These databases are also available on the internet from our online data service.

Annual CD-ROMS / Online Databases

- Energy Statistics of OECD Countries, 1960-2011 — Price: €550 (single user)
- Energy Balances of OECD Countries, 1960-2011 — Price: €550 (single user)
- Energy Statistics of Non-OECD Countries, 1971-2010 — Price: €550 (single user)
- Energy Balances of Non-OECD Countries, 1971-2010 — Price: €550 (single user)
- *Combined subscription of the above four series* — *Price: €1 400 (single user)*

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- Coal Information 2012 — Price: €550 (single user)
- Natural Gas Information 2012 — Price: €550 (single user)
- Oil Information 2012 — Price: €550 (single user)
- Renewables Information 2012 — Price: €400 (single user)
- CO_2 Emissions from Fuel Combustion, 1971-2010 — Price: €550 (single user)

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- Energy Prices and Taxes — Price: (four quarters) €900 (single user)

A description of these services are available on our website: **http://data.iea.org**

Other Online Services

The Monthly Oil Data Service

The IEA Monthly Oil Data Service provides the detailed databases of historical and projected information which is used in preparing the IEA's monthly *Oil Market Report* (OMR). The IEA Monthly Oil Data Service comprises three packages available separately or combined as a subscriber service on the Internet. The data are available at the same time as the official release of the Oil Market Report.

The packages include:
- Supply, Demand, Balances and Stocks — Price: €6 000 (single user)
- Trade — Price: €2 000 (single user)
- Field-by-Field Supply — Price: €3 000 (single user)
- *Complete Service* — *Price: €9 000 (single user)*

A description of this service is available on our website: **http://www.iea.org/stats/mods.asp**

The Monthly Gas Data Service

The service provides monthly natural gas data for OECD countries:

- supply balances in terajoules and cubic metres;
- production, trade, stock changes and levels where available, gross inland deliveries, own use and losses;
- highly detailed trade data with about 50 imports origins and exports destinations;
- LNG trade detail available from January 2002.

The databases cover the time period January 1984 to current month with a time lag of two months for the most recent data.

- Monthly Gas Data Service: Natural Gas Balances & Trade
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EXHIBIT E

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Aviation and the Global Atmosphere

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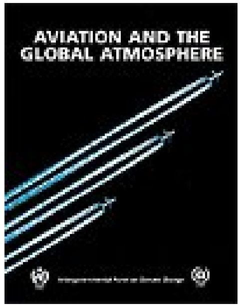

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9. Aircraft Emissions: Current Inventories and Future Scenarios

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Annex B: Glossary of Terms

AERONO$_x$ EU project to study impact of NO_x emissions from aircraft at altitudes between 8 to 15 km.

Aerosols Airborne suspension of small particles.

Aerosol Precursors Gases or chemi-ions that may undergo gas to particle conversion.

Aerosol Size Distribution Particle concentration per unit size interval.

AEROTRACE Project funded by the EU to measure trace species in the exhaust of aero engines.

Albedo The ratio between reflected and incident solar flux.

Anthropogenic Caused or produced by humans.

Background Atmosphere The atmosphere remote from anthropogenic or volcanic influences.

Binary Nucleation Nucleation from two gas phase species.

Black Carbon Graphitic carbon, sometimes referred to as elemental or free carbon.

Block Time The time elapsed from start of taxi out at origin to the end of taxi in at destination.

Bunker Fuels (International) Fuels consumed for international marine and air transportation.

Catalytic Cycle A cycle of chemical reactions, involving several chemical compounds, that depends on the presence of a specific compound which remains unchanged during these reactions.

Charged Particles Particles carrying a positive or negative electric charge.

Chemi-ion Charged cluster of a few molecules.

Cirrus High, thin clouds composed of mainly ice particles.

Climate Model A numerical representation of the climate system. Climate models are of two basic types: (1) static, in which atmospheric motions are neglected or are represented with a simple parameterization scheme such as diffusion; and (2) dynamic, in which atmospheric motions are explicitly represented with equations. The latter category includes general circulation models (GCMs).

Cluster A set of molecules forming an entity.

Coagulation Collision between two (or more) particles resulting in one larger particle.

Combustion Efficiency Ratio of the heat released in combustion to the heat available from the fuel.

Condensation The process of phase transition from gas to liquid.

Condensation Nucleus A particle that can be activated to continual growth through the condensation of water by exposure to a high supersaturation with respect to water.

Contrail Condensation trail (i.e., white line-cloud often visible behind aircraft).

Differential Mobility Analysis A technique for measuring a particle's size by putting an electric charge on it, and measuring its electric mobility in an electric field.

Direct Radiative Impact Radiative forcing of aerosols or gases by scattering and absorption of solar and terrestrial radiation.

Dp/F00 The ICAO regulatory parameter for gaseous emissions, expressed as the mass of the pollutant emitted during the landing/take-off (LTO) cycle divided by the rated thrust (maximum take-off power) of the engine.

Economies in Transition National economies that are moving from a period of heavy government control toward lessened intervention, increased privatization, and greater use of competition.

Emission Index The mass of material or number of particles emitted per burnt mass of fuel (for NO_x in g of equivalent NO_2 per kg of fuel; for hydrocarbons in g of CH_4 per kg of fuel).

Energy Efficiency Ratio of energy output of a conversion process or of a system to its energy input; also known as first-law efficiency.

Engine Pressure Ratio The ratio of the mean total pressure at the last compressor discharge plane of the compressor to the mean total pressure at the compressor entry plane, when the engine is developing its take-off thrust rating (in ISA sea-level static conditions).

Equivalence Ratio Ratio of actual fuel-air ratio to stoichiometric fuel-air ratio.

Feedback When one variable in a system triggers changes in a second variable that in turn ultimately affects the original; a positive feedback intensifies the effect, and a negative reduces the effect.

Freezing The process of phase transition from liquid to solid state.

Freezing Nucleus Any particle that, when present within a mass of supercooled water, will initiate growth of an ice crystal about itself.

Greenhouse Gas A gas that absorbs radiation at specific wavelengths within the spectrum of radiation (infrared) emitted by the Earth's surface and by clouds. The gas in turn emits infrared radiation from a level where the temperature is colder than the surface. The net effect is a local trapping of part of the absorbed energy and a tendency to warm the planetary surface. Water vapor (H_2O), carbon dioxide CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere.

Heterogeneous Chemistry Chemical reactions that involve both gaseous and liquid/solid ingredients.

Heterogeneous Nucleation Formation of liquid or solid particles on the surface of other material.

Homogeneous Chemistry Chemistry in the gas phase.

Homogeneous Nucleation Formation of particles from gas-phase species.

Indirect Radiative Impact Radiative forcing induced not directly but by changing other scattering or absorbing components of the atmosphere (clouds or gases).

Jet The continuous strong stream of exhaust gases leaving the engine exit.

Kerosene Hydrocarbon fuel for jet aircraft.

Landing/Take-Off (LTO) Cycle A reference cycle for the calculation and reporting of emissions, composed of four power settings and related operating times for subsonic aircraft engines [Take-Off - 100% power, 0.7 minutes; Climb - 85%, 2.2 minutes; Approach - 30%, 4.0 minutes; Taxi/Ground Idle - 7%, 26.0 minutes].

Lean Blow Out The fuel-air ratio of a combustion chamber at 'flame out.'

Lean Pre-Mixed Pre-Vaporized Description of principal combustor features.

Life-Cycle Cost The cost of a good or service over its entire lifetime.

Log Normal Function of the form y(x) = (C1/x)*exp(-(lnx-lnx0)**2/C2), where C1, C2, and x0 are constants.

Long-Wave Range The terrestrial spectral radiation range at wavelengths larger about 4 mm.

Low Emissivity A property of materials that hinders or blocks the transmission of a particular band of radiation (e.g., that in the infrared).

Mach Number Speed divided by the local speed of sound.

Mitigation An anthropogenic intervention to reduce the effects of emissions or enhance the sinks of greenhouse gases.

NO_x Oxides of nitrogen, defined as the sum of the amounts of nitric oxide (NO) and nitrogen dioxide (NO_2) with mass calculated as if the NO were in the form of NO_2.

Nucleation Phase change of a substance to a more condensed state initiated at a certain loci within a less condensed state.

Optical Depth or Optical Thickness The parameter of a transparent layer of gases or particles defined as the logarithm of the ratio between incident and transmitted radiative flux.

Organic Carbon The carbonaceous fraction of ambient particulate matter consisting of a variety of organic compounds.

Overall Efficiency (h) The ratio between mechanical work delivered by an engine relative to the chemical energy provided from burning a fuel [h = (thrust x speed)/(specific combustion heat x fuel consumption rate)].

Ozone A gas that is formed naturally in the stratosphere by the action of ultraviolet radiation on oxygen molecules. A molecule of ozone is made of up three atoms of oxygen.

Ozone Hole A substantial reduction below the naturally occurring concentration of ozone, mainly over Antarctica.

Ozone Layer A layer of ozone gas in the stratosphere that shields the Earth from most of the harmful ultraviolet radiation coming from the Sun.

Particulate Mass Emission Index The number of grams of particulate matter generated in the exhaust per kg of fuel burned.

Particulate Number Emission Index The number of particles generated in the exhaust per kg of fuel burned.

Plume The region behind an aircraft containing the engine exhaust.

Polar Stratospheric Clouds Large, diffuse, ice-particle clouds that form in the stratosphere usually over polar regions.

Polar Vortex In the stratosphere, a strong belt of winds that encircles the South Pole at mean latitudes of approximately 60°S to 70°S. A weaker and considerably more variable belt of stratospheric winds also encircles the North Pole at high latitudes during the colder months of the year.

Pressure Ratio The ratio of the mean total pressure exiting the compressor to the mean total pressure of the inlet when the engine is developing take-off thrust rating in ISA sea level static conditions.

Primary Energy The energy that is embodied in resources as they exist in nature (e.g., coal, crude oil, natural gas, uranium, or sunlight); the energy that has not undergone any sort of conversion.

Radiative Forcing A change in average net radiation (in W m^{-2}) at the top of the troposphere resulting from a change in either solar or infrared radiation due to a change in atmospheric greenhouse gases concentrations; perturbance in the balance between incoming solar radiation and outgoing infrared radiation.

Rated Output The maximum thrust available for take-off under normal operating conditions, as approved by the certificating authority.

Relative Humidity The ratio of the partial pressure of water vapor in an air parcel to the saturation pressure (usually over a liquid unless specified otherwise).

Reservoir Molecules Molecules in the atmosphere that bind with atoms or other molecules and prevent them from participating in chemical reactions.

Scavenging The process of removal of gases or small particles in the atmosphere by uptake (condensation, nucleation, impaction, or coagulation) into larger (cloud or precipitation) particles.

Short-Wave Range The solar spectral range from about 0.3 to 4 mm.

Soot Carbon-containing particles produced as a result of incomplete combustion processes.

Specific Fuel Consumption The fuel flow rate (mass per time) per thrust (force) developed by an engine.

Stakeholders Person or entity holding grants, concessions, or any other type of value which would be affected by a particular action or policy.

Stoichiometric Ratio The fuel-air ratio at which all oxygen is consumed (approximately 0.068).

Stratosphere The stably stratified atmosphere above the troposphere and below the mesosphere, at about 10- to 50-km altitude, containing the main ozone layer.

Surface Area Density Surface area of aerosol per unit volume of atmosphere.

Susceptibility Probability for an individual or population of being affected by an external factor.

Sustainable A term used to characterize human action that can be undertaken in such a manner as to not adversely affect environmental conditions (e.g., soil, water quality, climate) that are necessary to support those same activities in the future.

Tropopause The boundary between the troposphere and the stratosphere, usually characterized by an abrupt change in lapse rate (vertical temperature gradient).

Troposphere The layer of the atmosphere between the Earth's surface and the tropopause below the stratosphere (i.e., the lowest 10 to 18 km of the atmosphere) where weather processes occur.

Ultraviolet Radiation Energy waves with wavelengths ranging from about 0.005 to 0.4 µm on the electromagnetic spectrum. Most ultraviolet rays coming from the Sun have wavelengths between 0.2 and 0.4 µm. Much of this high-energy radiation is absorbed by the ozone layer in the stratosphere.

Volatiles Particles that evaporate at temperatures less than about 100°C.

Vulnerability The extent to which climate change may damage or harm a system; it depends not only on a system's sensitivity, but also on its ability to adapt to new climatic conditions.

Wake The turbulent region behind a body or aircraft.

Windmilling Inoperative engine with ram airflow through it.

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Annex C: Acronyms, Abbreviations, and Units

1-D   One-Dimensional
2-D   Two-Dimensional
3-D   Three-Dimensional
ACAC   Arab Civil Aviation Commission
ADS   Automatic Dependent Surveillance
AEA   Association of European Airlines
AEAP   Atmosphere Effects of Aviation Project
AER   Atmospheric and Environmental Research, Inc.
AESA   Atmospheric Effects of Stratospheric Aircraft
AFCAC   African Civil Aviation Commission
AMIP   Atmospheric Model Intercomparison Project
ANCAT   Abatement of Noises Caused by Air Transport
ANDES   Aircraft Noise Design Effects Study
API   American Petroleum Institute
APU   Auxiliary Power Unit
ASK   Available Seat-Kilometers
ASM   Air Space Management
AST   Advanced Subsonic Technology
ATC   Air Traffic Control
ATFM   Air Traffic Flow Management
ATM   Air Traffic Management
ATP   Advanced Turboprop
ATR   Air Traffic Region
ATS   Air Traffic Services
ATTAS   Advanced Technology Testing Aircraft System

AVHRR   Advanced Very High-Resolution Radiometer
BC   Black Carbon
BWB   Blended Wing Body
CAEP   Committee on Aviation Environmental Protection
CCM3   Community Climate Model 3
CE   Centre for Energy Conservation and Environmental Technology
CFC   Chlorofluorocarbon
CFD   Computational Fluid Dynamics
CGCM   Coupled General Circulation Model
CI   Chemi-Ion
CN   Condensation Nucleus
CNS/ATM   Communications, Navigation, and Surveillance
CSIRO   Commonwealth Scientific and Industrial Research Organization
CTM   Chemical Transport Model
DAC   Dual Annular Combustor
DEF STAN   Defence Standards
DERA   Defence Evaluation and Research Agency
DISORT   Discrete Ordinate Radiative Transfer
DJF   December-January-February
DLR   Deutsches Zentrum für Luft- und Raumfahrt
DOT   Department of Transportation
DTI   Department of Trade and Industry
DTR   Diurnal Surface Temperature Range
DU   Dobson Unit
EASG   Economic Analysis Subgroup
EATMS   European ATM System
ECMWF   European Centre for Medium-Range Weather Forecasts
ECON   Most Efficient Cruise Speed
ECS   Engine Control System
EDF   Environmental Defense Fund
EEI   Effective Emissions Index
EI   Emissions Index
EIDG   Emissions Inventory Database Group
EISG   Emissions Inventory Sub-Group
ENSO   El Niño Southern Oscillation
ERAA   European Regions Airline Association
ETOPs   Extended Twin Operations
EUROCONTROL   European Organisation for Safety and Navigation
FADEC   Full Authority Digital Engine Control
FANS   Future Air Navigation System
FEMs   Finite Element Models

FESG Forecast and Economics Sub-Group
FIR Flight Information Region
FLEM Flights and Emissions model
FMS Flight Management System
FPC Focal Point on Charges
FSU Former Soviet Union
FUA Flexible Use of Airspace
GAMA General Aviation Manufacturers Association
GCM General Circulation Model
GDP Gross Domestic Product
GFDC Geophysical Fluid Dynamics Laboratory
GISS Goddard Institute for Space Studies
GNBS Global Navigation Satellite System
GOES Geostationary Operational Environmental Satellite
GPS Global Positioning System
GSFC Goddard Space Flight Center
GWP Global Warming Potential
HALOE Halogen Occultation Experiment
HC Hydrocarbon
HCFC Hydrochlorofluorocarbon
HF High Frequency
HFC Hydrofluorocarbon
HIRS High-Resolution Infrared Radiation Sounder
HSCT High Speed Civil Transport
HYPR Supersonic/Hypersonic Transport
IATA International Air Transport Association
ICAO International Civil Aviation Organization
ICAS International Council on Aeronautical Sciences
ICCAIA International Coordinating Council of Aerospace Industries Association
IFR Instrument Flight Rule
IHPTET Integrated High Performance Turbine Engine
IMC Instrument Meteorological Conditions
IPCC Intergovernmental Panel on Climate Change
IR Infrared
IS92a IPCC Scenarios 1992a
ISA International Standard Atmosphere
ISCCP International Satellite Cloud Climatology Project
IWC Ice-Water Content
IWP Ice-Water Path
JGR Journal of Geophysical Research
JJA June-July-August

LACAC   Latin American Civil Aviation Commission
LaRC   Langley Research Center
LBO   Lean Blow Out
LES   Large Eddy Simulation
LIDAR   Light Detection and Ranging
LLNL   Lawrence Livermore National Laboratory
LPP   Lean Pre-Mixed Pre-Vaporized
LRC   Long-Range Cruise
LS   Lower Stratosphere
LTO   Landing and Take-Off
LW   Long-Wave
MD   Mass Density
MIT   Massachusetts Institute of Technology
MRC   Maximum Range Cruise
MS   Middle Stratosphere
NASA   National Aeronautics and Space Administration
NAT   Nitric Acid Trihydrate
NCAR   National Center for Atmospheric Research
NCEP   National Centers for Environmental Prediction
NSA   Nitro Sylsulfuric Acid
NH   Northern Hemisphere
NIPER   National Institute for Petroleum and Energy Research
NMC   National Meteorological Center
NMHC   Non-Methane Hydocarbons
NOA   North Atlantic Oscillation
NOAA   National Oceanic and Atmospheric Administration
NO_xAR Nitrogen Oxides and Ozone Measurements along Air Routes
NPRA   National Petroleum Refiners Association
OA   Objectively Analyzed
OAG   Official Airline Guide
OECD   Organisation for Economic Cooperation and Development
OEW   Operating Empty Weight
OPMET   Operational Meteorological
OPR   Overall Pressure Ratio
PAI   Propulsion/Airframe Integration
PAN   Peroxyacetylnitrate
PIANO   Project Interactive Analysis and Optimization
PMS   Performance Management System
PNA   Pacific North America
ppbv   Parts per Billion by Volume
ppmm   Parts per Million by Mass

ppmv Parts per Million by Volume
PSC Polar Stratospheric Cloud
PSC1 Type I Polar Stratospheric Cloud
PSC2 Type II Polar Stratospheric Cloud
RBQQ Rich Burn Quick Quench
RF Radiative Forcing
RFI Radiative Forcing Index
RH Relative Humidity
RNAV Area Navigation
RPK Revenue Passenger-Kilometer
RQL Rich Quench Lean
RVSM Reduced Vertical Separation
SAD Surface Area Density
SAGE Stratospheric Aerosol and Gas Experiment
SAM Stratospheric Aerosol Measurement
SAO Background Sulfate Surface Area Density
SARP Standard and Recommended Practice
SA1 Sulfate Surface Area Density Scenario based upon 500 HSCT Fleet with 50% Conversion of Fuel Sulfur to Particles
SA2 Sulfate Surface Area Density Scenario based upon 1000 HSCT Fleet with 50% Conversion of Fuel Sulfur to Particles
SA3 Sulfate Surface Area Density Scenario based upon 500 HSCT Fleet with 1000% Conversion of Fuel Sulfur to Particles
SA4 Sulfate Surface Area Density Scenario based upon 1000 HSCT Fleet with 100% Conversion of Fuel Sulfur to Particles
SA5 Sulfate Surface Area Density Scenario based upon 500 HSCT Fleet with 10% Conversion of Fuel Sulfur to Particles
SA6 Sulfate Surface Area Density Scenario based upon 1000 HSCT Fleet with 10% Conversion of Fuel Sulfur to Particles
SA7 Sulfate Surface Area Density Scenario based upon 500 HSCT Fleet with 0% Conversion of Fuel Sulfur to Particles
SBSTA Subsidiary Body for Scientific and Technological Advice
SBUV Solar Backscater Ultraviolet
SH Southern Hemisphere
T/W Thrust/Weight
UARS Upper Atmosphere Research Satellite
UDF Unducted Fan
UiO Universitet I Oslo
UKMO United Kingdom Meteorological Office
UN United Nations
UNIVAQ Universita' degli Studi-l' Acquila
UNEP United Nations Environment Programme
UT Upper Troposphere
UV Ultraviolet
UV-B Ultraviolet-B
UV_{ery} Erythemal Dose Rate
VOC Volatile Organic Compound

WAFS World Area Forecast System
WCRP World Climate Research Programme
WMO World Meteorological Organization
WWF World Wide Fund for Nature

UNITS

SI (Systéme Internationale) Units

Physical Quantity	Name of Unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
thermodynamic temperature	kelvin	K
amount of substance	mole	mol

Special Names and Symbols for Certain SI-Derived Units

Physical Quantity	Name of Unit	Symbol of Unit	Definition of Unit
force	newton	N	kg m s-2
pressure	pascal	Pa	kg m-1 s-2 (= Nm^{-2})
energy	joule	J	kg m^2 s-2
power	watt	W	kg m^2 s-3 (= Js^{-1})
frequency	hertz	Hz	s^{-1} (cycle per second)

Decimal Fractions and Multiples of SI Units Having Special Names

Physical Quantity	Name of Unit	Symbol of Unit	Definition of Unit
length	ångstrom	Å	10^{-10} m = 10^{-8}cm
length	micrometer	µm	10^{-6}m = µm
area	hectare	ha	10^{4} m^{2}
force	dyne	dyn	10^{-5} N
pressure	bar	bar	10^{5} N m^{-2}
pressure	millibar	mb	1hPa
weight	ton	t	10^{3} kg

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Annex D: List of Major IPCC Reports

Climate Change-The IPCC Scientific Assessment The 1990 Report of the IPCC Scientific Assessment Working Group (also in Chinese, French, Russian, and Spanish)

Climate Change-The IPCC Impacts Assessment The 1990 Report of the IPCC Impacts Assessment Working Group (also in Chinese, French, Russian, and Spanish)

Climate Change-The IPCC Response Strategies The 1990 Report of the IPCC Response Strategies Working Group (also in Chinese, French, Russian, and Spanish)

Emissions Scenarios Prepared for the IPCC Response Strategies Working Group, 1990

Assessment of the Vulnerability of Coastal Areas to Sea Level Rise-A Common Methodology 1991 (also in Arabic and French)

Climate Change 1992-The Supplementary Report to the IPCC Scientific Assessment The 1992 Report of the IPCC Scientific Assessment Working Group

Climate Change 1992-The Supplementary Report to the IPCC Impacts Assessment The 1992 Report of the IPCC Impacts Assessment Working Group

Climate Change: The IPCC 1990 and 1992 Assessments IPCC First Assessment Report Overview and Policymaker Summaries, and 1992 IPCC Supplement

Global Climate Change and the Rising Challenge of the Sea Coastal Zone Management Subgroup of the IPCC Response Strategies Working Group, 1992

Report of the IPCC Country Studies Workshop 1992

Preliminary Guidelines for Assessing Impacts of Climate Change 1992

IPCC Guidelines for National Greenhouse Gas Inventories Three volumes, 1994 (also in French, Russian, and Spanish)

IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations 1995 (also in Arabic, Chinese, French, Russian, and Spanish)

Climate Change 1994-Radiative Forcing of Climate Change and an Evaluation of the IPCC IS92 Emission Scenarios 1995

Climate Change 1995-The Science of Climate Change - Contribution of Working Group I to the Second Assessment Report 1996

Climate Change 1995-Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses - Contribution of Working Group II to the Second Assessment Report 1996

Climate Change 1995-Economic and Social Dimensions of Climate Change - Contribution of Working Group III to the Second Assessment Report 1996

Climate Change 1995-IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change 1996 (also in Arabic, Chinese, French, Russian, and Spanish)

Technologies, Policies, and Measures for Mitigating Climate Change - IPCC Technical Paper I 1996 (also in French and Spanish)

An Introduction to Simple Climate Models used in the IPCC Second Assessment Report - IPCC Technical Paper II 1997 (also in French and Spanish)

Stabilization of Atmospheric Greenhouse Gases: Physical, Biological and Socio-economic Implications - IPCC Technical Paper III 1997 (also in French and Spanish)

Implications of Proposed CO_2 Emissions Limitations - IPCC Technical Paper IV 1997 (also in French and Spanish)

The Regional Impacts of Climate Change: An Assessment of Vulnerability - IPCC Special Report 1998

Enquiries: *IPCC Secretariat, c/o World Meteorological Organization, 7 bis, Avenue de la Paix, Case Postale 2300, 1211 Geneva 2, Switzerland*

Aviation and the Global Atmosphere

9.1. Introduction

The nature and composition of aircraft emissions has been described in Chapter 1, and their effects on the composition of the atmosphere are described in Chapters 2 and 3. Chapter 4 uses aircraft emissions data in modeling studies to provide chemical perturbations that feed into the ultraviolet (UV) irradiance and radiative forcing calculations presented in Chapters 5 and 6, respectively. In this chapter, the aircraft emissions data that were used in calculations described in Chapters 4 and 6 are presented and discussed.

Compilation of global inventories of aircraft NO_x emissions has been driven by requirements for global modeling studies of the effects of these emissions on stratospheric and tropospheric ozone (O_3). Aircraft carbon dioxide CO_2) emissions are easily calculated from total fuel burned. Early studies used one- (1-D) and two-dimensional (2-D) models of the atmosphere (see Section 2.2.1). Most of these early studies considered effects on the stratosphere (e.g., COMESA, 1975), but some also included assessments of the (then) current subsonic fleet on the upper troposphere and lower stratosphere (e.g., Hidalgo and Crutzen, 1977; Derwent, 1982). An early height- and latitude-dependent emissions inventory of aircraft NO_x was given by Bauer (1979), based on earlier work by A.D. Little (1975). This work was used by Derwent (1982) in a 2-D modeling study of aircraft NO_x emissions in the troposphere.

Later estimations of global aircraft emissions of NO_x were still made by relatively simple methods, using fuel usage and assumed $EI(NO_x)$ (e.g., Nüßer and Schmitt, 1990; Beck et al., 1992). Concerted efforts were subsequently made by a number of groups to construct high-quality global 3-D inventories of aircraft emissions. Such work was undertaken for a variety of programs and purposes: United Kingdom input to ICAO Technical Working Groups (McInnes and Walker, 1992); the U.S. Atmospheric Effects of Stratospheric Aircraft (AESA) Program (Wuebbles et al., 1993); the German "Schadstoffe in der Luftfahrt" Program (Schmitt and Brunner, 1997); and the ANCAT/EC Emissions Database Group (ANCAT/EC, 1995), which combined European efforts to produce an aircraft NO_x inventory for the AERONO$_x$ Program (Gardner et al., 1997). Subsequently, methodologies for the production of global 3-D inventories of present-day aircraft NO_x emissions (based on 1991-92) have been refined and have produced results that have largely superseded earlier work. These inventories cover the 1976-92 time period and have been extended to the 2015 forecast period. These gridded inventories-which calculate aviation emissions as distributed around the Earth in terms of latitude, longitude, and altitude-have been produced by NASA, DLR, and ANCAT/EC for national and international work programs (Baughcum et al., 1996a,b; Schmitt and Brunner, 1997; Gardner, 1998).

This chapter is not the first attempt to synthesize information on aircraft emissions inventories; earlier assessments were made by the World Meteorological Organization (WMO)/ United National Environment Programme (UNEP) (1995) Scientific Assessment of Ozone Depletion, ICAO's Committee on Aviation Environmental Protection (CAEP) Working Group 3 (CAEP/WG3, 1995), the NASA Advanced Subsonic Technology Program (Friedl, 1997), and the European Scientific Assessment of the Atmospheric Effects of Aircraft Emissions (Brasseur et al., 1998).

Any assessment of present and potential future effects of subsonic and supersonic air transport emissions relies heavily on input emissions data. Thus, considerable effort has been expended on understanding the accuracy of present-day inventories and the construction of forecasts and scenarios. Forecasts are quite distinct from scenarios, as noted in Chapter 1. Forecasts of aviation emissions for a 20-25 year time frame are generally considered possible, whereas such confidence is not the case for longer time frames. Thus, scenarios generally rely on many more assumptions and are less specific than forecasts.

In planning this Special Report, it was clear that there were no gridded emission scenarios of NO_x emissions from subsonic aircraft for the year 2050 that could be used as input to 3-D chemical transport models (see Chapters 2 and 4). The IPCC made a request to ICAO to prepare 3-D NO_x scenarios, which was carried out under the auspices of ICAO's FESG (CAEP/4-FESG, 1998). The UK DTI also responded to this requirement, producing an independent 3-D NO_x scenario for 2050 (Newton and Falk, 1997). The EDF had also published scenarios of aircraft emissions of NO_x and CO_2 extending to 2100 (Vedantham and Oppenheimer, 1994, 1998), but these scenarios were not gridded; thus, although the aviation CO_2 scenarios could be used in radiative forcing calculations (see Chapter 6), the NO_x scenarios could not be used to calculate O_3 perturbations and subsequent radiative forcing. Other scenario data exist for aircraft emissions, including those from WWF (Barrett, 1994) and MIT (Schafer and Victor, 1997). As with the EDF data, these scenarios were not gridded for NO_x emissions, therefore could not be used in O_3 perturbation calculations in Chapter 4. Furthermore, the MIT data do not explicitly represent aircraft emissions; instead, they cover high-speed transport modes, including some surface transportation modes.

HSCT scenarios prepared for NASA's AESA Program are considered distinct from subsonic scenarios; these HSCT scenarios represent a technology that does not yet exist but might be developed. Therefore, the HSCT scenarios represent a quite different set of assumptions from other long-term scenarios, which only consider continued development of a subsonic fleet. The HSCT scenarios were used in modeling studies (Chapters 4 and 6) as sensitivity analyses for studying the effects of their emissions on stratospheric O_3.

In this chapter, methodologies of inventory and forecast construction are compared, and a review and assessment of long-term scenarios and their implicit assumptions provided. This is the first detailed consideration of long-term scenarios and their implications.

By way of background, Section 9.2 provides an overview of factors that affect aircraft emissions, such as market demand for air travel and developments in the technology. The aircraft emissions data discussed in this chapter are of four distinct types: Historical inventories (e.g., for 1976 and 1984); inventories that represent the "present day" (i.e., 1991-92); forecasts for 2015; and long-term scenarios for 2050 and beyond. The methodologies and a comparison of historical, present-day, and forecast inventories are presented in Section 9.3. Section 9.4 describes and comments on available long-term scenarios for 2050 and beyond. Scenarios of high-speed civil transport (HSCT) that incorporate certain assumptions about the development of a supersonic fleet and its impact on the subsonic fleet are presented separately in Section 9.5. Finally, Section 9.6 discusses underlying assumptions and drivers of long-term subsonic scenarios. The plausibility of the assumptions are also considered in terms of implications for fleet size, infrastructure requirements, and global fossil-fuel availability.

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9.2. Factors Affecting Aircraft Emissions

9.2.1. Demand for Air Travel

In the past 50 years, the air transport industry has experienced rapid expansion as the world economy has grown and the technology of air transport has developed to its present state. The result has been a steady decline in costs and fares, which has further stimulated traffic growth. As an example of this growth, the output of the industry (measured in terms of tonne-km performed) has increased by a factor of 23 since 1960; total GDP, which is the broadest available measure of world output, increased by a factor of 3.8 over the same period (ICAO, 1997a).

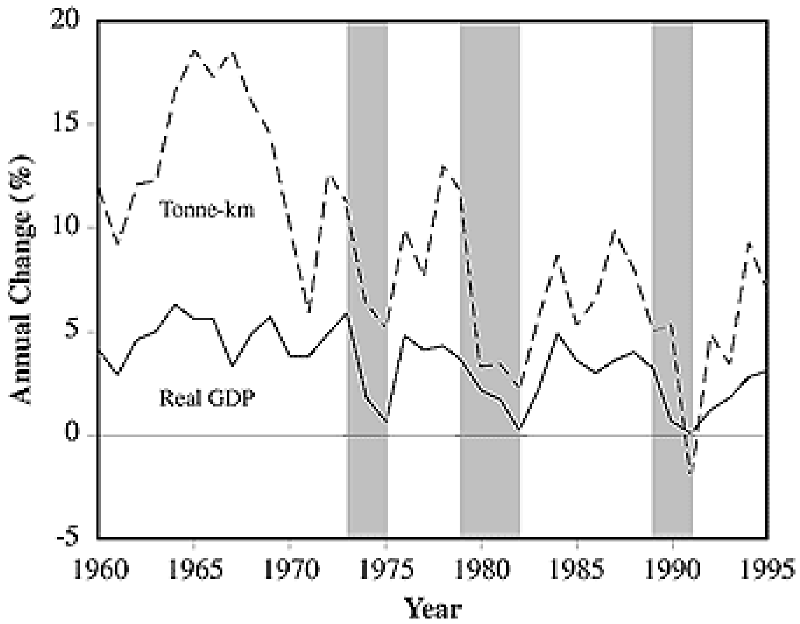

Figure 9-1:*Relationship between economic growth and traffic demand growth (IMF, WEFA, ICAO Reporting*

Although growth in world air traffic has been much greater than world economic growth, economic theory and analytical studies indicate that there is a high correlation between the two, and most forecasts of aviation demand are based on the premise that the demand for air transport is determined primarily by economic development. Statistical analyses have shown that growth in GDP now explains about two-thirds of air travel growth, reflecting increasing commercial and business activity and increasing personal income and propensity to travel. Demand for air freight service is also primarily a function of economic growth. Air travel growth in excess of GDP growth is usually explained by other economic and structural factors:

- Improvement in service offerings as routes and frequencies and infrastructure are added, stimulation from reductions in airline fares as costs decline, and increasing trade and the globalization of business (Boeing, 1998)
- Population and income distribution (Vedantham and Oppenheimer, 1998)
- Travel behavior, including travel time budgets and travel costs (Zahavi, 1981; Schafer and Victor, 1997).

Changes in technology and in the regulatory environment have also had great effects on the growth in air travel demand. The modern era of air transportation began in the 1960s, driven by the replacement of piston-engined aircraft with jet aircraft that increased the speed, reliability, and comfort of air travel while reducing the cost of operation. The continuing trend of declining fares (as measured in constant dollars) began in this period. In real terms, fares have declined by almost 2% per year since 1960. Deregulation of airline services in the United States in 1978 allowed airlines to improve services by expanding theirroute systems and reduce average costs by greatly increasing the efficiency of scheduling and aircraft use. Trends toward liberalization of airline services in Europe and elsewhere will continue to increase airline efficiency.

Sharp increases in oil prices have had important (though temporary) effects on traffic demand. In addition to an adverse effect on the world economy, the 10-fold increase in crude oil prices in 1973-74 and further escalation in 1979-81 (since ameliorated) greatly increased aviation fuel prices. Air fares increased in response to higher costs, with a resulting decline in demand growth rates.Figure 9-1 provides evidence of the relationship between the economy and traffic demand by illustrating fluctuations in the rate of growth of each from 1960 to the present. The economic recessions of 1974-75, 1979-82 (largely caused by the increase in oil prices), and 1990-91 (the Gulf War) and their impact on air traffic are clearly visible.

The growth rate in global passenger demand over the past 35 years is shown in Figure 9-2. Freight traffic, approximately 80% of which is carried in the bellies of passenger airplanes, has also grown over the same time period. The declining trend in the rate of growth as the size of the industry has increased by more than 20-fold is a natural result of the total size of the industry (it is difficult to sustain an "infant industry" growth rate as size increases) and a maturing of certain markets-primarily those in the developed world-that dominate the statistics.Changes in demand in regional markets are given in Table 9-1 for the period 1970-95. Over this period, global traffic measured in revenue passenger kilometers (RPK) increased by a factor of 4.6 (Boeing, 1996). Table 9-1 is ordered by 1995 regional RPK value.

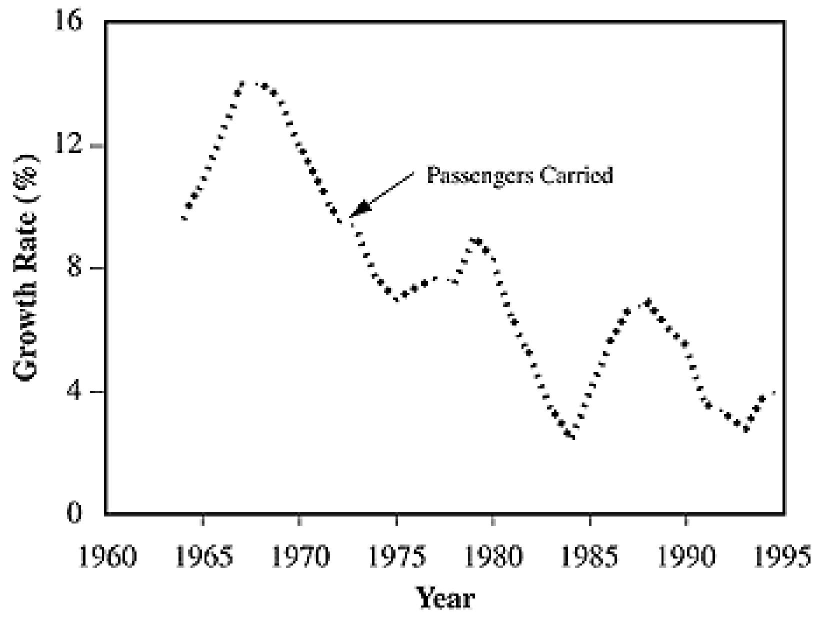

Figure 9-2: *Growth rate of passengers carried (ICAO Reporting Form A-1). Note the assumption of 5-year moving average of annual growth rates, excluding operations in the Commonwealth of Independent States (CIS).*

9.2.2. Developments in Technology

The trend in fuel efficiency of jet aircraft over time has been one of almost continuous improvement; fuel burned per seat in today's new aircraft is 70% less than that of early jets. About 40% of the improvement has come from engine efficiency improvements and 30% from airframe efficiency improvements (Figure 9-3, after Figure III-A-1 in Albritton et. al, 1997).

The growth rate of fuel consumed by aviation therefore has been lower than the growth in demand. Improvement in engine fuel efficiency has come mainly from the increasing use of modern high-bypass engine technology that relies on increasing engine pressure ratios and higher temperature combustors as a means to increase engine efficiency. These trends have resulted in drastic decreases in emissions of carbon moNO$_X$ide (CO) and unburned hydrocarbons (HC), though they tend to increase emissions of oxides of nitrogen (NO_X). As a result, total NO_X emissions from aircraft are growing faster than fuel consumption (see Figure 9-4, from NASA emissions inventories discussed in Section 9.3). A discussion of the technology required to reduce NO_X emissions while continuing to improve engine efficiency appears in Chapter 7.

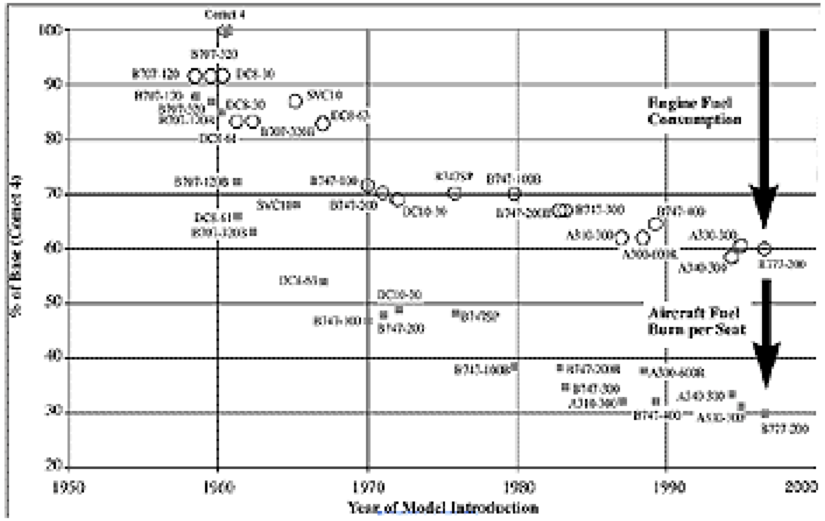

Figure 9-3: *Trend in transport aircraft fuel efficiency.*

Table 9-1: *Regional share of total demand.*

Regional Traffic Flow	**1970 RPK x 10^9**	**1995 RPK x 10^9**	**1970-95 Growth Factor**	**1970 Market Share**	**1995 Market Share**	**1970-95 Change in Share**
Intra North America	190.897	697.880	3.7	34.6%	27.5%	-7.1%
Intra Europe	61.275	317.099	5.2	11.1%	12.5%	1.4%
North America - Europe	72.143	277.909	3.9	13.1%	11.0%	-2.1%
China Domestic/Intra Asia/Intra Oceania	10.234	207.405	20.3	1.9%	8.2%	6.3%
North America - Asia/Oceania	14.760	188.799	12.8	2.7%	7.4%	4.8%
Europe - Asia	6.732	134.343	20.0	1.2%	5.3%	4.1%
Asia - India/Africa/Middle East	13.959	115.204	8.3	2.5%	4.5%	2.0%
North America - Latin America	16.087	75.538	4.7	2.9%	3.0%	0.1%
Europe - Latin America	7.124	73.090	10.3	1.3%	2.9%	1.6%
Domestic Former Soviet Union	75.496	67.603	0.9	13.7%	2.7%	-11.0%
Japan Domestic	8.181	61.607	7.5	1.5%	2.4%	0.9%
Europe - Africa	18.478	61.045	3.3	3.4%	2.4%	-0.9%
Intra/Domestic Latin America	13.432	55.331	4.1	2.4%	2.2%	-0.3%
Europe - Middle East	9.838	41.224	4.2	1.8%	1.6%	-0.2%
Intra/Domestic Middle East - Africa	5.065	39.213	7.7	0.9%	1.5%	0.6%
International Former Soviet Union	3.677	29.508	8.0	0.7%	1.2%	0.5%
Indian Subcontinent - Asia/ Middle East/Oceania	3.249	29.500	9.1	0.6%	1.2%	0.6%

Europe - Indian Subcontinent	2.333	19.858	8.5	0.4%	0.8%	0.4%
Intra/Domestic Africa	5.826	16.808	2.9	1.1%	0.7%	-0.4%
Intra Indian Subcontinent	3.215	13.218	4.1	0.6%	0.5%	-0.1%
North America - Africa/Middle East	1.149	10.777	9.4	0.2%	0.4%	0.2%
U.S. Military Airlift	8.112	3.605	0.4	1.5%	0.1%	-1.3%
Total	**551.262**	**2536.561**	**4.6**	**100.0%**	**100.0%**	**0.0%**

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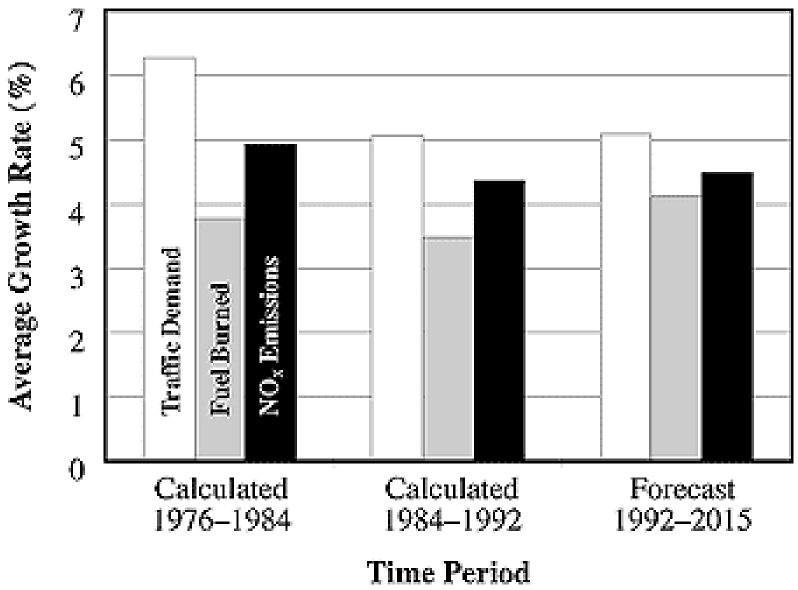
9.3. Historical, Present-Day, and 2015 Forecast Emissions Inventories

Studies on the effects of CO_2 emissions from aircraft on radiative forcing require only a knowledge of total emissions. However, to examine the potential effects of other emissions from aviation (e.g., those considered in Chapter 4), estimates of the amount and the distribution of emissions are required. Such 3-D inventories for present and projected future aviation operations have been produced under the aegis of NASA's Atmospheric Effects of Aviation Project (AEAP), the European Civil Aviation Conference's ANCAT and EC Emissions Inventory Database Group (EIDG), and DLR.

These inventories consist of calculated aircraft emissions distributed over the world's airspace by latitude, longitude,and altitude. Historical inventories of aviation emissions have been produced for 1976 and 1984 by NASA. Present-day and 2015 forecast inventories (where present-day is taken to be the most recent available-1991-92) have been produced by NASA, ANCAT, and DLR. DLR has also produced emissions inventories of scheduled international aviation only for each year from 1982 through 1992, and for total scheduled aviation for 1986 and 1989. DLR has also constructed a four-dimensional (4-D) inventory with diurnal cycles for scheduled aviation in March 1992.



All of the aforementioned 3-D emissions inventories have a common approach of combining a database of global air traffic (fleet mix, city-pairs served, and flight frequencies) with a set of assumptions about flight operations (flightprofiles and routing) and a method to calculate altitude-dependent emissions of aircraft/engine combinations in the fleet. Figure 9-5 shows how these processes are combined.

ll of the historical, present-day, and 2015 forecast inventories considered in this section assume idealized flight routings and profiles, with no winds or system delays. Thus, minimum fuel burn and emissions possible for each flight operation are implicit, given the onboard load assumed. Simplifying assumptions for military operations vary according to aircraft type.

Figure 9-4: Comparison of growth rates for civil traffic, fuel consumption, and NO_x emissions.

9.3.1. NASA, ANCAT/EC2, and DLR Historical and Present-Day Emissions Inventories

The NASA, ANCAT, and DLR 3-D inventories adopt a similar overall approach but differ in some of the components and data used. This section describes thecommon approaches and explains the differences. More detailed information appears in the source material for these inventories (Baughcum et al., 1996a,b; Schmitt and Brunner, 1997; Gardner, 1998).

All of the inventories use a "bottom-up" approach in which an aircraft movement database was compiled, aircraft/engine combinations in operation were identified (to differing levels of detail), and calculations of fuel burned and emissions along great-circle paths between cities were made. Flight operation data were calculated as the number of departures for each city pair by aircraft and engine type-which, combined with performance and emissions data, gave fuel burned and emissions by altitude along each route. This approach resulted in data on fuel burned and emissions of NO_x (as NO_2) on a 3-D grid for each flight. In addition, the NASA inventories provide 3-D distributions of CO and total HC. NASA and ANCAT inventories were calculated on a 1° longitude x 1° latitude x 1-km altitude resolution, whereas the DLR inventory used a 2.8° longitude x 2.8° latitude horizontal resolution. Different approaches were taken for constructing underlying traffic movements databases. The NASA inventories use scheduled jet and turboprop aviation operations for the years 1976, 1984, and 1992 (Baughcum et al., 1996a, b). Movements for charter carriers, military operations, general aviation, and the domestic fleets of the former Soviet Union (FSU) and the People's Republic of China were estimated separately (Landau et al., 1994; Metwally, 1995; Mortlock and Van Alstyne, 1998). Military aircraft contributions to emissions were calculated by estimating the flight activity of each type of military aircraft by country. The 1976 and 1984 NASA inventories were based on operations for 1 month in each quarter of the year, whereas the 1992 inventory compiled movements on a monthly basis to reflect the seasonality of aviation operations.

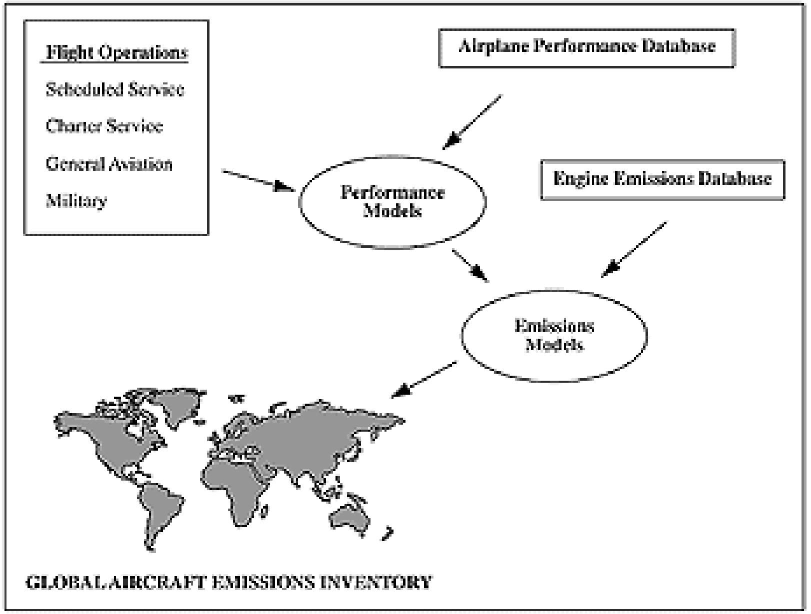


Figure 9-5: Aircraft emissions inventory calculation schematic.

The ANCAT approach used a combination of air traffic control (ATC) data and scheduled movements, favoring ATC data where available (Gardner, 1998). Where ATC data were unavailable, scheduled data were taken from the ABC Travel Guide (ABC), the Official Airline Guide (OAG), the Aeroflot time table, and a German study of Chinese domestic aircraft movements. Only jet aircraft were represented in the ANCAT/EC2 inventory. The most significant omission of ATC data was the United States, for which data were unavailable for security reasons. Thus, only time table data were used for the United States; so nonscheduled U. S. domestic charters and other flights were not recorded. To compensate for this problem, fuel usage data were factored up by 10% (Gardner, 1998). ATC data accounted for half of the non-U. S. aircraft movements in the database. Military movements were estimated by allocating fuel and emissions to countries' boundaries from an analysis of the world's military fleet composition.

The DLR inventory for 1991/92 (Schmitt and Brunner, 1997) used the ANCAT/EC2 civil movements database.Emissions inventories for 1986, 1989, and 1992 were based on scheduled air traffic only; a 4-D inventory with diurnal cycles for March 1992 was based on ABC data. ICAO data (ICAO, 1997b) were used for emissions inventories for international (only) scheduled air traffic in the years 1982 to 1992.

Calculation of fuel burned and emissions for aircraft differs between the three inventories. NASA used detailedmanufacturers' proprietary performance information on each aircraft-engine combination and the flight profile shown in Figure 9-6. Emissions were calculated from the information in the ICAO Engine Exhaust Emissions Data Bank (ICAO, 1995), through the use of Boeing "Method 2" procedures (Baughcum et al., 1996b, Appendix D), which allow extrapolation of sea-level data in the ICAO data bank to the operating altitudes and temperatures encountered throughout the aircraft flight profile.

The ANCAT/EC2 inventory used commercial software for flight and fuel profiling, along with Project Interactive Analysis and Optimization (PIANO), a parametric aircraft design model. The global civil fleet was modeled with a selection of 20 representative aircraft types. These representative aircraft were assumed to be fitted with generic engines typical of the technology and thrust requirements of each type. PIANO generated fuel profiles covering the entire flight cycle, including steps in cruise for each aircraft. Fuel use during ground operations was estimated from ICAO certification timings (ICAO, 1993).

The DLR inventory used airline data and an in-house flight and fuel profile model (Deidewig et al., 1996). The DLR approach also used different aircraft/engine combinations from those utilized by ANCAT. The aircraft mission was simulated by using a simplified flight modeling code as point-to-point missions with no step cruise. Although the climb was calculated in iterative steps, the cruise segment was treated as one section, applying the Breguet formula to calculate the cruise fuel. Descent was assumed to be a gliding path with minimum engine load; no separate approach procedure was used. A thermodynamic model for design and off-design operation of a two-shaft fan engine was applied. Constant efficiencies and constant relative pressure losses for main engine components were assumed for simplicity.

The ANCAT/EC2 and DLR inventories calculated NO_x emissions from the fuel using the DLR fuel flow method. This method has been tested and correlated with information from airlines, flight measurements, and altitude chamber measurements (Deidewig et al., 1996; Schulte et al., 1997).

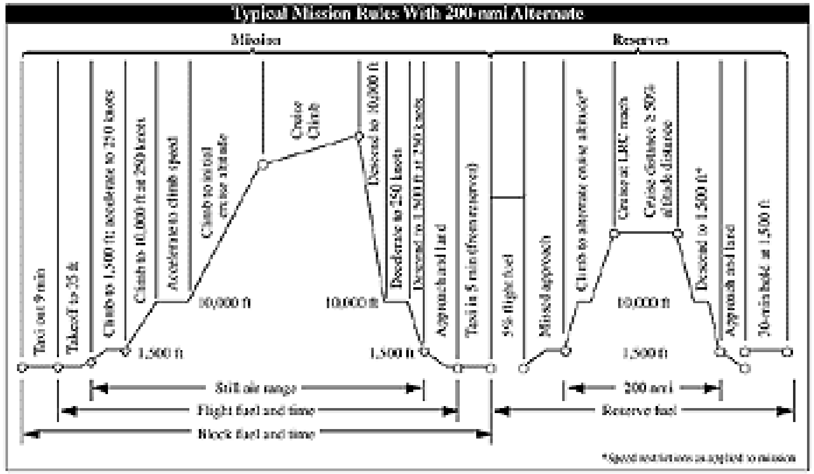


Figure 9-6: *Scheduled aircraft mission profile.*

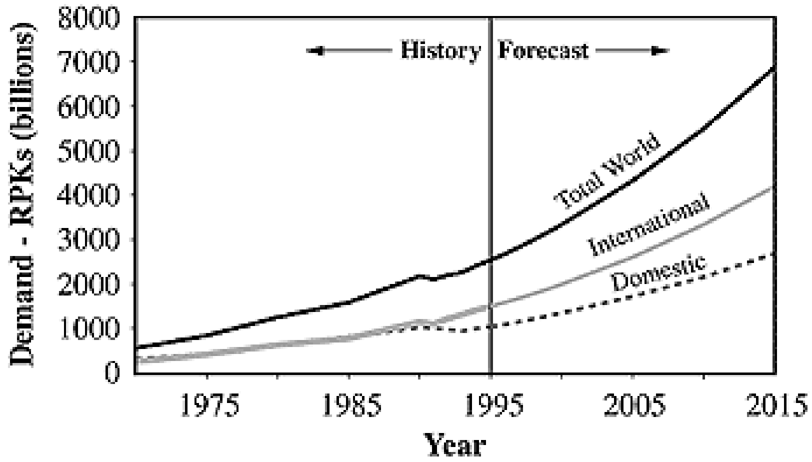


Figure 9-7: *Passenger traffic demand growth to 2015.*

9.3.2. NASA, ANCAT/EC2, and DLR 2015 Emissions Forecasts

The first NASA subsonic aircraft emissions inventory for 2015 was created as part of an assessment of the effects of a future HSCT (Baughcum et al., 1994); it has now been superseded by a new study (Baughcum et al., 1998; Mortlock and Van Alstyne, 1998) that includes new emissions technology assumptions and more detailed fleet mix and route system calculations. The NASA 2015 forecast inventory was calculated using methods similar to those used for NASA's historical and present-day inventories. Separate forecasts were created for scheduled operations (flights shown in the OAG database), charter operations, cargo operations, domestic operations in the FSU and China, military operations, and general aviation.

The forecast for scheduled traffic was based on the 1996 Boeing Current Market Outlook (Boeing, 1996), which projects separate traffic growth rates by region. Growth in worldwide demand for air travel was expected to average about 5% per year to the year 2015, with international travel growing at a slightly faster rate than domestic travel (Figure 9-7). By 2015, demand for air travel is projected to be 2.5 times greater than in 1996.

The total projected demand for scheduled air travel in the year 2015 was assigned to actual aircraft on a projected city-pair schedule derived from the schedules for 1995 published in the OAG. Individual city-pair service schedules for 1995 within each of the traffic flow regions were grown to 2015 by using the consolidated regional growth rate applicable for that region. Aircraft types were assigned to routes by using a market share forecast model. The turboprop market (for which there was no detailed forecast) was projected for 2015 by assuming that city pairs not served by the smallest turbojet category (50-90 seats) after demand growth to 2015 will continue to be served by small, medium, or large turboprops.

The result of the fleet assignment task was a detailed city-pair flight schedule by aircraft type required to satisfy forecast scheduled passenger demand in 2015. This schedule was used to calculate the 3-D emissions inventory for scheduled passenger service. Simplifying assumptions were the same as those used in calculating the historical and present-day inventories.

Projections of engine and aircraft technology levels for the 2015 scheduled fleet with regard to fuel efficiency and NO_x emissions were made by assuming a continuation of present trends. In general, engines in the 2015 scheduled fleet represent the state-of-the-art in engine technology available either in production or in the final stages of development at the time the assignments were made (1997). These engines include low-emissions derivatives of previously existing engines. It is unlikely that any radical changes in airframe or engine design-even if such designs were acceptable-would have much of an effect on the 2015 fleet, given the time required to bring new designs into service. The combined effects of 2015 fleet mix and technology projections on the NO_x technology level of the projected 2015 fleet appear in Figure 9-8, which shows the percentage of total fleet fuel burned by aircraft having landing/take-off cycle (LTO) emissions at a given level relative to the CAEP/2 NO_x limit. (CAEP is chartered to propose worldwide certification standards for aircraft emissions and noise. The CAEP/2 designation refers to emissions certification standards adopted at the second meeting of the CAEP in December 1991.) Much more of the fleet consists of low-NO_x aircraft-engine combinations in 2015, with ~70% of fuel burned in engines with NO_x emission levels between 20 and 40% below the CAEP/2 certification limit.

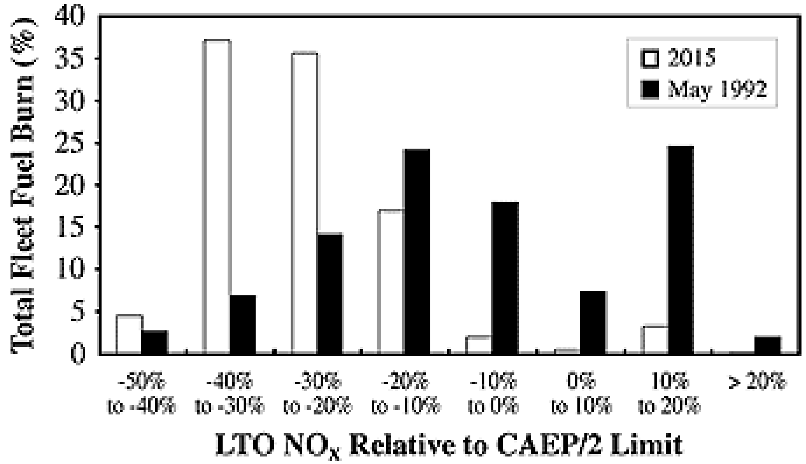


Figure 9-8: *Percentage of total scheduled fleet fuel burned by aircraft in specific LTO NO_x emissions categories for May 1992 (Baughcum et al., 1996b) and the year 2015 projection (Baughcum et al., 1998).*

DTI has developed a traffic and fleet forecast model for civil aviation, which was adapted under the direction of ANCAT and EIDG to produce an estimate of fuel burned and NO_x emitted by civil aviation for the forecast year of 2015 (Gardner, 1998). Fuel and NO_x growth factors-base to forecast-were calculated and applied to the ANCAT/EC2 city-pair gridded 1992 base year inventory to produce a gridded 2015 forecast.

DTI's top-down regional traffic demand forecasting model has a horizon of 25 years. Traffic coverage in the model includes all scheduled civil operations but excludes the former Soviet Union, Eastern Europe, freight, military, non-European charter traffic, business jets, and general aviation. Factors were developed to account for these traffic sectors in the forecast. The traffic forecast assumes a relationship between traffic [available seat-kilometers (ASK)] and GDP growth, and is assessed on a regional and flow basis (i.e., traffic flow between specific regions). The relationship is modified by assumptions on airline yields-a surrogate for fares price-and by a market maturity term that modifies demand as a function of time. Future fleets are estimated from traffic forecasts in terms of size and composition.

The concept of "traffic efficiency" was used to estimate fuel consumption from traffic values. Traffic efficiency is defined as the amount of traffic or capacity (ASK) per unit of fuel consumed. Aircraft manufacturers' traffic efficiency data for current aircraft types and projections for future aircraft types were used to develop efficiency trends for the eight categories of generic aircraft adopted for forecasting purposes, over a range of flight sector lengths. This approach permitted estimation of fuel consumption on the basis of regional and global traffic forecasts. Average efficiency figures were also calculated for the eight generic aircraft types in the 1992 base year fleet; a fleet average value of about 24.0 seat-km per liter was found. This figure compares well with those in Greene (1992) and Balashov and Smith (1992) for the years 1989 and 1990, respectively, which gave traffic efficiencies of 20.5 seat-km per liter.

Table 9-2: *Future trends in fuel efficiency improvement*

Time Period	Fuel Efficiency Improvement
1993-2000	1.3% yr^{-1}
2000-2010	1.3% yr^{-1}
2010-2015 (extrapolation)	1.0% yr^{-1}

Greene (1992) and Balashov and Smith (1992) forecast an annual improvement in commercial air fleet fuel efficiency (see Table 9-2). These efficiencies include improvements arising from the introduction of new aircraft into the fleet and changes to operating conditions and passenger management. For the DTI work, the Greene (1992) forecasts were used to 2010. Annual improvements in fuel efficiency was assumed to decrease to 1% per year beyond 2010.

Using this efficiency trend, traffic efficiencies were calculated for the future aircraft fleet. The base year fleet average was estimated to increase to 31.8 seat-km per liter by 2015.

Table 9-3: *Results from AERO modeling analysis.**

Annual Change	1992	2015	
Aircraft kilometers (km yr^{-1})	20.7×10^9	49.6×10^9	3.9%
Fuel consumption (Tg yr^{-1})	144	278	2.9%
CO_2 emissions (Tg yr^{-1})	453	877	2.9%
NO_x emissions (Tg yr^{-1})	1.84	3.86	3.3%

The same trends in fuel efficiency were applied to all size and technology classes. This approach represents a simplification because improvement figures are really a fleet average and would be influenced strongly by the rate of introduction of new aircraft. Given the much smaller contribution of older aircraft to global traffic performance, however, this factor will be only a second-order effect.

The emission performance of the forecast fleet was determined in part by the assumed response of the engine manufacturing industry to an assumed regulatory scenario. An emissions certification stringency regime was proposed for the forecast period, and compliance with the tighter limits was achieved by modifying the emissions performance of engines as they became noncompliant. This calculation was assessed from a base year engine fleet, comprising engines typical of and representing those found in the fleet (and compatible with the aircraft generic types described above). Performance improvements were applied only to new fleet entrants and were appropriate for staged and ultra-low NO_x control technology in some cases.

This process results in an estimate of fuel burn and NO_x emissions for the base year and forecast fleet using the same methodology; 1992-2015 fuel and NO_x growth factors are thereby calculated. The growth factors were applied to the ANCAT/EC2 base year gridded fuel and NO_x estimates to provide a 2015 gridded forecast.

The methods used to project civil aviation traffic demand for the DLR 2015 inventory were based on regional growth factors calculated by DTI. Thus, the DLR 2015 forecast differs from the ANCAT/EC2 forecast only in that the base year inventory is slightly different because of the different fuel and profiling methodology and the aircraft generic types. Thus, in the comparison of results, ANCAT and DLR 2015 forecasts are not assumed to be different because the DLR forecast is essentially an application of the DTI/ANCAT forecast.

Table 9-4: *Calculated fuel and emissions from NASA, ANCAT, and DLR inventories.*

	NASA 1976	**NASA 1984**	**NASA 1992**	**ANCAT 1992**	**DLR 1992**	**NASA 2015**	**ANCAT 2015**	**DLR 2015**
Calculated Fuel Burned (Tg)								
Scheduled	45.83	64.17	94.84			252.73		
Charter	8.47	9.34	6.57			13.50		
FSU/China	6.05	7.43	8.77			15.79		
General Aviation	4.04	5.62	3.68			6.03		
Civil Subtotal	64.38	86.56	113.85	114.20	112.24	288.05	272.32	270.50
Military	35.66	29.76	25.55	17.08	17.10	20.59	14.54	14.50
Global Tota	100.04	116.31	139.41	131.3	129.34	308.64	287.86	285.00
Calculated CO_2 Emissions (Tg C)								
Scheduled	39.41	55.18	81.56			217.35		
Charter	7.28	8.03	5.65			11.61		
FSU/China	5.20	6.39	7.54			13.58		
General Aviation	3.47	4.83	3.16			5.18		
Civil Subtotal	55.36	74.44	97.91	98.22	96.52	247.72	234.21	232.63
Military	30.67	25.59	21.98	14.68	14.71	17.71	12.50	12.47
Global Total	86.03	100.03	119.89	112.92	111.23	265.43	246.71	245.10
Calculated NO_x Emission (Tg as NO_2)								
Scheduled	0.50	0.79	1.23					
Charter	0.09	0.11	0.09					
FSU/China	0.04	0.06	0.06					

General Aviation	0.06	0.07	0.05					
Civil Subtotal	0.70	1.02	1.44	1.60	1.60	3.95	3.37	3.41
Military	0.28	0.25	0.23	0.20	0.20	0.18	0.16	0.16
Global Total	0.98	1.28	1.67	1.81	1.80	4.12	3.53	3.57
Calculated Fleet Average NO_x Emission Index [g NO_x (as NO_2) kg^{-1} fuel burned]								
Scheduled	10.9	12.3	13.0			14.1		
Charter	10.8	11.3	13.3			13.8		
FSU/China	7.4	7.4	7.4			7.4		
General Aviation	14.5	12.6	14.4			11.3		
Civil Subtotal	10.8	11.8	12.6	14.0	14.2	13.7	12.4	12.6
Military	8.0	8.5	8.9	11.9	11.8	8.7	10.7	10.8
Global Total	9.8	11.0	12.0	13.8	13.9	13.4	12.3	12.5

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Aviation and the Global Atmosphere

Chapter 9 Aircraft Emissions: Current Inventories and Future Scenarios Go

9.3.3. Other Emissions Inventories

Studies of atmospheric effects of aviation were conducted using the global inventory of McInnes and Walker (1992) and emissions data sets produced by the Dutch Institute of Public Health and Environmental Protection for 1990, 2003, and 2015 (Olivier, 1995) based on the McInnes and Walker (1992) data. Other emissions estimates are predominantly made on a national level (e.g., in Austria and Sweden).

The Dutch Aviation Emissions and Evaluation of Reduction Options (AERO) Project was initiated in 1994 by the Dutch Civil Aviation Department to estimate economic and environmental impacts of possible measures to reduce aviation emissions (see Chapter 10). Within this project, the flights and emissions model (FLEM) was developed for the calculation of worldwide fuel use and emissions per grid cell (ten Have and de Witte, 1997). The base year traffic movements database is a combination of data from ANCAT/EC2, International Air Transport Association, the ABC schedule, ICAO, and the U.S. Department of Transportation (DOT). Global volumes for aircraft kilometer, fuel consumption, and emissions CO_2, NO_x) resulting from computations of the AERO modeling system for civil aviation for base year 1992 and forecast for 2015 (called FPC-2015 scenario) are listed in Table 9-3. Further details appear in Pulles (1998).

Table 9-5: *Emissions of CO and HC from NASA inventories.*

	NASA 1976	**NASA 1984**	**NASA 1992**	**NASA 2015**
Calculated CO Emissions (Tg)				
Scheduled	0.41	0.41	0.50	1.12
Charter	0.03	0.04	0.02	0.05
FSU/China	0.10	0.12	0.15	0.26
General Aviation	0.73	0.75	0.62	0.60

Civil Subtotal	1.27	1.32	1.29	2.04
Military	0.43	0.35	0.29	0.23
Global Total	1.70	1.67	1.57	2.27
Calculated Fleet Average CO Emissions Index (g CO kg^{-1} fuel burned)				
Scheduled	8.9	6.3	5.3	4.5
Charter	4.0	4.0	3.7	3.9
FSU/China	16.6	16.6	16.6	16.6
General Aviation	180.1	133.0	167.6	99.4
Civil Subtotal	19.7	15.2	11.3	7.1
Military	12.0	11.9	11.2	11.3
Global Total	17.0	14.4	11.3	7.4
Calculated HC Emissions (Tg)				
Scheduled	0.27	0.20	0.20	0.17
Charter	0.01	0.01	0.00	0.01
FSU/China	0.02	0.02	0.03	0.05
General Aviation	0.03	0.05	0.04	0.05
Civil Subtotal	0.33	0.28	0.26	0.28
Military	0.09	0.07	0.06	0.05
Global Total	0.42	0.35	0.32	0.33
Calculated Fleet Average HC Emissions Index (g HC kg^{-1} fuel burned)				
Scheduled	5.8	3.2	2.1	0.7
Charter	0.9	0.9	0.5	0.6
FSU/China	3.2	3.2	3.2	3.2
General Aviation	8.2	8.5	9.9	8.6
Civil Subtotal	5.1	3.3	2.3	1.0
Military	2.5	2.3	2.4	2.5
Global Total	4.2	3.0	2.3	1.1

9.3.4. Comparisons of Present-Day and 2015 Forecast Emissions Inventories (NASA, ANCAT/EC2, and DLR)

Table 9-4 lists the totals for calculated fuel burned and emissions from the NASA, ANCAT, and DLR inventories for 1976, 1984, 1992, and 2015. Because these inventories consisted of 3-D data sets, the differences in spatial distributions as well as totals are compared. The NASA inventories also included emissions of CO and HC, which are summarized in Table 9-5.

The NASA inventories include piston-powered aircraft in the general aviation fleet. This category of aircraft is excluded from the ANCAT and DLR inventories, but the contribution to total fuel burned from these aircraft is small (2.6% of fuel burned in 1992). Piston-powered aircraft are large contributors to CO and HC emissions relative to the amount of fuel they burn (39% of CO and 13% of HC emissions in 1992). This large relative contribution is reflected in the emissions indices of these two pollutants in the general aviation category.

A comparison of calculated global total values for fuel burned and NO_x emissions from the NASA, ANCAT, and DLR inventories for 1992 and 2015 is shown in Figure 9-9. All three inventories for 1992 have approximately the same calculated values for total fuel burned in the civil air fleet; the difference in total fuel (7% maximum) arises almost entirely from different calculated contributions for military aviation operations, for which the ANCAT inventory calculates 33% lower fuel burned. Because military fuel is estimated to be between 13 and 18% of total fuel in 1992, the effect of this large difference in estimates between military sectors on the total is small. Use of the NASA inventories as a base is arbitrary and does not imply that differences from the NASA results are errors. Exclusion of turboprop operations from the ANCAT inventory results in about a 2% underestimate (if data from the NASA inventory are used). Calculated values for total NO_x emissions from the three inventories for 1992 are within 9% of each other. The ANCAT and DLR values are higher than those from NASA-a result of a combination of differing fleet mixes, a different method of calculating NO_x emissions, and the offsetting effects of civil and military calculations. This variation is also reflected in the calculated

$EI(NO_x)$ for the fleet components: The ANCAT and DLR inventories have a total fleet emission index that is 15% higher than that of the NASA inventory.

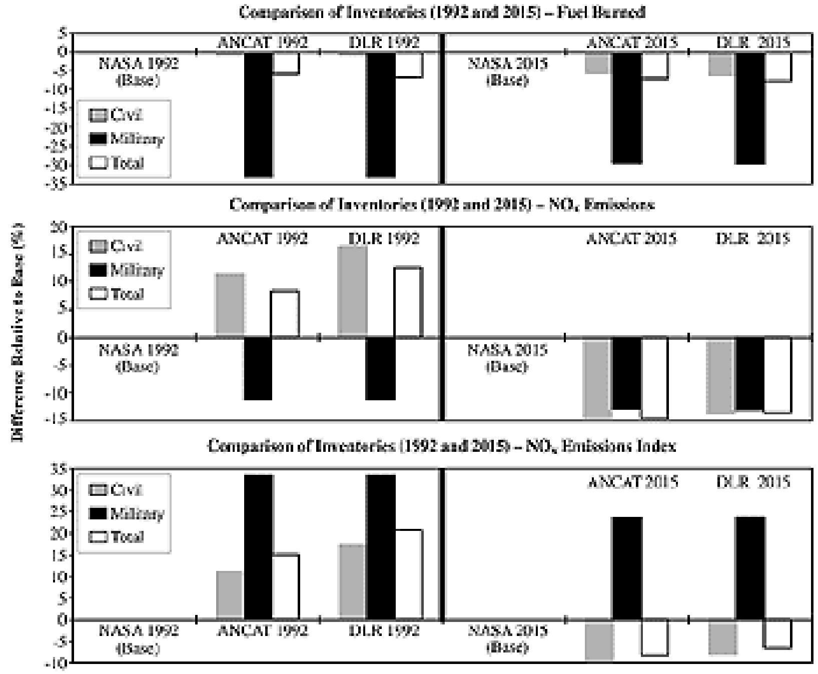

Figure 9-9: *Comparison of inventories*

Differences between inventory totals widen for the 2015 case, although total fuel burned is still within 8%. Total NO_x emissions in the NASA 2015 forecast are almost 15% greater than those in the ANCAT forecast, a result of different assumptions about the direction of NO_x reduction technology (the NASA assumptions result in an increase in NO_x emissions index in the civil sector, whereas the ANCAT forecasts assume a reduction). Other differences between the NASA, ANCAT, and DLR inventories relate to the distribution of calculated fuel burned and emissions, geographically (latitude and longitude) and with altitude. Although all three inventories place more than 90% of global fuel burned and emissions in the Northern Hemisphere, there are differences between inventories in the details of the distribution. Figure 9-10 shows the distribution of fuel burned as calculated in 1 month (May) of the 1992 NASA inventory. The most heavily trafficked areas are clearly visible (United States, Europe, North Atlantic, North Asia).

For geographical comparison purposes, data in the files of the NASA and ANCAT 1992 inventories were divided into 36 regions, defined by 60° spans of longitude and 20° spans of latitude. Figure 9-11 shows the differences between the ANCAT and NASA 1992 inventories with regard to geographical distribution. The major differences between the NASA and ANCAT inventories (on a geographical basis) lie in the estimate of fuel burned and NO_x emissions in the regions covering North America and Europe. The ANCAT inventory places 32% of total fuel burned and 30% of total NO_x over North America, whereas the NASA inventory places 27% of fuel burned and 27% of NO_x over that region. ANCAT places 16% of the fuel and 15% of the NO_x over Europe, whereas the NASA inventory places 21% of the fuel and 19% of total NO_x over that region. Part of this difference may be explained by the 10% scaling of U.S. traffic assumed by ANCAT as a method of approximating the U.S. charter market.

NASA and ANCAT fuel and NO_x emissions projections for 2015 are similar to the respective 1992 inventories in that no new city pairs were used in the 2015 traffic projections. Growth rates from 1992 to 2015 vary with region, so the geographical distribution of emissions changes over time. The altitudinal distributions of fuel burned in the present-day NASA, ANCAT, and DLR inventories are shown for civil aviation in Figure 9-12 and for military aviation in Figure 9-13. The civil aviation distributions are similar, with the NASA inventory showing more fuel burned at higher altitudes. The military distributions are quite different, with fuel burned in the NASA inventory concentrated at the higher altitudes and fuel burned in the ANCAT inventory at lower altitudes. This difference may be because of a higher proportion of transport operations in the NASA inventory. The altitudinal distribution of NO_x emissions follows closely that of fuel burned.

The three inventories show that more than 60% of the fuel burned and NO_x emissions occur above 8 km, whereas a major fraction of CO and HC are emitted near the ground.

Although the three inventories show comparably low variations for total global monthly figures over the year, the seasonal dependency can be quite large for some regions (Figure 9-14). Operations in the North Atlantic and North Pacific show a clear yearly cycle, with a maximum in the northern summer and a minimum during winter. In contrast, Southern Hemisphere operations show little seasonal variation overall, with small peaks in February and November. DLR has also examined longer trends in fuel burned and emissions for air traffic (Schmitt and Brunner, 1997). 3-D gridded inventories of fuel burned and emissions were calculated for 1982 through 1992 using ICAO statistics on annual values for international scheduled air traffic and ABC time table data of all scheduled air traffic for the same week of September in 1986, 1989, and 1992. Emissions inventories were produced for each of these data sets using the same methods as in the 1992 DLR inventory described above. These inventories concentrate on scheduled services because reasonably accurate calculations are possible for this segment of aviation. Because these data do not include nonscheduled flights, military traffic, general aviation, or former Soviet Union/China traffic, they are of limited use in global modeling studies. However, they do provide a consistent set of data to track the growth of the international and domestic scheduled sector. Table 9-6 gives the totals for the yearly inventories.

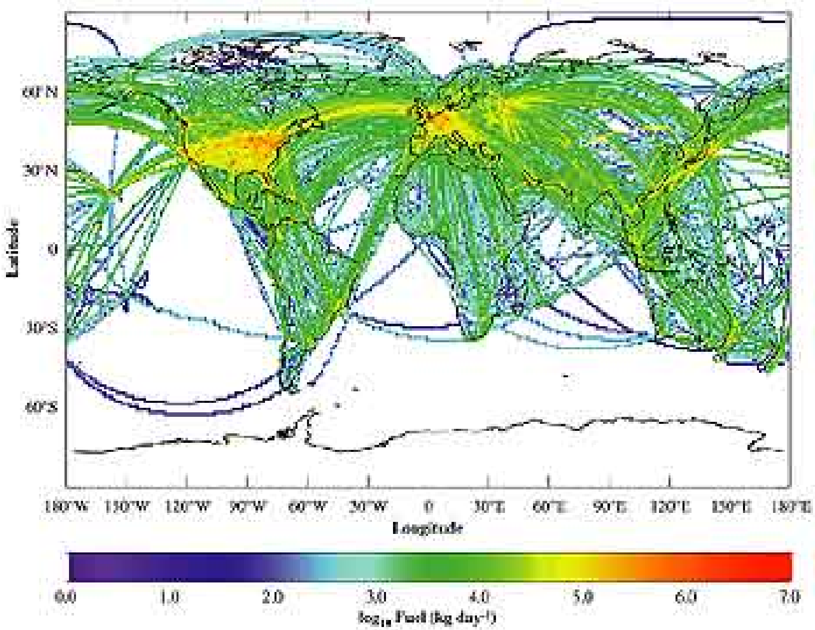

Figure 9-10: *Geographical distribution of fuel burned by civil aviation (May 1992).*

9.3.5. Error Analysis and Assessment of Inventories

Simplifying assumptions used in creating all of the 3-D emissions inventories have introduced systematic errors in the calculations. An analysis of the effects of the simplifying assumptions on fuel burned used in the 1992 NASA inventory has been performed by Baughcum et al. (1996b). All of the assumptions have the effect of biasing the calculation toward an underestimate of fuel burned and emissions produced, as detailed in Table 9-7. The effects of the assumptions on the ANCAT and DLR inventories may be expected to be similar, because most of the simplifying assumptions used in those inventory calculations were similar to those in the NASA inventory.

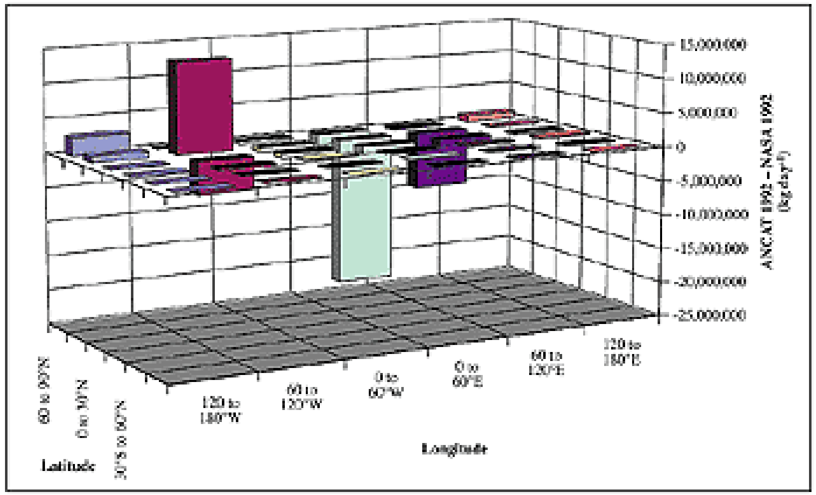

Figure 9-11: *Differences in geographical distribution of fuel burned.*

The assumption of great-circle flight paths results in an underestimate of distance flown, although the practice of routing to take advantage of winds may result in lower fuel consumption than a great-circle path for a given flight. A study of international and domestic flights from German airports showed an average increase in flight distance of 10% for medium- and long-haul flights above 700 km, with larger deviations from great-circle routes for shorter flights (Schmitt and Brunner, 1997). Ground delays and in-flight holding at relatively low altitudes caused by congestion in the air traffic control system also adds to fuel consumption. Aircraft in service are subject to factors that may increase fuel consumption by up to 3% (e.g., engine deterioration, added weight from added systems, and increased surface roughness). Factors that cause underestimates of fuel burned do not necessarily operate at the same time, so they are not additive. Sutkus et al. (1999) compared fuel burned for certain carriers and certain specific aircraft types reported to DOT by U.S. air carriers, with the value for fuel burned calculated for these carriers and aircraft types in the 1992 NASA inventory. The comparison shows that a combination of factors outlined above results in systematic underestimation of total fleet fuel burned by 15-20% for domestic operations. The assumptions in the foregoing analysis apply to the civil aviation fleet. An error analysis of the calculation of fuel burned and emissions from military operations is not possible, given the nature of the estimates used in the calculations.

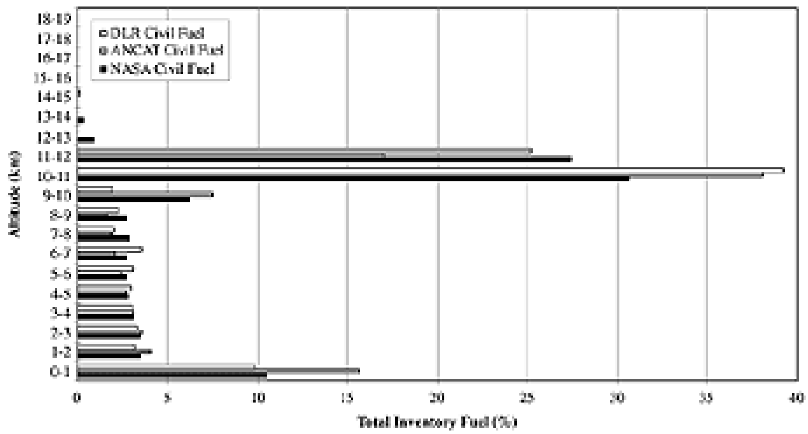

Figure 9-12: Comparison of altitude distribution of 1992 inventories for civil aviation fuel burned.

The present-day inventories described above have reported global fuel consumption values for 1992 ranging from 129 to 139 Tg. However, reported aviation fuel production was somewhat larger, at 177 Tg (OECD, 1998a,b). Calculated fuel consumption therefore accounts for 73-80% of total fuel reported produced in 1992. Simplifying assumptions used in calculating the inventories probably account for most of the difference. Reported fuel production values are not an ideal reference, however, because they do not necessarily represent fuel delivered to airports for use in aircraft. Jet fuel, in particular, is a fungible product; it can be reclassified and sold as kerosene or mixed with fuel oils or diesel fuel, depending on market requirements (e.g., when low freezing point fuel oil is needed in winter). Other distillate fuels from refineries may satisfy jet fuel requirements and could be purchased and used as jet fuel. As a consequence, reported jet fuel production data do not provide a rigorous upper or lower limit to jet fuel use. Fuel production data represent a compilation of reports of varying accuracy from many (not all) countries, whose overall accuracy has not been evaluated (Baughcum et al., 1996b; Friedl, 1997).

OECD data on aviation fuel production from 1971 (the first year the data includes the former Soviet Union) to 1996 are shown in Figure 9-15. These data shown are the sum of OECD and non-OECD country production data. Reported data include production of aviation gasoline, naphtha-type jet fuel (mostly JP-4, used for military aircraft), and kerosene-type jet fuel (Jet A, the most common transport aircraft jet fuel). Also shown are calculated values of aviation fuel burned from the NASA, ANCAT, and DLR present-day inventories. (NASA values have been increased by 15% as a rough estimate of systemic underestimate of civil fuel burned.)

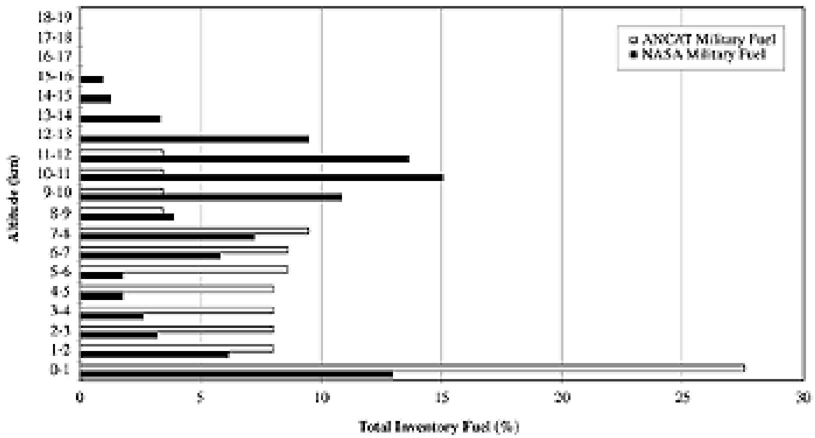

Figure 9-13: Comparison of altitude distribution of 1992 inventories for military aviation fuel burned.

Aviation gasoline has declined as a percentage of total aviation fuel-from 4% of production in 1971, to just over 1% in 1995. Production of naphtha-type jet fuel reached just over 10% of total fuel in 1983, but has since declined to less than 1% as military aviation has phased out its use in favor of kerosene-type fuels. Prior to 1978, production of naphtha-type fuel was not reported as a separate item in the OECD database; it was included in the kerosene-type production data.

The three inventories are in good agreement; given the different approaches and data sources used, the inventory results (particularly for the present day) are remarkably consistent. Assumptions regarding the state of NO_x reduction technology in 2015 cause the biggest difference in the results of the three forecasts. The 1992 and 2015 inventories of NASA, ANCAT, and DLR are all suitable for calculating the effects of aircraft emissions on the atmosphere, taking account of differences in the details of the inventories and systematic underestimates examined above. To correct for the systematic underestimation of fuel burned in the inventories when calculating the effects of aviation CO_2 emissions, fuel burned values for 1992 should be increased by 15% and those for 2015 should be increased by 5%, based on the assumption that inefficiencies in the air traffic control system responsible for extra fuel burned will be much reduced by 2015. A summary of the results from these inventories is given in Table 9-8. The DLR "trend" inventories (1982-92) include only a portion of total aviation operations (scheduled international service for all years and total scheduled service in 1986, 1989, and 1992); as such, they are valuable for historical growth analysis and for comparisons with the NASA and ANCAT/EC2 scheduled traffic segments.

***Table 9-6:** Fuel burned and emissions from scheduled air traffic, 1982-92 (DLR).*

Year	Fuel [Int'l] (Tg)	NO_x [Int'l] (Tg)	CO [Int'l] (Tg)	HC [Int'l] (Tg)	Fuel [Total] (Tg)	NO_x [Total] (Tg)	CO [Total] (Tg)	HC [Total] (Tg)
1982	19.2	0.31	0.05	0.02				
1983	20.9	0.35	0.06	0.02				
1984	24.7	0.41	0.06	0.03				
1985	24.9	0.41	0.06	0.02				
1986	26.7	0.44	0.07	0.03	72.2	1.03	0.24	0.10
1987	30.0	0.51	0.08	0.03				
1988	32.6	0.55	0.09	0.03				
1989	35.8	0.61	0.10	0.03	76.5	1.14	0.27	0.09
1990	37.2	0.62	0.11	0.04				
1991	36.3	0.59	0.11	0.04				
1992	39.3	0.62	0.10	0.03	93.0	1.31	0.34	0.10

***Table 9-7:** Analysis of the underestimate of fuel burned caused by simplifying assumptions (Baughcum et al., 1996b).*

Changes to Simplifying Assumptions	Maximum % Fuel Burned Increase
No winds to actual winds	2.6 (Autumn winds, North Pacific route)

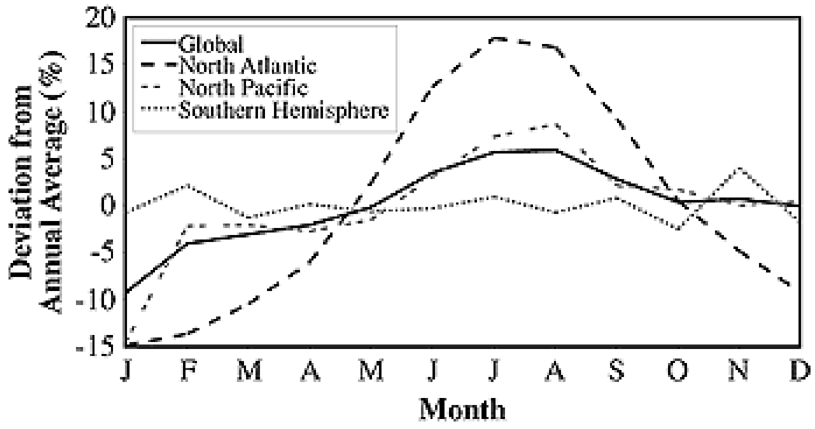

***Figure 9-14:** Regional seasonality of traffic.*

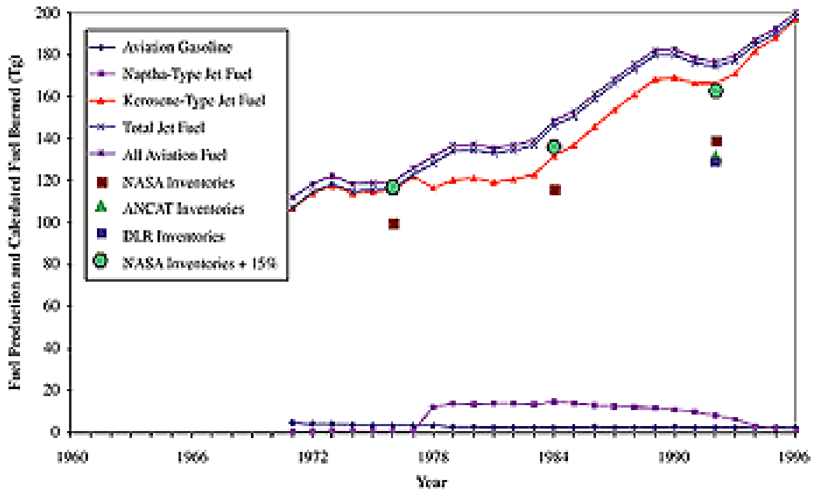

***Figure 9-15:** Comparison of calculated fuel burned by aviation with reported production.*

Standard temperatures to actual temperatures	0.7 (Summer temperature, North Pacific route)
Combined wind and temperature effects	3.1 (Autumn winds, ISA+5°C temperature, North Pacific)
Payload: increase load factor to 75%	0.8 (747-400, North Pacific)
Payload: increase load factor to 75%	2.5 (737-300, Los Angeles-San Francisco)
Payload: volume limited cargo	7.7 (747-400, North Pacific)

Table 9-8: *Summary comparison of historical, present-day, and 2015 forecast 3-D emissions inventories.*

Inventory Year	Inventory Source	Calculated Fuel Burned (Tg)	Calculated CO_2 (as C) (Tg)	Calculated NO_x (as NO_2) (Tg)	Calculated Fleet $EI(NO_x)$ (g NO_2 kg^{-1} fuel)
1976	NASA	100.0	86.0	1.0	9.8
1984	NASA	116.3	100.0	1.3	11.0
1992	NASA	139.4	119.9	1.7	12.0
1992	ANCAT	131.2	112.9	1.8	13.8
1992	DLR	129.3	111.2	1.8	13.9
2015	NASA	308.6	265.4	4.1	13.4
2015	ANCAT	287.1	246.9	3.5	12.3
2015	DLR	285.0	245.1	3.6	12.5

9.4. Long-Term Emissions Scenarios

Long-term projections to the year 2050 producing 3-D emissions data have been made by the Forecasting and Economic Analysis Subgroup of CAEP, using the NASA studies as a base (CAEP/4-FESG, 1998), and by DTI using the ANCAT studies as a base (Newton and Falk, 1997). Long-term projections of total demand, fuel consumption, and emissions (but not providing 3-D data) have also been made by EDF (Vedantham and Oppenheimer, 1994, 1998), WWF (Barrett, 1994), and MIT (Schafer and Victor, 1997).

Table 9-9: *Summary of IPCC GDP scenarios used in FESG model.*

	Average Annual Global GDP Growth	
Rate Scenario	1990-2025	1990-2100
IS92a	2.9%	2.3%

Predictions of traffic demand and resulting emissions beyond 2015 become increasingly uncertain because the probability for unforeseeable major changes in key factors influencing the results steadily increases. The best approach for insight into the evolution of long-term futures is the application of scenarios. A scenario is simply a set of assumptions devised to reflect the possible development of a particular situation over time. These assumptions are used as inputs to a model that describes the manner in which an activity might develop over time. A range of possible futures can be described by a set of independent scenarios. The results of the scenario are difficult to judge in terms of confidence level: They are simply the outcome of input assumptions. However, scenarios can be objectively judged as implausible by showing that their assumptions or outcomes conflict with industry trends or with invariant rules and laws that might reasonably be expected to remain unchanged during the scenario time period or by revealing internal inconsistencies or incompatibilities with other dominating external developments. Investigation of the consequences and implications of scenarios can be used to support a subjective assessment regarding which of the remaining possible scenarios might be more plausible than others.

Table 9-10: *Traffic projections and 5-year average growth rates from FESG (CAEP/4 - FESG Report 4, 1998).*

Year	Fa Demand (10^9 RPK)	Fa Growth Rate (%)	Fc Demand (10^9 RPK)	Fc Growth Rate (%)	Fe Demand (10^9 RPK)	Fe Growth Rate (%)
1995	2,536.6[a]		2,536.6[a]		2,536.6[a]	
2000	3,238.0	5.0	3,068.8	3.9	3,336.1	5.6
2005	3,981.4	4.2	3,591.9	3.2	4,322.4	5.3
2010	4,782.6	3.7	4,103.0	2.7	5,491.7	4.9
2015	5,638.6	3.3	4,596.1	2.3	6,876.2	4.6
2020	6,552.9	3.1	5,070.7	2.0	8,302.4	3.8
2025	7,533.6	2.8	5,530.7	1.8	9,908.5	3.6
2030	8,592.7	2.7	5,981.4	1.6	11,727.0	3.4
2035	9,744.9	2.5	6,429.8	1.5	13,794.9	3.3
2040	11,006.8	2.5	6,881.5	1.4	16,155.8	3.2
2045	12,396.5	2.4	7,342.5	1.3	18,864.2	3.1
2050	13,933.5	2.4	7,817.2	1.3	21,978.2	3.1

9.4.1. FESG 2050 Scenarios

9.4.1.1. Development of Traffic Projection Model

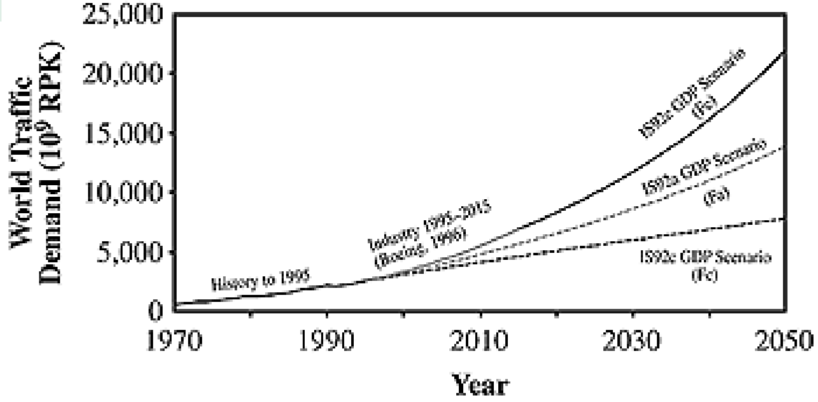

Figure 9-16: *ICAO/FESG traffic demand scenarios to 2050 (based on IPCC IS92a, IS92c, and IS92e).*

In developing long-term traffic scenarios, various models of traffic demand were considered (CAEP/4-FESG, 1998), particularly those incorporating a market maturity concept. Under this concept, historical traffic growth rates in excess of economic growth are considered unlikely to continue indefinitely, and traffic growth will eventually approach a rate equal to GDP growth as the various global markets approached maturity. Based on this assumption, a single global model of traffic demand per unit of GDP was developed, based on a logistics growth curve function:

t = time
RPK = revenue passenger-km
GDP = gross domestic product

The parameters in the model equation were estimated from historic values of RPK/GDP for the period 1960 through 1995. No constraints were imposed on the values the parameters could take. Further details of the modeling process appear in CAEP/4-FESG (1998). Table 9-9 lists the GDP growth assumptions used in developing these scenarios (Leggett et al., 1992). The key assumptions of this approach follow:

- The world can be treated as a single, gradually maturing aviation market that is the sum of regional markets at various stages of maturity.
- Historical values of world demand and GDP over time provide sufficient information about the stage of development of the industry to provide reliable estimates of market maturity.
- Business and personal travel sectors can be combined.
- Global traffic growth is driven primarily by global GDP; as markets mature, overall passenger growth rates will eventually grow in line with GDP growth.
- Fuel will be available, and fuel prices will not increase greatly relative to other costs.
- Whatever aviation technological or regulatory changes occur, they will have no significant impact on ticket prices, demand, or service availability.
- Infrastructure will be sufficient to handle demand.
- There will be no significant impacts from other travel modes (e.g., high-speed rail) or alternative technologies (e.g., telecommunications).

Perhaps the most critical assumption of this methodology was that historical global traffic totals contained sufficient information about the maturity of the industry as a whole to provide a reasonable basis upon which long-term aviation trends could be projected. There is a question of whether the signals of recent years (i.e., that overall traffic growth is slowing) are sufficiently robust to provide a reliable indication of future long-term growth. A related concern is that historical world traffic totals are dominated by OECD experience, thus may not adequately capture the potential for growth in other, less-developed regions (CAEP/4-FESG, 1998). To a large extent, the FESG scenarios for 2050 reflect assumptions of no fundamental change in overall revenue/cost structure trends of the aviation industry and no fundamental changes in the trends in technology or society. They also assume that the growth of air traffic demand will not be significantly constrained by other limiting factors. Sections 9.6.5 and 9.6.6 examine the availability of infrastructure and fuel with regard to the plausibility of all of the long-term scenario projections.

Growth rates from the model were applied to 1995 reported world traffic demand (Boeing, 1996)-together with GDP growth rates from the IPCC IS92a, IS92e, and IS92c scenarios-to produce FESG base case (Fa), high (Fe), and low (Fc) scenarios of scheduled traffic demand. The high case (Fe) was adjusted slightly to match the NASA traffic forecast for 2015 on which the NASA 2015 emission inventory was based. The basis for the NASA 2015 traffic forecasts were GDP forecasts that were similar to the IS92e GDP scenario (Boeing, 1996). The resulting traffic demand and average growth rate for the three 2050 scenarios are illustrated in Figures 9-16 and 9-17 and listed in Table 9-10. The traffic demand scenarios have been labeled Fa through Fe for brevity; these labels, when combined with the appropriate technology assumption designator (1

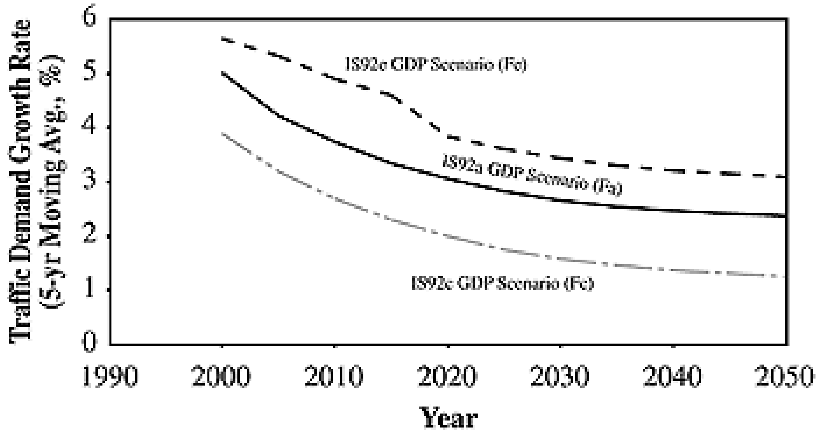

Figure 9-17: *Average traffic growth rates from FESG*

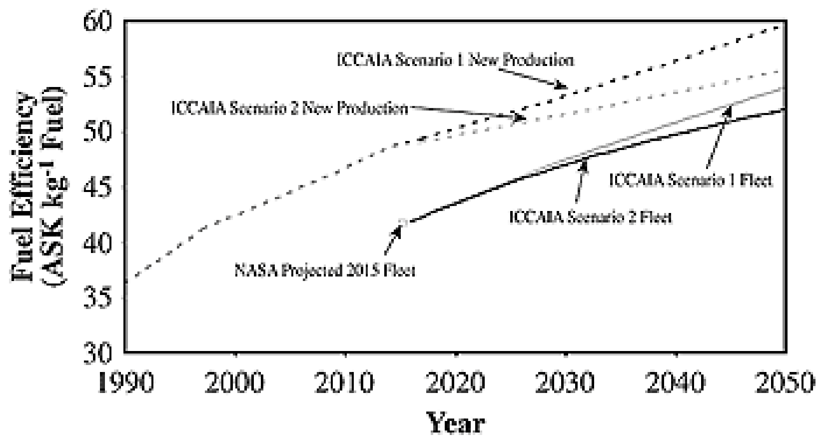

Figure 9-18: *Fuel efficiency trends to 2050 corresponding to the two ICCAIA technology scenarios for the FESG high traffic demand case.*

or 2; see Section 9.4.1.2), form the complete designator for the FESG scenarios used throughout the rest of this report.

Global traffic from the model projections was apportioned over 45 regional traffic flows with a separate market share model because certain regions grow faster than others, and the correct distribution of traffic is important in the calculation of the effects of emissions on the atmosphere. In this procedure, regional traffic flows were expressed as a share of the global market; using the market share and historical growth patterns ensures consistency between regional flows and the global forecast. The underlying assumption of this procedure is that each regional share approaches its ultimate share of the total market asymptotically. Mature markets tend to have declining shares approaching an asymptotic value, whereas developing markets tend to increase their shares. Adjustments of traffic flows were made so that the "top-down" traffic projections of the FESG global model were matched by a reasonable "bottom-up" distribution of regional traffic flows. These traffic flows include all traffic in all regions, and regional variations in growth rates are highlighted. Factors that affect the operations of military and general aviation aircraft were also estimated, and projections were made of the growth of these sectors (CAEP/4-FESG, 1998).

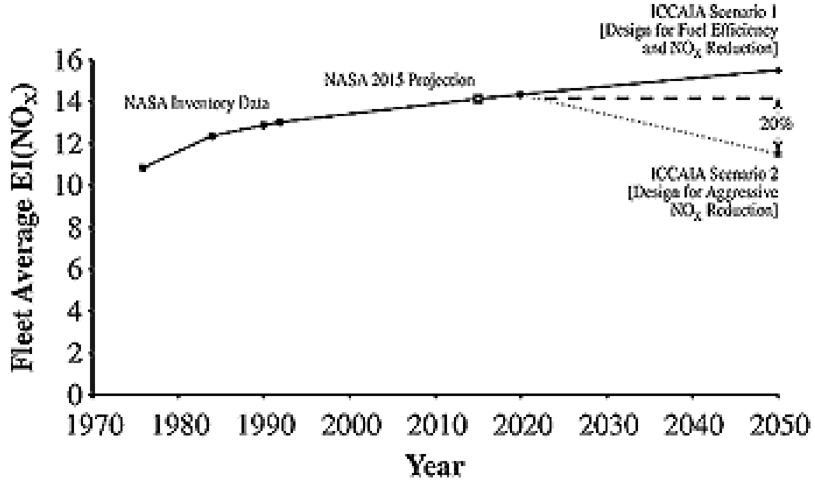

Figure 9-19: *Fleet average trends in EI(NO_x) showing projections for the two ICCAIA technology scenarios.*

Table 9-11: *ICCAIA NO_x and fuel-efficiency technology assumptions for 2050.*

Technology Scenario	**Fuel Efficiency Increase by 2050**	**LTO NO_x Levels**
Design for fuel efficiency and NO_x reduction	Average of production aircraft will be 40-50% better relative to 1997 levels	Fleet average will be 10-30% below CAEP/2 limit by 2050; fleet average EI(NO_x) = 15.5 in 2050
Design for aggressive NO_x reduction	Average of production aircraft will be 30-40% better relative to 1997 levels	Average of production aircraft will be 30-50% below CAEP/2 limit by 2020 and 50-70% below CAEP/2 limit by 2050; fleet average

Table 9-12: *Projected scheduled fleet fuel efficiency (Sutkus, 1997).*

	Scheduled Fleet Fuel Efficiency (ASK kg^{-1} Fuel)
2015 NASA Inventory	41.8

Traffic Scenario	Technology Scenario 1	Technology Scenario 2
Demand scenario Fa	53.6	51.8
Demand scenario Fc	53.1	51.4
Demand scenario Fe	54.0	52.0

Table 9-13: *Results of FESG year 2050 scenarios calculations.*

Sector	Fa1	Fa2	Fc1	Fc2	Fe1	Fe2
Calculated Fuel Burned (Tg)						
Scheduled	396.1	410.8	224.0	232.3	620.0	643.9
Charter	21.4	22.2	12.1	12.6	33.5	34.8
FSU/China	30.3	31.4	8.8	9.1	67.5	70.1
General Aviation	8.8	8.8	8.8	8.8	8.8	8.8
Civil Subtotal	456.6	473.2	253.8	262.8	729.8	757.7
Military	14.4	14.4	14.4	14.4	14.4	14.4
Global Total	471.0	487.6	268.2	277.2	744.3	772.1
Calculated CO_2 Emissions (Tg C)						
Scheduled	340.7	353.3	192.7	199.7	533.2	553.7
Charter	18.4	19.1	10.4	10.8	28.8	29.9
FSU/China	26.0	27.0	7.5	7.8	58.1	60.3
General Aviation	7.6	7.6	7.6	7.6	7.6	7.6
Civil Subtotal	392.7	407.0	218.2	226.0	627.7	651.6
Military	12.4	12.4	12.4	12.4	12.4	12.4
Global Total	405.1	419.4	230.6	238.4	640.1	664.0
Calculated NO_x Emissions (Tg as NO_2)						
Scheduled	6.1	4.7	3.5	2.7	9.6	7.4
Charter	0.4	0.3	0.2	0.2	0.6	0.4
FSU/China	0.5	0.3	0.1	0.1	1.0	0.8

General Aviation	0.1	0.1	0.1	0.1	0.1	0.1
Civil Subtotal	7.0	5.4	3.9	3.0	11.3	8.7
Military	0.1	0.1	0.1	0.1	0.1	0.1
Global Total	7.2	5.5	4.0	3.1	11.4	8.8
Calculated Fleet Average EI(NO_x) [g NO_x (as NO_2) kg^{-1} fuel burned]						
Scheduled	15.5	11.5	15.5	11.5	15.5	11.5
Charter	16.7	12.4	16.7	12.4	16.8	12.4
FSU/China	14.9	11.1	14.9	11.1	14.9	11.0
General Aviation	9.0	9.0	9.0	9.0	9.0	9.0
Civil Subtotal	15.4	11.5	15.3	11.4	15.4	11.5
Military	8.7	8.7	8.7	8.7	8.7	8.7
Global Total	15.2	11.4	15.0	11.3	15.3	11.4

9.4.1.2. FESG Technology Projections

Calculations of fuel burned and NO_x emissions produced by the 2050 scheduled fleet were made by applying projections of overall improvement in fleet fuel efficiency and emission characteristics to regional traffic flows and summing the results. These projections were created from technology-level estimates for new aircraft over time made by a working group of the International Coordinating Council of Aerospace Industries Associations (ICCAIA) (Sutkus, 1997); they are discussed in Section 7.5.5. A "fleet rollover" model was used to project a fleet average fuel efficiency trend, using characteristics of the present-day fleet and traffic demand from the FESG scenarios (Greene and Meisenheimer, 1997). The ICCAIA projections were made for two technology scenarios. The first scenario assumes that fuel efficiency and NO_x reduction will be considered in the design of future aircraft in a manner similar to the current design philosophy. The second technology scenario assumes a more aggressive NO_x reduction design strategy that will result in smaller improvements in fuel efficiency. The assumptions associated with the two technology scenarios are given in Table 9-11. The basis for projections of aircraft emissions made by FESG for the year 2050 was the 3-D NASA emissions scenarios for the year 2015 discussed in Section 9.3.2. The NASA 2015 emissions inventory was factored on the basis of the product of the ratios of regional traffic (as departures), fleet fuel efficiency, and fleet $EI(NO_x)$ as calculated for 2050 over the same values in 2015. For all flights in a given region:

$$NO_x\ Emissions_{2050} = NO_x\ Emissions_{2015}$$
$$(regional\ traffic_{2050}/\ regional\ traffic_{2015})$$
$$(fleet\ fuel\ efficiency_{2050}/\ fleet\ fuel\ efficiency_{2015})$$
$$(fleet\ EI(NO_x)_{2050}/\ fleet\ EI(NO_x)_{2015})$$

Figure 9-18 shows the trend for average new production and fleet average fuel efficiency as a function of time, derived from ICCAIA inputs and the fleet rollover model for the FESG high-demand traffic growth scenario. The average NO_x emission index for the scheduled fleet over the same time period is shown in Figure 9-19. The 2050 fleet average values used in the calculation of emissions from scheduled traffic as well as the baseline 2015 value are given in Table 9-12 (Sutkus, 1997). Fleet fuel efficiency is predicted to improve by about 30% between 2015 and 2050. Traffic in the FSU and the People's Republic of China has not historically been reported in airline schedule databases such as the OAG. Fuel burned and emissions from aviation in these regions were estimated individually and projected to 2015 (Mortlock and Van Alystyne, 1998), then extended to 2050 (CAEP/4-FESG, 1998).

9.4.1.3. FESG Emissions Scenario Results

Results of calculations of fuel burned and NO_x emissions for the year 2050 based on the long-term scenarios described above are given in Table 9-13. The FESG complete scenarios are identified below and in the remainder of this chapter by combining the demand scenario (e.g., Fa) with the technology scenario number (e.g., Fa1, Fe2).

9.4.2. DTI 2050 Scenarios

The DTI projection for air traffic and emissions for 2050 (Newton and Falk, 1997) has been developed from the DTI traffic and fleet forecast demand model, in conjunction with data from the ANCAT/EC2 inventory. The forecast model was developed from DTI's global and regional traffic forecast models for passenger and freight traffic. Fuel consumption trends were estimated with a fleet fuel efficiency model, and fleet emissions performance were estimated on the basis of assumed regulatory change. Finally, appropriate fuel and emissions factors were calculated to estimate 2050 figures from the base year; these factors were then applied to the 1992 ANCAT/EC2 emissions inventory to produce gridded results for the 2050 scenario.

Table 9-14: *Actual and forecast global capacity growth rates used in the DTI model.*

Year	ASK Annual Global Growth Rate (%)
1994	5.36
2000	5.16
2010	4.82
2020	3.62
2030	3.01
2040	2.49
2050	1.72

Table 9-15: *Assumed annual improvements in fuel efficiency in DTI model.*

Year	Annual Improvement in Fuel Efficiency (%)
1991-2000	1.3 (Greene, 1992)
2001-2010	1.3 (Greene, 1992)

2011-2020	1.0 (DTI extrapolation)
2021-2030	0.5 (DTI extrapolation)
2031-2040	0.5 (DTI extrapolation)
2041 on	0.5 (DTI extrapolation)

Table 9-16: *Trend of civil fleet EI(NO_x) in DTI projections.*

Year	**EI(NO_x)**
1992	11.1
2010	10.73
2020	10.43
2030	10.3
2040	9.5
2050	7.0

Table 9-17: *Results of DTI 2050 projections (military operations not included).*

Scenario	**Traffic (10^9 RPK)**	**Fuel (Tg)**	**NO_x (Tg NO_2)**	**EI(NO_x)**
DTI	18106	633.2	4.45	7.0

The DTI model relates air traffic demand in RPKs with regional and global economic performance as reflected in GDP trends, as was the case with the ANCAT/EC2 2015 forecast. Generally, a load factor of 70% is assumed to estimate ASKs (capacity) from traffic demand. Long-term traffic demand is also assumed to be modified by the same assumptions on fares pricing, market maturity, and so forth that the ANCAT/EC2 2015 forecast used. Capacity estimates are converted to fuel consumption estimates by using the concept of traffic efficiency as described in Section 9.3.2 and a fuel efficiency trend for the scenario period. Model coverage includes all global aviation markets, but separate fuel consumption estimates are made for freight and for the FSU on the basis of aligning growth with global civil passenger market trends.

The scenario modeled for 2050 assumes that sufficient aviation infrastructure would be available to accommodate the forecast increase in traffic. No new city pairs are introduced during the scenario period, and aircraft flight profiles remain unaltered from the present day; altitude, speed, and method of operation are assumed to be the same as present-day values, even for larger aircraft types (600+ seats) that are assumed to enter service beginning in about 2005. All traffic is assumed to be carried by a subsonic aircraft fleet (i.e., no HSCT would be operating by 2050). The model forecasts traffic growth to be positive throughout the scenario, but growth rate declines during the period. Decadal capacity growth rates-actual and forecast-are given in Table 9-14. The traffic forecast includes civil and freight operations as well as civil charter and business jet traffic but excludes military aviation activity and possible future supersonic operations.

Fuel usage was determined for the base year fleet from the capacity offered in that year (ASKs) and the fleet's traffic efficiency (ASK per kg fuel). A fuel efficiency trend suggested by Greene (1992) and modified by DTI was included as a scenario parameter, as given in Table 9-15.

Table 9-18: *Definition of regional economic groups in the EDF model.*

Group	Members
1	OECD members, except Japan
2	Asian newly industrialized countries (NICs), Japan
3	China and the rest of Asia
4	Africa, Latin America, Middle East
5	Former Soviet Union (FSU), Eastern Europe

The traffic efficiency of the fleet over the scenario period was estimated to range from 30 ASK kg^{-1} in the base year 1992 to 48 ASK kg^{-1} in 2050 (a 60% improvement). This estimate was based on the performance of existing aircraft types and forecasts of the type and number of aircraft (categorized by seat band and technology level) that might be flying in 2050. Future aircraft types included size developments to 799 seats.

A major scenario element was the NO_x reduction technology assumption. Current technology will allow engines to achieve reductions of around 30% below the current certification level (CAEP/2 standards). The basis of the technology scenario was that NO_x regulations would be made considerably more stringent than today and that the manufacturing industry would develop appropriate technology solutions. This development was modeled by assuming that from 1992:

- CAEP/2 certification standard applies to all new production from 2000
- 30% reduction in ICAO recommended limits from CAEP/2 in 2005
- 60% reduction from CAEP/2 phased in equally over 8 years from 2035.

With a fleet development trend determined by the capacity forecast, the rate of introduction of the scenario above implies a global fleet emissions index trend that is as compatible with the relatively modest fuel efficiency assumption given in Table 9-16. The fleet EI(NO_x) of 7.0 implies widespread use of ultra-low NO_x technology (Section 7.5). The total calculated fuel burned and emissions for 2050 under the DTI/ANCAT scenario are given in Table 9-17.

9.4.3. Environmental Defense Fund Long-Term Scenarios

EDF has produced projections of total traffic demand, fuel use, and emissions through 2100 (Vedantham and Oppenheimer, 1994, 1998). The EDF projections use a logistic model to simulate the stages of demand growth in aviation markets, focusing particularly on demand growth in developing countries (where aviation has only recently become a commonplace travel mode). Two sets of aviation demand scenarios-base-level and high-level-describe traffic under each of the six IPCC 1992 scenarios (IS92a through IS92f) for global expectations of gross national product (GNP), population, and emissions (Leggett et al., 1992). Data produced are regional and global totals.

The model logic incorporates the assumption (based on observation) that latent demand in a region previously not served by airlines will result in an initial period of rapid growth; once an airport network is in place, business and personal habits will incorporate the new transport option, causing a period of continuing strong growth rates. Barring unforeseen developments, the experience of some OECD nations suggests that aviation demand will eventually reach maturity, and relative growth rates will slow as the market approaches saturation. Continued growth of GNP and population imply continuing, albeit slow, growth in demand, even over the very long term.

EDF uses a logistic model with a time-varying capacity to model the dynamics in several sectors of rapid expansion, continued growth, and eventual slowdown in growth rates without imposing a zero growth-rate ceiling. Growth rates and market capacities for different regions of the world were chosen after a review of economic and aviation market history in industrial nations. The demand model is consistent with the history of the U.S. domestic market.The EDF model sorts the nations of the world into five economic groups (see Table 9-18). For each of the five economic groups, the three sectors of civil business passenger, civil personal passenger, and civil freight are modeled as logistics with time-varying market capacities. The civil business passenger and civil freight sectors experience logistic expansion toward a time-varying capacity level that is proportional to the nation's GNP.

The model assumes that expansion in business travel is accompanied by expansion in personal travel, which includes tourism and leisure visits.Personal travel by air has high income elasticity, and aviation demand will increase rapidly when a poor nation experiences an economic boom and per capita income increases. Depending on the income distribution, there can be significant demand for aviation even in countries with very low per capita incomes (Atkinson, 1975). As incomes rise and seat prices (as well as cargo costs) fall, growth in aviation demand will result from the penetration of aviation services into lower income brackets (Boeing, 1993). The civil personal passenger sector experiences logistic expansion toward a time-varying capacity level proportional to the nation's population (the model does not account for possible feedback relationships between GNP and population). The military and general aviation sectors do not experience logistic expansion; both sectors grow nominally, at the same rate as global GNP. The mathematical basis of the model and further details on the assumptions are given by Vedantham and Oppenheimer (1994, 1998).

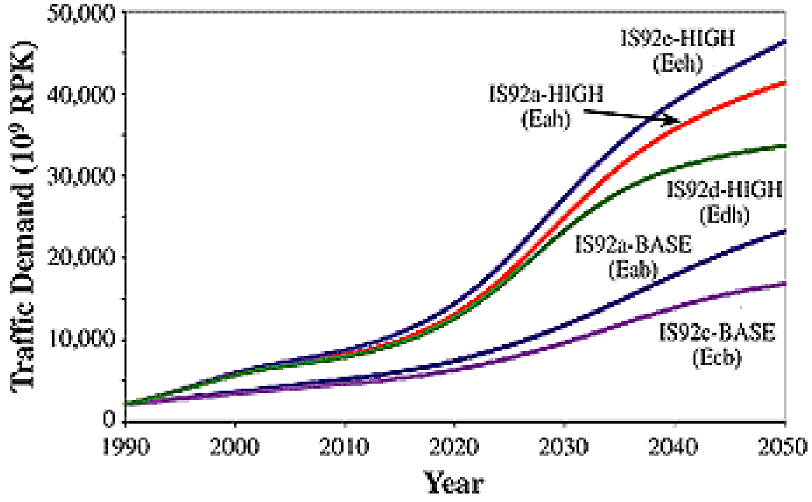

Figure 9-20: *EDF global aviation demand projections*.

The base-demand and high-demand sets include expected start date for market expansion, market capacity levels, and maturity period length. These assumptions for the two demand sets reflect implicit assumptions about diverse social factors, including travel trends in developing countries (Gould, 1996), penetration of future telecommunications technologies, and development of competing modes of transportation. Assumptions on start dates of aviation market expansion for rapidly developing economies, slowly developing economies, and post-Communist economies reflect EDF's own assessment of near-term economic expectations and were not made in relation to IPCC scenarios. Prior to the start date, demand is assumed to grow nominally, at the same rate as global GNP. The base-demand and high-demand sets include assumptions on market capacity levels based on multiples of 2 (base-demand) and 3 (high-demand) relative to the 1990 demand levels for Economic Group 1 (OECD less Japan), because these markets are closest to maturity today.

EDF's analysis of the history of the U.S. domestic market concluded that there was approximately a 70-year period from start of market expansion to maturity. The model assumes that nations that are building their airport infrastructure today may well attain market maturity faster because they will benefit from technological improvements and some fraction of their populace will be more familiar with lifestyle and business habits that incorporate aviation. Another region-specific assumption was that markets in the post-Communist economies may mature faster because they have undergone industrialization.

Table 9-19: *Excerpt of EDF results-demand, fuel use, CO_2, % of global CO_2, and NO_x.*

		Year				
IPCC Scenario	**Factor**	**1990**	**2000**	**2015**	**2025**	**2050**
IS92a Base (Eab)	Demand (10^9 RPK)	2,171	3,629	6,115	9,339	23,256
	Fuel Use (Tg)	179	258	374	544	1,143
	CO_2 (Tg C)	154	222	322	468	983
	Percentage of Global CO_2	2.1%	2.6%		3.8%	6.8%
	NO_x (Tg)	1.96	2.57	3.28	4.42	7.88

IS92a High (Eah)	Demand (10^9 RPK)	2,171	5,801	9,954	18,332	41,392
	Fuel Use (Tg)	179	395	610	1,123	2,086
	CO_2 (Tg C)	154	340	525	966	1794
	Percentage of Global CO_2	2.1%	4.1%		7.9%	12.4%
	NO_x (Tg)	1.96	3.92	5.34	9.12	14.39
IS92c Base (Ecb)	Demand (10^9 RPK)	2,171	3,447	5,337	7,802	16,762
	Fuel Use (Tg)	179	243	325	455	837
	CO_2 (Tg C)	154	209	280	391	720
	Percentage of Global CO_2	2.1%	2.8%		4.5%	9.6%
	NO_x (Tg)	1.96	2.42	2.85	3.70	5.77
IS92d High (Edh)	Demand (10^9 RPK)	2,171	5,729	9,647	17,619	33,655
	Fuel Use (Tg)	179	390	592	1,082	1,689
	CO_2 (Tg C)	154	336	510	932	1,453
	Percentage of Global CO_2	2.1%	4.5%		10.0%	16.2%
	NO_x (Tg)	1.96	3.88	5.19	8.79	11.64
IS92e High (Eeh)	Demand (10^9 RPK)	2,171	5,964	10,850	20,202	46,362
	Fuel Use (Tg)	179	408	668	1,234	2,297
	CO_2 (Tg C)	154	351	574	1,061	1,975
	Percentage of Global CO_2	2.1%	3.9%		7.0%	9.8%
	NO_x (Tg)	1.96	4.05	5.85	10.02	15.84

The six IPCC scenarios for GNP and population, combined with the two demand sets described above, provide a total of 10 demand projections (because the IS92a and IS92b scenarios share the same GNP and population expectations). Figure 9-20 shows five of the global demand scenarios; sharp upswings when different regions start expansion are clearly visible. Annotations attached to the curves are shorthand nomenclatures for the scenarios used in this report.

Under the IS92a scenario (the IPCC base case), the base-demand level in 2050 is higher than the 1990 level by a factor of 10.7 and has an average annual demand growth rate of 4.03% over the 60-year forecast period (forecasts to 2100 are given by Vedantham and Oppenheimer, 1998). For the base-demand set, the range of traffic demand expected for different population and GNP estimates spans a factor of almost 5 in 2050; the full range across all 10 scenarios spans a factor of more than 20. Assumptions about rates of expansion and maturity have a sizable impact: The high-demand projection for the IS92a scenario in 2050 is 78% higher than the base-demand value.

The 10 demand scenarios produced by the EDF model are synthesized with expectations for fuel efficiency improvement and changes in emissions indices to produce fuel use, CO_2 emissions, and NO_x emissions scenarios.

Although fuel efficiency has increased steadily over the past few decades, improvements in fuel efficiency are becoming less dramatic over time. The technology projections of the EDF model use a constant-capacity logistic that extrapolates Greene's (1992) forecast for a base-case annual increase of 1.3% in fleet-wide fuel efficiency from 1989 to 2010. Significant differences in fuel efficiency exist today across regions, and there may be a tendency toward higher fuel efficiency in wealth ier regions. The EDF model assumes differences in fuel efficiency across economic groups and builds projections on the assumption that the technology gap between wealthier and poorer nations will close over time.

The NO_x emissions scenarios reflect changes in EI(NO_x) based on a constant-capacity logistic that extrapolates a best-fit approximation to the 1993 NASA numbers for EI(NO_x) in 1990 and 2015 (Stolarski and Wesoky, 1993). The model does not reflect specific technology choices for fuel efficiency or changes in EI(NO_x), although the fleet EI(NO_x) of 6.9 that results from the extrapolation is in the ultra-low technology regime. Results for all scenarios are summarized in Table 9-19.

Figure 9-21 shows CO_2 emissions scenarios [which assume a constant EICO_2) of 3.16]. Under the base IS92a scenario, CO_2 emissions grow at an annual rate of 3.2% to reach 983 Tg C in 2050-an increase of a factor of 6.6. For all scenarios, projected CO_2 emissions climb rapidly after 2015. For the IS92c scenario (which reflects low population and GNP growth) under both demand sets, the level of CO_2 emissions in 2100 is lower than that in 2050, reflecting a successful catch-up effect whereby technological improvements have compensated for demand growth (Vedantham and Oppenheimer, 1998). Comparing the EDF scenarios for aviation's CO_2 emissions projections with the IPCC scenarios for total anthropogenic CO_2 emissions (including emissions from energy consumption and deforestation) provides a benchmark measure of the environmental importance of the aviation sector. For the base-demand

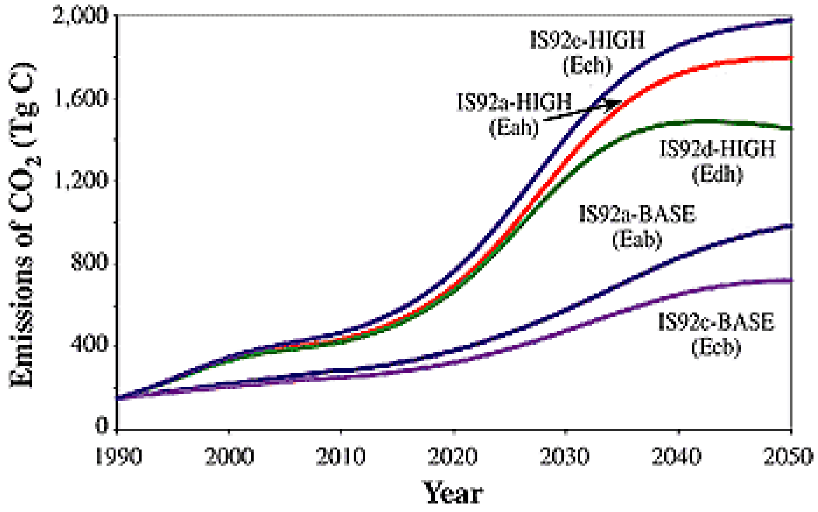

Figure 9-21: *EDF CO_2 emissions projections.*

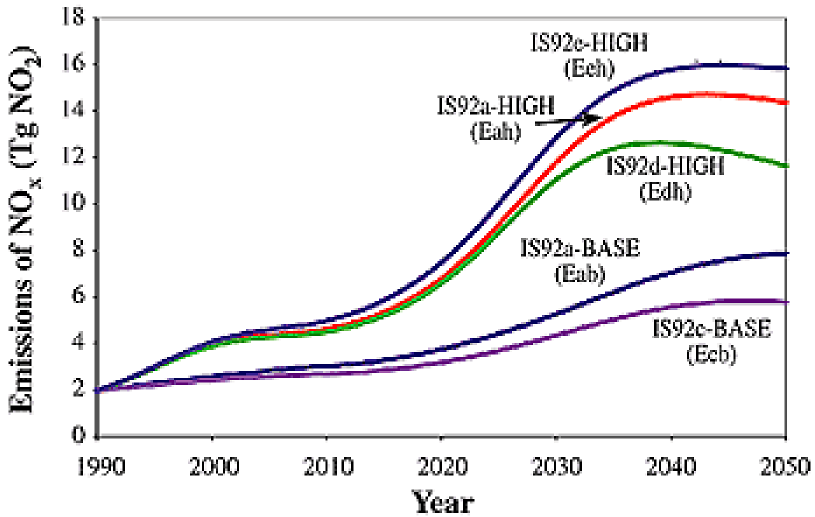

Figure 9-22: *EDF NO_x emissions projections.*

IS92a scenario, aviation's share of global CO_2 emissions rises from its current value of 2.1% to a level of 3.8% in 2025 and 6.8% in 2050. Across all scenarios, aviation's share of global CO_2 emissions ranges between 3.3 and 10% in 2025 and between 5.6 and 17.6% in 2050. These scenarios imply that aviation may become a significant contributor to global CO_2 emissions.

Figure 9-22 shows the NO_x emissions scenarios; these scenarios incorporate the effects of fuel efficiency improvements as well as changes in EI(NO_x). For the base-demand IS92a scenario, NO_x emissions rise sharply from almost 2 Tg (as NO_2) in 1990 to 7.9 Tg in 2050. Because total NO_x emissions are reduced as a result of fuel efficiency improvements and EI(NO_x) reduction, technological improvement can compensate for a greater fraction of demand growth than in the case of CO_2 emissions.

Table 9-19 presents an excerpt of EDF model results of traffic demand, fuel burned, and emissions of CO_2 and NO_x through the year 2050 for the several sets of assumptions. The three-letter designators for the EDF scenarios (e.g., Eab, Eeh) are used throughout this report.

9.4.4. World Wide Fund for Nature Long-Term Scenario

Table 9-20: *Results of MIT reference scenario-passenger travel and carbon emissions.*

	1990 (10^{12} pkm[a])	2050 (10^{12} pkm[a])	1990 (10^{12} mt C)	2050 (10^{12} mt C)
Industrialized				
High-Speed	1.5	32.7	32.7	0.66
Total	12.4	44.4	0.52	1.12
Reforming				
High-Speed	0.3	2.1	0.02	0.04
Total	2.3	7.1	0.07	0.20
Developing				
High-Speed	0.4	7.2	0.02	0.14
Total	8.6	53.8	0.18	1.29
World				
High-Speed	2.2	42.0	0.13	0.84
Total	23.3	105.3	0.77	2.61

Source: *Schafer and Victor (1997); additional data supplied by David Victor (June 1998).*
apkm=passenger kilometers.

A study by WWF addresses future aviation demand by analyzing load factors and capacity constraints, particularly in the freight market (Barrett, 1994). Analysis of historical data shows that increases in the number of seats per aircraft have begun to level off. The study examines the effects of pollution control strategies such as phasing out of air freight and policies to encourage intermodal shifts to road and rail. Technological options for reducing the environmental impact of aviation (such as operational improvements, changes in cruise altitude and alternative fuel sources) are examined. In particular, these models consider the feasibility that increases in load factors (percentage of total passenger seats that are occupied) could increase fuel efficiency per seat-km for aviation. The model evaluates a wide range of policy and operational choices, including a 100% load factor and a 100% fuel tax.

The model includes explicit assumptions of fixed growth rates in leisure travel, business travel, average trip length for passenger and freight traffic, and freight tonnage. It assumes that passenger load factors rise to 75% by 2020 in the base case. Constant rates of improvement are assumed for aircraft size, airframe efficiency, and EI(NO_x).

With an annual growth rate of 5.2%, demand rises by a factor of more than 12 between 1991 and 2041 in the "business-as-usual" case. Proposed policies, including changes in load factor, and technological improvements result in a forecast for demand increase of about a factor of 3 in the "demand management" case. Carbon emissions in 2041 constitute 550 Tg C, and aviation's share of global carbon emissions rises to 15% by 2041.

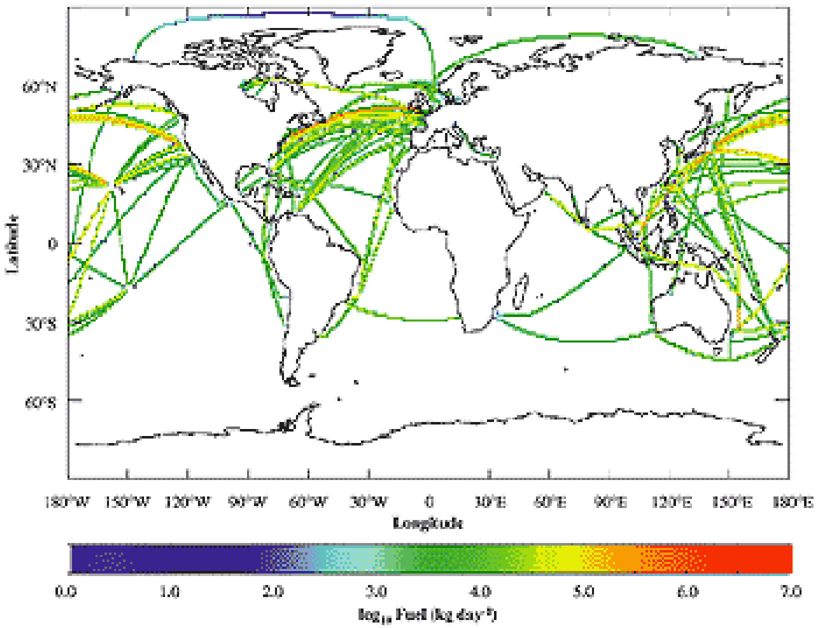

Figure 9-23: *Flight tracks above 13-km altitude for a fleet of 500 high-speed civil transports (Baughcum and Henderson, 1998).*

9.4.5. Massachusetts Institute of Technology Long-Term Scenarios

A study of the long-term future mobility of the world population has been undertaken at MIT. This study constructed scenarios based on the simple yet powerful assumption that time spent and share of expenditures on travel remain constant (Zahavi, 1981), on average, over time and across regions of the globe (Schafer and Victor, 1997). Stability of average time budgets for travel (motorized and nonmotorized) is substantiated by a considerable amount of aggregate historical data. Although there is some variability in travel budgets from poorer to richer nations, within each society travel budgets have generally followed a predictable pattern-rising with income and motorization and stabilizing at 10-15%.

Using the constant travel budget hypothesis, Schafer and Victor (1997) produced global passenger mobility scenarios for 11 world regions and four transport modes for the period 1990-2050. Adding estimates of changes in the energy intensity of transportation modes, they also generated scenarios of CO_2 emissions from passenger transport (see Table 9-20).

The high-speed travel category includes aviation, but the aviation portion of high-speed travel is not explicitly characterized. Results of this model projection therefore cannot be used directly in evaluations of the effect of aviation on the atmosphere, nor can they be directly compared to other long-term projections of emissions from aviation.

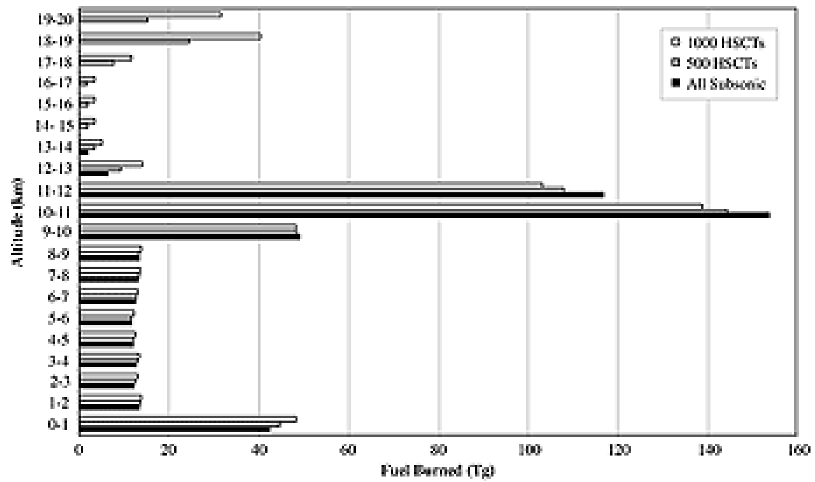

Figure 9-24: *Altitude distribution of fuel burned-with and without HSCT fleet-based on IS92a scenario (Fa1,2).*

Table 9-21: Results of substitution of 1,000-unit parametric HSCT fleet in 2050.

Scenario	**Fuel (Tg)**	**CO_2 (Tg as C)**	**% Change (Fuel)**	**NO_x (Tg as NO_2)**	**% Change (NO_x)**	**Fleet EI (NO_x)**
Fa1-All Subsonic	471	405	Base	7.2	Base	15.2
Fa1H-With 1,000 active HSCTs	557	479	+18	7.0	-2	12.6
Fe1-All Subsonic	744	641	Base	11.4	Base	15.3
Fe1H-With 1,000 active HSCTs	831	715	+12	11.3	-1	13.6

9.5. High-Speed Civil Transport (HSCT) Scenarios

The technology for commercial (supersonic) HSCT is being developed in the United States, Europe, and Japan. The goal is to develop an aircraft that can carry approximately 300 passengers, with a 9,260-km range, cruising at Mach 2.0-2.4 at altitudes of 18-20 km. As described in Chapter 7, NASA has an aggressive technology program to develop combustors with NO_x emission levels of 5 g NO_x (as NO_2) per kg fuel burned at supersonic cruise conditions. The HSCT is expected to fly supersonically only over water because of the need to mitigate sonic booms over populated land masses. The potential market for the HSCT is limited by economic and environmental considerations.

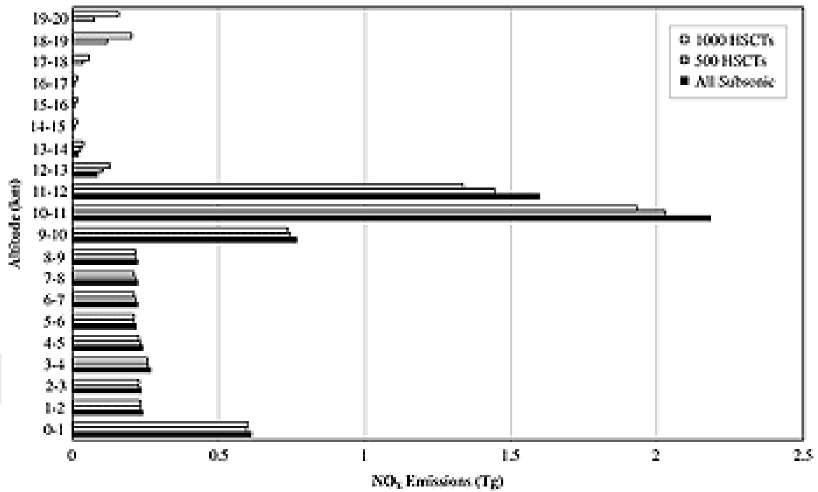

Figure 9-25: *Altitude distribution of NO_x emissions-with and without HSCT fleet-based on IS92a scenario (Fa1, FaH).*

9.5.1. Description of Methods

3-D emissions inventories of fuel burned, NO_x, CO, and unburned HC for fleets of 500 and 1,000 active (high utilization) HSCTs have been developed based on market penetration models and forecasts of air traffic in 2015 (Baughcum et al., 1994; Baughcum and Henderson, 1995, 1998). Although such large fleets clearly will not be in operation by 2015, the year was chosen as a base year because detailed industry projections of air traffic on a route-by-route basis are available only to that time period. Although the introduction of an economical HSCT may stimulate total traffic growth by an unknown amount, the HSCT will certainly displace some traffic from the subsonic fleet on major long-range intercontinental routes. For this study, possible stimulative effects were ignored to reduce the number of variables, and HSCT-generated RPKs were explicitly substituted for subsonic RPKs on a route-by-route basis.

The most recent set of scenarios based on the NASA technology concept aircraft (TCA) HSCT were used for most of the atmospheric impact calculations presented in Chapter 4. It is not clear when HSCT technology will be mature enough for viable commercial service, so fleet sizes and technology levels are treated parametrically. The projected flight tracks for a fleet of 500 HSCTs above 13-km altitude are shown in Figure 9-23. Because of its speed advantage over subsonic aircraft, the HSCT would likely be used primarily on long intercontinental routes, where that advantage can best be utilized. Because of the sonic boom that trails below the aircraft, the best HSCT routes have a large portion of the flight path over water. These conditions combine to put a majority of HSCT routes at northern mid-latitudes over the North Atlantic and North Pacific.

To project the HSCT fleets and their displacement of subsonic aircraft in the scenarios to 2050, the following procedure was used:

1. 3-D displacement scenarios of subsonic traffic by a fleet of 1,000 active HSCTs was calculated for the year 2015 using differences in the 3-D scenarios calculated for the NASA all-subsonic fleet (Baughcum et al., 1998) and the NASA subsonic fleet in the presence of an HSCT fleet (Baughcum and Henderson, 1998).
2. This subsonic displacement scenario was then scaled for the technology growth factors described in the discussion of the FESG scenario and combined with the HSCT only-scenario (assuming the TCA technology level) and 2050 all-subsonic scenarios.

The 1,000-unit fleet should not be considered a forecast of the actual number of HSCTs that might be in the fleet in 2050. For this sensitivity study, the 1,000-unit value was chosen to represent a fleet that would be the result of a successful HSCT program; this fleet size also was chosen so that previous fleet projections could be used (Baughcum and Henderson, 1998). No changes in fuel efficiency or NO_x emissions technology relative to the assumptions used in the reference were assumed for the 2050 HSCT. A detailed description of the route system flown by the 1,000 HSCTs is given by Baughcum and Henderson (1998).

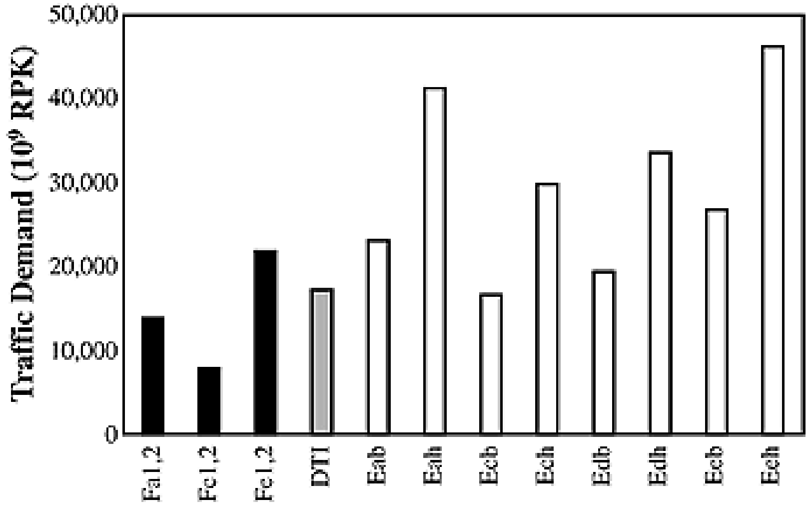

Figure 9-26: *Comparison of traffic demand in 2050.*

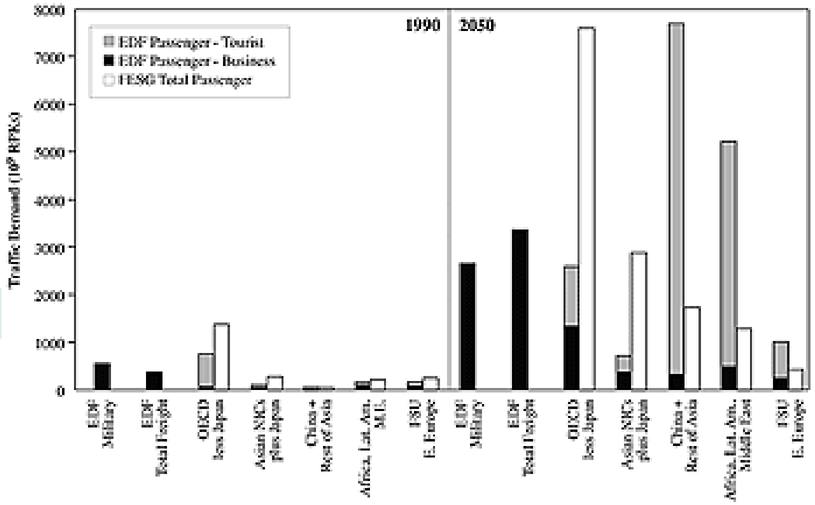

Figure 9-27: *Comparison of 1990 and 2050 regional demand values based on EDF and FESG models (IS92a scenario).*

9.5.2. Description of Results

Fleet fuel burned with the HSCT was calculated by assuming that the fuel efficiency and NO_x emissions of the subsonic fleet were described by NO_x technology scenario 1, the "fuel efficiency" scenario. Table 9-21 gives the total fleet fuel burned and NO_x emissions with and without the assumed 1,000-unit HSCT fleet. Fleet fuel burned increases as a result of the substitution of less fuel efficient HSCTs for subsonic airplanes (present HSCT designs have about half the fuel efficiency, measured as RPK per fuel burned, of present subsonic airplanes). However, fleet NO_x emissions decrease in spite of the increase in fuel burned because the HSCT is assumed to be designed for very low NO_x emissions [cruise EI(NO_x) of 5].

A comparison of the altitudinal distributions of fuel use and NO_x emissions between the all-subsonic fleet and a fleet containing subsonic and HSCT aircraft is shown in Figures 9-24 and 9-25 for the FESG year 2050 IS92a scenario. The introduction of an HSCT fleet with EI(NO_x)=5 combustors would be expected to increase emissions above 12-km altitude and lead to a decrease of NO_x emissions below 12, particularly in the 10-12 km band, assuming that the introduction of an HSCT will cause a displacement of subsonic traffic.

Table 9-22: *Comparison of FESG and EDF model results for year 2050 based on IS92a.*

Region	1990 % World GNP	1990 % World Population	1990 FESG % Demand	1990 EDF % Demand	2050 % World GNP	2050 % World Population	2050 FESG % Demand	2050 EDF % Demand
1) OECD, less Japan	57	12	63	62	45	8	55	15
2) Asian NICs + Japan	16	3	13	5	13	2	21	4
3) China, Rest of Asia	6	52	2	5	15	49	12	45
4) Africa, Latin America, Middle East	9	25	10	14	18	37	9	30
5) FSU, Eastern Europe	12	7	11	14	9	5	3	6

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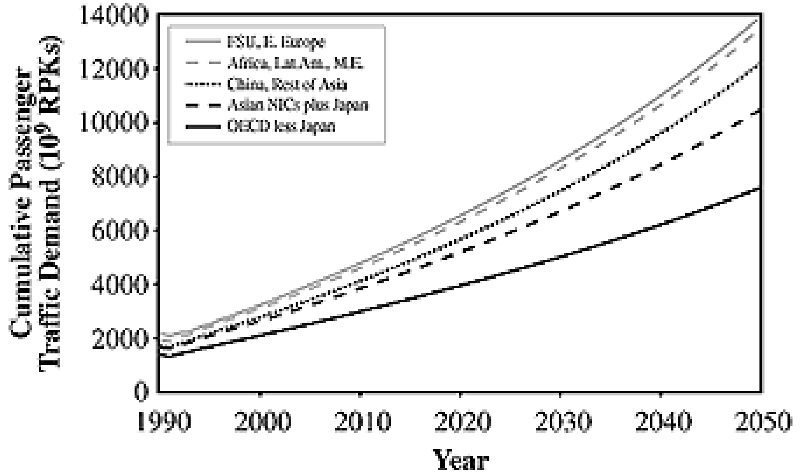
9.6. Evaluation and Assessment of Long-Term Subsonic Scenarios

9.6.1. Difficulties in Constructing Long-Term Scenarios

Long-term (beyond 20 years) projections of aviation traffic demand, fleet fuel burned, and fleet emissions are inevitably speculative. Difficulty in forecasting technological developments that might be appropriate for the long term, possible shifts in traffic demand, and myriad uncertainties resulting from human society's development over the period in question all conspire to make long-term projections unreliable-sometimes astoundingly so. Given the state of the aviation industry 50 years ago (in 1947), it is doubtful that either the technology or the scope of the industry in 1997 could have been forecast. However, because the transport aviation market and aviation technology seem to be maturing, a plausible way of making projections far into the future is to make reasonable extrapolations based on our knowledge of present trends in the world and in the aviation industry. These extrapolations are termed scenarios, rather than forecasts, as outlined in Section 9.1.

9.6.2. Structure and Assumptions



Before we review the outcomes of the scenario studies in the following section, we consider some differences and similarities between the models. This comparison is restricted to the EDF, DTI, and FESG models. Although the MIT model provides an interesting insight into future travel options based on the thesis of invariant travel time and travel expenditure budgets, it is excluded from this comparison because it provides only a highly aggregated scenario for the future mobility of total motorized passenger traffic; air traffic is only one-albeit important-portion of this picture, and the aircraft component cannot be identified. The WWF aviation scenario for 2041 provides aggregated fuel burned and CO_2 emissions projections but does not provide regionally distributed NO_x emissions estimates.

Of the long-term scenarios considered, the EDF, FESG, and DTI studies allow assessment of the impacts of CO_2 from aviation. However, only the results from the DTI and the FESG models are suitable for use in chemical transport models for modeling other emissions (see Chapters 2 and 4) and their effects on radiative forcing (see Chapter 6) because they provide gridded data that include a consideration of the potential changes in the spatial distribution of emissions. Only the EDF study provides scenarios for demand from the aviation sector and subsequent global CO_2 and NO_x emissions to 2100. The EDF study provided 10 scenarios based on five different IPCC IS92 world scenarios for the long-term development of world economy and population and two air traffic demand scenarios (base case and high case). The FESG study calculated three air traffic demand scenarios based on the IPCC IS92a, IS92c, and IS92e world scenarios, which were combined with two engine technology scenarios to produce six different emissions inventories. The FESG scenarios of regional and global air traffic were based on a logistic regression model of traffic demand since 1960 using global GDP as a predictor. The FESG model used a combination of top-down and bottom-up approaches, in which global volumes of civil aircraft flight kilometers were predicted using the regression model for different GDP scenarios. All available information on regions, including regional variation in growth, was then used to disaggregate these global values in a consistent way over 45 traffic flows within and between the regions of the world by using a market share allocation model. Year 2050 values of fuel burned and NO_x emissions for military traffic were estimated separately.

Figure 9-28: *Cumulative traffic demand (IS92a scenario, Fa1,2).*

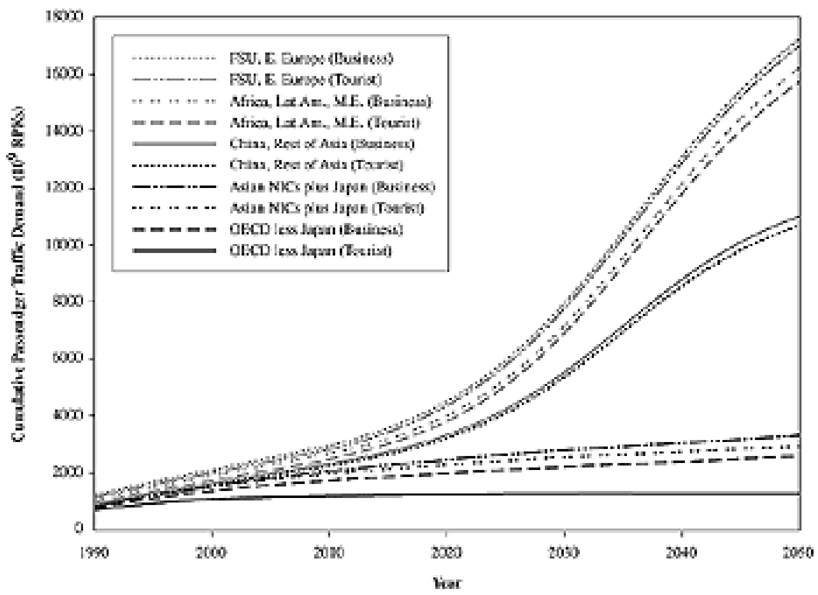


Figure 9-29: *Distribution of passenger demand (IS92a scenario, Eab).*

The EDF scenarios also were based on the use of logistic growth curves to model air traffic growth for business and personal travel (plus military and freight traffic). Model parameters were chosen through observation of historical traffic trends in the United States. Regional population was used as a predictor of personal passenger travel, and regional GNP was used as a predictor of business passenger travel and freight demand. Both the FESG and EDF models incorporate the underlying assumption that the chosen parameters are satisfactory predictors of aviation demand and that aviation markets eventually mature.

There are large differences between the EDF and FESG models with respect to the development of emissions scenarios. The EDF model uses a constant capacity logistic to describe fuel efficiency improvements, which extrapolates Greene's (1992) forecast to 2010 with varied rates for five geographic world regions and the military/freight aviation sector. For the trend in fleet EI(NO_x) a single global logistic model extrapolates from the 1990 and 2015 values. The FESG scenarios are based on two engine technology scenarios developed by ICCAIA for ICAO/FESG and IPCC (see Chapter 7). These scenarios represent an industry perspective on likely future developments in fuel efficiency and NO_x reduction technologies, as well as further potentials and limitations. The fuel efficiency technology element of the DTI scenario was similar in this respect, but a NO_x technology scenario appropriate to stricter emissions regulations was assumed, in which subsonic engine research programs would deliver emissions levels similar to those targeted in the NASA HSCT program.

Additional assumptions are also important to the results of the scenario models. In the EDF model, assumptions about the dates of market expansion and maturity and the ultimate capacity levels chosen for the economic regions strongly influence the outcomes. The EDF, FESG, and DTI models all use statistics of traffic/air traffic from international organizations and OECD countries, as well as numerous other recently published sources, and adopt one or more of the IPCC IS92 scenarios to describe the long-term development of worldwide economic growth and population. The FESG, EDF, and DTI models also use information from the NASA and ANCAT/EC gridded inventories of traffic flows and related emissions. The FESG models used new, partly proprietary, information from industry as a base to project emissions in the year 2050.

None of the 3-D gridded inventories for 2050 assume any changes in design that would alter the cruise altitudes of subsonic aircraft. Furthermore, no consideration was given in any of the 2050 scenarios reported here to the possible stimulative (or otherwise) effect of HSCT introductions on traffic.

Table 9-23: *Comparison of fleet EI(NO_X) from technology projections to 2050.*

Scenario	**Fleet EI(NO_X)**
Fa1	15.5
Fa2	11.5
DTI	7.0
Eab	6.9

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9.6.3. Traffic Demand

Total traffic demand projected for the year 2050 for three of the long-range scenarios is shown in Figure 9-26. The values shown for the FESG model projection do not include military or general aviation traffic. Military and general aviation fuel burned and emissions were estimated separately for the year 2050; they were 3.1 and 1.8% of total fuel burned, respectively (Fa1,2). The demand values shown for the EDF model include military as well as freight demand, with projected billion tonne-km values converted to RPK. The DTI model includes passenger, freight, and business jet traffic but excludes military operations. The WWF model includes passenger and freight only, but a demand value for 2041 was not published.

Although the FESG and EDF models use the same IS92 economic scenarios (IS92 population scenarios also are inputs to the EDF model), the traffic demand projections for 2050 from the EDF model are higher than those of the FESG model by a factor of 1.2 to almost 4, depending on the scenario. The DTI model, which does not directly depend on the IS92 scenarios, projects a traffic demand about 80% that of the FESG high case (Fe1,2). Clues to the reasons behind the large differences in projected traffic demand between the FESG and EDF models can be found by examining the details of the results of each model. The EDF model projects passenger business and personal traffic in five world regions, plus military and freight traffic. To make comparisons between the two models, the 45 traffic demand flows (allocated from the global growth projection) in the FESG model were assigned to the five regions used in the EDF model. Demand flows between two of the EDF-defined regions were allocated by assigning 50% of the FESG traffic demand to each region.

On the previous page, Figure 9-27 shows a comparison of traffic demand in 1990 and 2050 from the FESG and EDF models, with demand sorted by region and/or type. The EDF base case demand (Eab) is compared with the Fa1,2 demand scenario. Large differences in the distribution of demand between the two models are apparent: The FESG model assigns the largest share of passenger traffic in 2050 to the OECD area, whereas the EDF model assigns the largest share to the China-Africa area (with personal travel making up the bulk of the demand).

Table 9-22 provides data on passenger demand from the EDF and FESG models by region in 1990 and 2050 and regional distribution of world GNP and population over the same time periods. The basis of both models in this comparison is the IS92a GNP and population scenario. In 1990, the demand distributions of both models are roughly the same and reflect to a great extent the regional distribution of GNP. In 2050, the regional demand distribution from the FESG model reflects the shift in GNP distribution, demonstrating the economics-driven basis of the FESG model. The 2050 FESG values also show that the market share tool has probably underestimated the share of demand in region 4; percentage of GNP has increased from 1990 to 2050, but percentage of demand has decreased.

In contrast, the 2050 demand distribution from the EDF model differs greatly from the distribution of GNP in 2050 and reflects the population-driven basis of much of the EDF model.

The differences between the FESG and EDF models are further illustrated in Figures 9-28 and 9-29, which show the cumulative distribution of traffic growth over time for the IS92a scenario. Figure 9-28 shows the growth and regional proportions of traffic demand as projected by the FESG model. The shares of demand reflect the GDP of each region. Figure 9-29 shows the cumulative distribution of demand for the five regions as projected by the EDF model. The EDF model, unlike the FESG model, projects

business and personal passenger demand separately (business demand is a function of GNP; personal demand is a function of population); both sectors of demand are shown in the figure. Notable is the lack of projected growth in personal demand in region 1 (OECD less Japan). Driven by projected slow growth and eventual decline in OECD population, demand growth in this sector is projected to be less than 1% per year after 2005 and negative after 2035. Notable also is the relative lack of growth projected for region 2 (Asian newly industrialized countries + Japan). The effect of the population-driven personal demand sector is shown by the rapid growth in regions 3 (China + rest of Asia) and 4 (Africa, Latin America, Middle East). Personal demand in these two regions is projected by the EDF model to grow at rates exceeding 12% per year for 25 years (region 3) and 10% per year for 20 years (region 4) to create 75% of total passenger demand in 2050 (up from 19% in 1990). This value contrasts with the 21% of total passenger demand projected for these two regions in the FESG model, based on the two regions' 33% share of GNP.

9.6.4. NO_x Technology Projections

A list of NO_x emissions index projections is given in Table 9-23 for the three long-term models (IS92a scenarios).

The fleet $EI(NO_x)$ in 1992 was calculated as 12.0 (NASA), 13.8 (ANCAT/EC2), and 13.9 (DLR).

Expectations for the development of NO_x technology are quite different among the models. The two FESG model NO_x technology estimates were based on ICCAIA technology projections for new aircraft (Sutkus, 1997) and estimates of how quickly such new technology would enter the fleet (Greene and Meisenheimer, 997). The assumptions in the DTI model were that regulatory pressures would require reductions in NO_x emissions, and the fleet emissions index would be forced down as the engine industry responded with specific technology developments through 2035. These developments assumed the introduction of emission control technology that would produce engine emissions indices appropriate to those anticipated for staged combustor and ultra-low NO_x combustor technology-the latter of the type being developed for HSCT applications [$EI(NO_x)$ =5]. Ultra-low NO_x technology concepts now being developed may not be suitable for future high pressure ratio subsonic engine designs, so achieving fleet NO_x emission levels assumed in the DTI and EDF models may be very difficult (see Section 7.5).

The EDF model used a logistic extrapolation of NO_x trends from NASA work (Stolarski and Wesoky, 1993), but no changes in technology were explicitly specified.

Table 9-24: *Projected traffic and size of global fleet.*

Traffic (RPK x 10[9]) and Global Flee			
Scenario	Year 1990 (*1995)	Year 2050	Fleet[a])
Eab	2,171	23,256	35,000
Eeh	2,171	46,362	69,000
Fa1,2	2,536*	13,934	21,000
Fc1,2	2,536*	7,800	15,000
DTI	2,553	18,106	30,000

[a]*Passenger fleet rounded to nearest 1000.*

Table 9-25: *Effect of freighter fleet on 2050 total fleet size*

Sector	**Current Fleet**	**2050 Fleet** Lowest Growth	**Forecast**[a] Highest Growth
Passenger	10,000	5,000 (Fc1,2)	69,000 (Eeh)
Freighter	1,347	8,000 (2.5% growth)	19,000 (5.1% growth)
Total Fleet	11,347	23,000	88,000

[a]*Rounded to nearest 1000*

Table 9-26: *Number of new airports required to accommodate year 2050 fleet.*

	New Airports Required (Lowest Growth Case - Passenger Fleet)			**New Airports Required (Highest Growth Case - Passenger Fleet)**		
Present Airport Inventory	10 gates/airport	15 gates/airport	20 gates/airport	10 gates/airport	15 gates/airport	20 gates/airport
1,490[a]	103	0	0	3,026	1,779	1,155
3,750[b]	0	0	0	1,941	6,94	70
	New Airports Required (Lowest Growth Case - Total Fleet)			**New Airports Required (Highest Growth Case - Total Fleet)**		

Present Airport Inventory	10 gates/airport	15 gates/airport	20 gates/airport	10 gates/airport	15 gates/airport	20 gates/airport
1,490[a]	521	0	0	4,041	2,455	1,663
3,750[b]	0	0	0	2,956	1,371	578

[a]*Now having 1 or more jet departure/day.*
[b]*All airports in OAG.*

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9.6.5. Infrastructure and Fuel Availability Assumptions

All of the long-term scenarios reviewed in this chapter were developed with the implicit assumption that sufficient system infrastructure and capacity will be available to handle the demand in an unconstrained fashion (infrastructure and capacity are defined for airports as runways, terminals, gates and aprons, roads, etc., and for airways as air navigation services, air traffic control, etc.). However, lack of infrastructure development may well impede future aviation growth. Lack of infrastructure will result in congestion and delay, additional fuel burn (in the air and on the ground), higher operating costs, higher ticket prices, and reduced service.

In some parts of the world, particularly in North America and Europe, the airway and airports system is currently operating under constraints that limit its ability to provide service. These constraints are likely to become more acute in the future as the demand for aviation services continues to grow. Congestion resulting from capacity constraints impairs the economic and environmental performance of airlines and the entire aviation system. To accommodate future demand, physical and technological infrastructure must be upgraded and expanded. In many areas, however, strong local pressures (especially related to noise created by aircraft movements) have constrained development of new airports and capacity improvements at existing airports. It is therefore important to note that the traffic forecasts reviewed in this chapter are all unconstrained forecasts that do not evaluate system capacity constraints when estimating future traffic growth.

Aviation also depends on petroleum fuels. For the past 50 years, known reserves of petroleum have continued to expand to satisfy 20-30 years of predicted demand. Over the short-term future, little change in the demand/supply situation is expected. Oil companies predict continued supply of their raw material, and kerosene supplies should have similar availability as the present day. Despite the forecast for increasing demand, oil prices are projected to rise only moderately over the next 20 years (Hutzler and Andersen, 1997).

Over the period of these scenarios (to 2050), estimates of availability are less clear, but there is a general view that the oil industry will continue to meet demand (Rogner, 1997). There are, however, less optimistic views for oil production, with some predictions of a production decline occurring within the next decade (Campbell and Laherrere, 1998). The long-term scenarios assessed for this report implicitly assume continued availability of fuel at moderate prices. This is a key assumption for all scenarios because large increases in the price of fuel and/or shortages in supply would act to restrain demand for passenger and cargo air transport.

All of the scenarios ignore (in their baseline assumptions) possible changes in service patterns or infrastructure that a future HSCT might require. The effects of an HSCT fleet are considered in Section 9.5.

Table 9-27: *Required yearly delivery rates of aircraft implied by scenarios.*

	Total Aircraft Deliveries (in these years)			
Year	Eab	Eeh	Fa1,2	DTI
2020	1,106	1,667	813	1,012
2030	1,072	1,933	686	945
2040	1,566	3,058	931	1,354
2050	1,714	3,831	948	1,440

9.6.6. Plausibility Checks

Although none of the long-term scenarios reviewed here is considered impossible, some may be more plausible than others. We devised three simple checks to assess plausibility. The first estimated the fleet size required to carry projected traffic in 2050; the second examined implications for airport and infrastructure; and the third examined implications for kerosene demand. These plausibility checks represent an initial examination of the implications of the scenarios and are intended to illustrate possible consequences of traffic estimates resulting from the different scenarios. It must be emphasized that the fleet numbers produced by this analysis are approximate and are provided for comparative purposes only.

9.6.6.1. Fleet Size

Table 9-28: *Sensitivity of fleet size to aircraft capacity.*

Aircraft Size	**Fleet at 2050 - Total Aircraft**	
Growth Assumption	1% yr^{-1}	2% yr^{-1}
Eeh scenario	69,275	42,448
Fa1,2 scenario	21,209	11,913

Table 9-29: *Summary data from long-term scenarios.*

Scenario	**Scenario**	**Traffic Demand**	**Calculated Fuel Burned**	**Calculated CO_2 (as C)**	**Calculated NO_x (as NO_2)**	**Calculated Fleet $EI(NO_x)$**

Year	Name	(10^9 RPK)	(Tg yr^{-1})	(Tg yr^{-1})	(Tg yr^{-1})	(g NO_2/kg fuel)
2041	WWF	n/a	639.5[a]	550.0	n/a	n/a
2050	Fa1	13,934	471.0	405.1	7.2	15.2
2050	Fa1H	13,934	557.0	479.0	7.0	12.6
2050	Fa2	13,934	487.6	419.4	5.5	11.4
2050	Fc1	7,817	268.2	230.6	4.0	15.0
2050	Fc2	7,817	277.2	238.4	3.1	11.3
2050	Fe1	21,978	744.3	640.1	11.4	15.3
2050	Fe1H	21,978	831.0	714.7	11.3	13.6
2050	Fe2	21,978	772.1	664.0	8.8	11.4
2050	Eab	23,257	1,143.0	983.0	7.9	6.9
2050	Eah	41,392	2,086.0	1,794.0	14.4	6.9
2050	Ecb	16,762	837.0	720.0	5.8	6.9
2050	Ech	29,934	1,528.0	1,314.1	10.5	6.9
2050	Edb	19,555	959.0	824.8	6.6	6.9
2050	Edh	33,655	1,689.4	1,452.8	11.6	6.9
2050	Eeb	26,886	1,298.0	1,116.3	9.0	6.9
2050	Eeh	46,363	2,297.0	1,975.4	15.8	6.9
2050	DTI	18,106	633.2	544.6	4.5	7.0
2050	MIT	n/a[b]	977.0[a]	840.0[b]	n/a	n/a

[a]*Fuel burned calculated from published CO_2 data.*

[b]*Contains unspecified fraction from high-speed rail.*

The fleet sizes implied by five of the scenarios were determined from the DTI traffic and fleet forecast model (see Section 9.3.2), which was developed primarily to project demand for new aircraft implied by 25-year traffic forecasts. The DTI model requires an annual traffic growth rate as an input; for this assessment purpose, this value was assumed to be a constant annual rate calculated from the base year traffic and the model's projection for 2050. The model assumes the fleet to comprise a range of jet aircraft types, described by seat capacity as follows: 80-99, 100-124, 125-159, 160-199, 200-249, 250-314, 315-399, 400-499, 500-624, and 625-799. The larger aircraft sizes have yet to be produced but are assumed to enter service beginning about 2005. Regional variations in fleet composition are reflected in the global fleet, based on current trends. This analysis does not capture the effects of compositional change that could be created as new markets develop. Average aircraft size growth is assumed (reflecting the historical trend of greater seating capacity for individual aircraft types over time). The future fleet required to satisfy the scenario demand estimates is derived through an iterative process by matching capacity to traffic demand, based on assumptions regarding aircraft unit productivity in capacity terms. Other model assumptions are as follows:

- Subsonic aircraft supply-projected demand (no supersonics)
- A short- and long-haul market share
- Future market functions as does the present day (i.e., no assumptions regarding wider deregulation are made)
- Unconstrained demand
- Aircraft retired at an average age of 25 years (reduced productivity from 20-30 years)
- Aircraft productivity to improve by an average of 0.75% annually.

The assumption regarding lack of constraints requires comment. Today's civil aviation market is constrained only by the practical limitations of airport capacity and access restrictions, airspace restrictions, and economic restraint resulting from taxation, charges, and so forth that affect ticket price. Any constraints in the future, whether to address environmental problems or as a result of government policy, will affect or limit demand and therefore affect the emissions burden from civil aviation. In contrast, measures such as the introduction of advanced air traffic control systems may improve the efficiency of traffic management (see Chapter 8) but could lead to a traffic increase, with the consequence of increasing emissions from aircraft. Neither the scenarios nor the analysis of their impact have examined such possibilities because there would be too many permutations of possibilities to define a scenario acceptable to all.

Table 9-24 summarizes the estimated traffic in RPK x 10^9 for five of the scenarios. The global fleets (numbers of aircraft of all types) appropriate for each traffic estimate are also given.

In addition, it is necessary to consider the extent to which the freighter fleet might grow. An independent study was performed using figures for the current inventory of freighters and extrapolating the Boeing freighter forecast from 2015 at two growth rates-5.1% (high) and 2.5% (low). Assuming the high growth rate, the freighter fleet could grow to approximately 19,000 aircraft by 2050. The low-growth rate would require 8,000 freighter aircraft (Campbell-Hill Aviation Group, 1998). This calculation results in the adjusted commercial fleet profile given in Table 9-25.

9.6.6.2. Airport and Infrastructure Implications

From the implied 2050 fleet sizes, it is likely that more airports will be required to support the growth in traffic and flight operations. The number of new airports required will depend on the total fleet, the number of airports now capable of handling jet operations, and the number of gates available at each airport. Table 9-26 shows the number of new airports required, assuming the lowest and highest growth cases for the passenger fleet and total fleet (from model by Campbell-Hill Aviation Group, 1998). The present inventory of airports was taken as the number of airports now having one or more jet departures per day, thereby obviously capable of handling large jet transport aircraft, and the total number of airports in the OAG-that is, airports with scheduled air service (many not presently capable of handling large jet transport aircraft). For example, if all of the airports now having one or more jet departures per day had 15 or more gates, no new airports would be needed to handle the fleet in the lowest growth case. Conversely, the highest growth case would require more than 1,300 new airports of 15 gates each (two new airports per month for 60 years) even if all 3,750 airports now listed in the OAG had 15 gates and were capable of handling large jet transport aircraft (which they do not and are not). This analysis ignores infrastructure location and the problems associated with its provision. In populous parts of the world, where civil aviation is established, the addition of airport capacity is often difficult given local environmental pressures such developments create. However, in developing countries, where much of the future traffic growth is anticipated, new infrastructure might encounter less environmental sensitivity and therefore be more readily provided. Nonetheless, the infrastructure projects required to satisfy the highest growth scenarios are unprecedented in scope.

9.6.6.3. Fuel Availability

All of the 2050 scenarios imply large increases in fuel consumption by aircraft. In the highest FESG scenario (Fe2), aircraft fuel consumption increases from 139 to 772 Tg yr^{-1} over the period 1992 to 2050. In the highest EDF scenario (Eeh), the increase is from 179 Tg yr^{-1} in 1990 to 2,297 Tg yr^{-1} in 2050. Because both scenarios are based on the IS92e scenario, it is appropriate to compare these figures to total energy use in the IS92e scenario. According to scenario Fe2, aircraft will account for 13% of the total transportation energy usage in 2050 and require 15% of the world's liquid fossil fuel production. The EDF scenario (Eeh) implies that aircraft account for 39% of the transportation energy usage and require 45% of the world's liquid fuel production. These comparisons assume that aircraft do not use biomass fuels or fuels derived from natural gas.

Under either scenario, the world will be straining the limits of conventional oil resources by 2050. Total remaining resources of conventional petroleum, discovered and undiscovered, have been estimated at between one trillion (Campbell and Laherrere, 1998) and two trillion barrels (Masters et al., 1994-based on the optimistic 5%

probability estimate of undiscovered oil). The IS92e scenario implies cumulative production of liquid fuels of 1 trillion barrels by 2025 and 2 trillion barrels by 2050. Cumulative consumption by 2050 by aircraft alone amounts to 0.15 trillion barrels in the Fe2 scenario and 0.35 trillion barrels in the Eeh scenario. However, production of liquid fuels is not necessarily limited by conventional oil resources. Liquid fuels can be produced from heavy oil, tar sands, oil shale, or even coal, albeit with significantly greater environmental consequences and at higher costs. High fuel prices would violate the explicit assumptions used in developing the scenarios.

9.6.6.4. Manufacturing Capability and Trends in Aircraft Capacity

In 1997, the global aircraft manufacturing capability delivered 634 passenger jet aircraft, bringing the global jet passenger fleet to approximately 10,000 aircraft. The rate of new aircraft deliveries has followed a generally increasing trend since the mid-1950s, and this trend must continue over the scenario period to satisfy predicted demand for new and replacement aircraft. For the demand cases examined above, deliveries of new aircraft are estimated to reflect the schedule given in Table 9-27.

The delivery rate for the Fa1 and Fa2 scenarios would be achievable with existing manufacturing capacity. The delivery rate required by the highest scenario, Eeh, implies a considerable increase in manufacturing capacity-approximately six times that existing today. Although this level is not impossible, such an expansion of aircraft manufacturing capability is likely to be difficult to achieve and sustain during the period. The Eab scenario implies a delivery rate that is approximately three times the level existing today, which is not implausible for 2050.

One assumption intrinsic to the fleet size analysis was that the average number of seats per aircraft will increase by 1% each year, reflecting current trends. This assumption has a large effect on fleet size estimates, particularly for high-demand cases. As a sensitivity analysis, the factor was changed to 2% per year for the Eeh high scenario and for the Fa1 and Fa2 scenarios. Such a change may reflect potential market pressures for larger aircraft, which is not inappropriate for a high traffic growth scenario. The results are given in Table 9-28.

As this analysis shows, a different assumption in aircraft size growth has a significant effect on the estimated future fleet. The projected numbers of the largest aircraft types (between 625 and 799 seats) in future fleets are particularly sensitive in this analysis, which suggests that there might be more than 7,000 such aircraft in the fleet by 2050 in the Eeh scenario (compared with about 10,000 passenger aircraft of all sizes today) or about 4,000 additional aircraft for the more conservative Fa1 and Fa2 scenarios.

Increased capacity can be supplied by additional aircraft, increased flying hours (i.e., more efficient use of the fleet), larger aircraft, or a combination of these factors. The high aircraft growth assumption used as a sensitivity analysis here suggests that about 70% of future capacity growth will be supplied by an increase in aircraft size. Although such an industry trend is not impossible, it is unlikely to occur in such a prescriptive manner if the industry remains relatively deregulated. Deregulation tends to favor increased frequency and direct flights with smaller aircraft between departure and destination. However, it is likely that some markets would favor the proliferation of very large aircraft, especially those with dense traffic flows. The size of the fleets suggested by the 2% per year aircraft size growth assumption must therefore be regarded as toward the low end of the range.

9.6.6.5. Synthesis of Plausibility Analyses

Given the range of estimates for traffic, fuel consumption, and emissions from the 2050 aircraft scenarios available to this assessment, it is necessary to comment on the plausibility of the results-not least to demonstrate that results used in subsequent analyses are bounded by sensible limits within which the aviation industry is currently envisaged to develop.

The foregoing analyses suggest that although none of the scenarios considered for 2050 is impossible, some of the high-growth scenarios (e.g., Eah and Eeh) are probably less plausible. The fleet size and infrastructure implications suggest radical developments that are likely to be beyond the scope of changes observed in the industry thus far (or anticipated for the future). Similarly, the low-growth scenarios-though plausible in terms of achievability-give traffic estimates that are likely to be exceeded given the present state of the industry and planned developments. Although all of the FESG scenarios discount the possibility of truly radical developments in technology over the next 50 years, they are considered to fall within a plausible range of outcomes and suggest achievable developments for the industry.

The 3-D gridded output from scenarios Fa-Fe (with T1 and T2 technology scenarios) and from DTI are suitable for use as input to chemical transport models and may be used to calculate the effect of aviation CO_2 emissions. Scenarios Eab and Edh are suitable for use in Chapter 6 to calculate the effect of CO_2 emissions as sensitivity analyses because the latter scenario projects CO_2 emissions levels from aviation that are 2.2 times greater in 2050 than the highest of the FESG scenarios. Table 9-29 provides a summary of all of the long-term scenarios examined in the chapter.

References

ANCAT/EC, 1995: *A Global Inventory of Aircraft NO_x Emissions.* A first version (April 1994) prepared for the $AERONO_x$ programme. Abatement of Nuisances Caused by Air Transport (ANCAT) and European Community Working Group, European Civil Aviation Conference, London, United Kingdom, 20 pp.

Albritton, D.L, G.T. Amanatidis, G. Angeletti, J. Crayston, D.H. Lister, M. McFarland, J.M. Miller, A.R. Ravishankara, N. Sabogal, N. Sundararaman, and H.L. Wesoky, 1997: *Global Atmospheric Effects of Aviation: Report of the Proceedings of the Symposium.* NASA-CP-3351, National Aeronautics and Space Administration, Washington, DC, USA, 52 pp.

Atkinson, A.B., 1975: *The Economics of Inequality.* Clarendon Press, Oxford, United Kingdom, pp. 22, 246.

Balashov, B. and A. Smith, 1992: ICAO analyses--trends in fuel consumption by world's airlines. *ICAO Journal,* **47(8),** 18-21.

Barrett, M., 1994: *Pollution Control Strategies for Aircraft.* World Wide Fund for Nature, Gland, Switzerland, 60 pp.

Bauer, E., 1979: A catalog of perturbing influences on stratospheric ozone, 1955-1975. *Journal of Geophysical Research,* **84,** 6929-6940.

Baughcum, S.L., S.C. Henderson, P.S. Hertel, D.R. Maggiora, and C.A. Oncina, 1994: *Stratospheric Emissions Effects Database Development.* NASA-CR-4592, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA, 156 pp.

Baughcum, S.L., and S.C. Henderson, 1995: *Aircraft Emission Inventories Projected in Year 2015 for a High Speed Civil Transport (HSCT) Universal Airline Network.* NASA-CR-4659, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA, 117 pp.

Baughcum, S.L., S.C. Henderson, and T.G. Tritz, 1996a: *Scheduled Civil Aircraft Emission Inventories for 1976 and 1984: Database Development and Analysis.*

NASA-CR-4722, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA, 144 pp.

Baughcum, S.L., S.C. Henderson, T.G. Tritz, and D.C. Pickett, 1996b: *Scheduled Civil Aircraft Emission Inventories for 1992: Database Development and Analysis.* NASA-CR-4700, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA, 196 pp.

Baughcum, S.L., D.J. Sutkus, Jr., and S.C. Henderson, 1998: *Year 2015 Aircraft Emission Scenario for Scheduled Air Traffic*. NASA-CR-1998-207638, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA, 44 pp.

Baughcum, S.L., and S.C. Henderson, 1998: *Aircraft Emission Scenarios Projected in Year 2015 for the NASA Technology Concept Aircraft (TCA) High Speed Civil Transport.* NASA CR-1998-207635, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA, 31 pp.

Beck, J.P., C.E. Reeves, F.A.A.M. de Leeuw, and S.A. Penkett, 1992: The effect of aircraft emissions on tropospheric ozone in the Northern Hemisphere. *Atmospheric Environment,* **26A,** 17-29.

Boeing Commercial Airplane Group, 1993: *1993 Current Market Outlook* [Sepanen, D. (ed.)]. Boeing Commercial Airplane Group, Seattle, WA, USA, March 1993, 58 pp.

Boeing Commercial Airplane Group, 1996: *1996 Current Market Outlook* [Meskill, T. (ed.)]. Boeing Commercial Airplane Group, Seattle, WA, USA, March 1996, 38 pp.

Boeing Commercial Airplane Group, 1998: *1998 Current Market Outlook* [Meskill, T. (ed.)]. Boeing Commercial Airplane Group, Seattle, WA, USA, March 1998, 60 pp.

Brasseur, G.P., R.A. Cox, D. Hauglustaine, I. Isaksen, J. Lelieveld, D.H. Lister, R. Sausen, U. Schumann, A. Wahner, and P. Wiesen, 1998: European scientific assessment of the atmospheric effects of air craft emissions. *Atmospheric Environment,* **32,** 2329-2418.

CAEP/4-FESG, 1998: *Report 4. Report of the Forecasting and Economic Analysis Sub-Group (FESG): Long-Range Scenarios.* International Civil Aviation Organization Committee on Aviation Environmental Protection Steering Group Meeting, Canberra, Australia, January 1998, 131 pp.

CAEP/WG3, 1995: *Report of the Emissions Inventory Sub-group.* International Civil Aviation Organization Committee on Aviation Environmental Protection Working Group 3 [Ralph, M. (ed.)], London, United Kingdom, 45 pp.

Campbell-Hill Aviation Group, 1998: *Airport and Infrastructure Implications,* private communication, Brian M. Campbell to Anu Vedantham, December 1998.

Campbell, C.J. and J.H. Laherrere, 1998: The end of cheap oil. *Scientific American,* **278(3).**

COMESA, 1975: *Report of the Committee on Meteorological Effects of Stratospheric Aircraft.* UK Department of Defence, Bracknell, Berks, United Kingdom

Deidewig, F., A. Döpelheuer, and M. Lecht, 1996: *Methods to Assess Aircraft Engine Emissions in Flight.* Proceedings of the 20th International Council of Aeronautical

Sciences Congress, Sorrento, Italy, Sept. 1996. American Institute of Aeronautics and Astronautics, Reston, Virginia, USA, Vol. I, pp 131-141.

Derwent, R.G., 1982: Two-dimensional model studies of the impact of aircraft exhaust emissions on tropospheric ozone. *Atmospheric Environment,* **16,** 1997-2007.

Friedl, R.R. (ed.), 1997: *Atmospheric Effect of Subsonic Aircraft: Interim Assessment Report of the Advanced Subsonic Technology Program.* NASA Reference Publication 1400, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD, USA, 154 pp.

Gardner, R.M., K. Adams, T. Cook, F. Deidewig, S. Ernedal, R. Falk, E. Fleuti, E. Herms, C.E. Johnson, M. Lecht, D.S. Lee, M. Leech, D. Lister, B. Masse, M. Metcalfe, P. Newton, A. Schmitt, C. Vandenbergh, and R. Van Drimmelen, 1997: The ANCAT/EC global inventory of NO_x emissions from aircraft. *Atmospheric Environment,* **31(12),** 1751 and 1766.

Gardner, R.M. (ed.), 1998: *ANCAT/EC2 Global Aircraft Emissions Inventories for 1991/1992 and 2015: Final Report.* EUR-18179, ANCAT/EC Working Group, ISBN-92-828-2914-6, 84 pp. + appendices.

Greene, D.L., 1992: Energy-efficiency improvement potential of commercial aircraft. In: *Annual Review of Energy and the Environment* [Hollander, J., J. Harte, and R. H. Socolow (eds.)]. Annual Reviews, Inc., Palo Alto, CA, USA, Vol. 17, pp. 537-574.

Greene, D.L. and L. Meisenheimer, 1997: *Commercial Air Transport Emission Scenario Model.* Oak Ridge National Laboratory Center for Transportation Analysis, Oak Ridge, TN, USA, October 6, 1997, 6 pp.

Gould, R., 1996: *Environmental Management for Airports and Aviation: Jane's Special Report.* Jane's Information Group, Surrey, United Kingdom, January 1996, 253 pp.

Hidalgo, H. and P.J. Crutzen, 1977: The tropospheric and stratospheric composition perturbed by NO_x emissions of high-altitude aircraft. *Journal of Geophysical Research,* **82,** 5833-5866.

Hutzler, M.J. and A.T. Andersen, 1997: *International Energy Outlook 1997.* Energy Information Agency, Washington, DC, USA.

ICAO, 1993: *Environmental Protection: Annex 16 to the Convention on International Civil Aviation - Volume II, Aircraft Engine Emissions*. International Civil Aviation Organization, Montreal, Quebec, Canada, 63 pp.

ICAO, 1995: *ICAO Engine Exhaust Emissions Databank, 1st Edition--1995.* ICAO-9646-AN/943, International Civil Aviation Organization, Montreal, Quebec, Canada, 173 pp.

ICAO, 1997a: *Outlook for Air Transport to the Year 2005.* ICAO Circular 270-AT/111, International Civil Aviation Organization, Montreal, Quebec, Canada, 53 pp.

ICAO, 1997b: *Traffic: Commercial Air Carriers 1982-96, Digest of Statistics No. 337*. International Civil Aviation Organization,

Montreal, Quebec, Canada, 353 pp.

Landau, Z.H., M. Metwally, R. Van Alstyne, and C.A. Ward, 1994: *Jet Aircraft Engine Exhaust Emissions Database Development--Year 1990 and 2015 Scenarios.* NASA-CR-4613, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA, 88 pp.

Leggett, J., W.J. Pepper, and R.J. Swart, 1992: Emissions scenarios for the IPCC: an update. In: *Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment.* Prepared by IPCC Working Group I [Houghton, J.T., B.A. Callander, and S.K. Varney (eds.)] and WMO/UNEP. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, pp. 68-95.

Little, A.D., 1975: *Preliminary Economic Impact Assessment of Possible Regulatory Action to Control Atmospheric Emission of Selected Halocarbons.* Report C77327-10, U.S. Environmental Protection Agency, Menlo Park, CA, USA.

McInnes, G. and C.T. Walker, 1992: *The Global Distribution of Aircraft Air Pollutant Emissions.* Warren Spring Laboratory Report LR 872, Department of Trade and Industry, Warren Spring Laboratory, Stevenage, Hertfordshire, United Kingdom, 41 pp.

Metwally, M., 1995: *Jet Aircraft Engine Emissions Database Development--1992 Military, Charter, and Nonscheduled Traffic.* NASA-CR-4684, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA, 61 pp.

Mortlock, A.M. and R. van Alstyne, 1998: *Military, Charter, Unreported Domestic Traffic and General Aviation: 1976, 1984, 1992, and 2015 Emission Scenarios.* NASA-CR-1998-207639, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA, 118 pp.

Newton, P.J. and R.S. Falk, 1997: *DTI Forecast of Fuel Consumption and Emissions from Civil Aircraft in 2050 Based on ANCAT/EC2 1992 Data.* DTI/ADI3c/199701/1.0, Department of Trade and Industry, London, United Kingdom, 13 November 1997, 15 pp.

Nüßer, H.-G. and A. Schmitt, 1990: The global distribution of air traffic at high altitudes, related fuel consumption and trends. In: *Air Traffic and the Environment, Lecture Notes in Engineering* [Schumann, U. (ed.)]. Springer-Verlag, Berlin, Germany, pp. 1-11.

OECD, 1998a: *Energy Balances of OECD Countries* (database software). Organization for Economic Cooperation and Development, OECD Publications, Paris, France.

OECD, 1998b: *Energy Balances of Non-OECD Countries* (database software). Organization for Economic Cooperation and Development, OECD Publications, Paris, France.

Olivier, J.G.J., 1995: *Scenarios for Global Emissions from Air Traffic. The Development of Regional and Gridded (5º x 5º) Emissions Scenarios for Aircraft and for Surface Sources, Based on CPB Scenarios and Existing Emission Inventories for Aircraft and Surface Sources.* RIVM-773002003, Rijksinstituut voor Volksgezondheid en Milieu, Bilthoven, The Netherlands, July 1995, 113 pp.

Pulles, H., 1998: *Report of the (ICAO/CAEP) Focal Point on Charges (FPC) Prepared for CAEP/4. Emission Charges and Taxes in Aviation.* International Civil Aviation Organization Committee on Aviation Environmental Protection, The Hague, The Netherlands, March 1998, 79 pp. + appendices.

Rogner, H.H., 1997: An assessment of world hydrocarbon resources. In: *The Annual Review of Energy and the Environment*. Annual Reviews, Inc., Palo Alto, CA, USA, Vol. 22, pp. 217-262.

Schafer, A. and D.G. Victor, 1997: *The Future Mobility of the World Population.* Discussion Paper 97-6-4, Center for Technology, Policy and Industrial Development and the MIT Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology, Cambridge, MA, USA, Rev. 2, September 1997, 39 pp.

Schmitt, A. and B. Brunner, 1997: Emissions from aviation and their development over time. In: *Final Report on the BMBF Verbundprogramm, Schadstoffe in der Luftfahrt* [Schumann, U., A. Chlond, A. Ebel, B. Kärcher, H. Pak, H. Schlager, A. Schmitt, and

P. Wendling (eds.)]. DLR-Mitteilung 97-04, Deutsches Zentrum für Luft- und Raumfahrt, Oberpfaffenhofen and Cologne, Germany, pp. 37-52.

Schulte, P., H. Schlager, H. Ziereis, U. Schumann, S.L. Baughcum, and F. Deidewig, 1997: NO_x emission indices of subsonic long-range jet aircraft at cruise altitude: *In situ* measurements and predictions. *Journal of Geophysical Research,* **102,** 21431-21442.

Stolarski, R., and H. Wesoky, 1993: *The Atmospheric Effects of Stratospheric Aircraft: A Third Program Report.* NASA Reference Publication 1313, National Aeronautics and Space Administration, Washington, DC, USA, November 1993, 422 pp.

Sutkus, D.J., Jr., 1997: *2050 Fuel Efficiency and NO_x Technology Scenarios.* International Coordinating Council of Aerospace Industries Association Working Paper WG3-WP4/22 presented at the Fourth Meeting of International Civil Aviation Organization Committee on Aviation Environmental Protection Working Group 3 (Emissions), 12-14 November 1997, Bern, Switzerland, 22 pp.

Sutkus, D.J. Jr., D.L. Daggett, D.P. DuBois, and S.L. Baughcum, 1999: *An Evaluation of Aircraft Emissions Inventory Methodology by Comparisons with Reported Airline Data.* National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA, (in press).

ten Have, H.B.G. and T.D. de Witte, 1997: *User Manual of the Flights and Emissions Model--Model Version 3.11.* NLR-CR 97063-L, National Aerospace Laboratory, Amsterdam, The Netherlands.

Vedantham, A. and M. Oppenheimer, 1994: *Aircraft Emissions and the Global Atmosphere.* Environmental Defense Fund, New York, NY, USA, 77 pp.

Vedantham, A. and M. Oppenheimer, 1998: Long-term scenarios for aviation: demand and emissions of CO_2 and NO_x. *Energy Policy,* **26(8),** 625-641.

WMO, 1995: *Scientific Assessment of Ozone Depletion: 1994.* Report no. 37, Global Ozone Research and Monitoring Project, World Meteorological Organization, Geneva, Switzerland, 578 pp.

Wuebbles, D.J., D. Maiden, R.K. Seals, S.L. Baughcum, M. Metwally, and A. Mortlock, 1993: Emissions scenarios development: report of the emissions scenarios committee. In: *The Atmospheric Effects of Stratospheric Aircraft: A Third Program Report* [Stolarski, R.S. and H.L. Wesoky (eds.)]. NASA Reference Publication 1313, National Aeronautics and Space Administration, Washington, DC, USA, pp. 63-85.

Zahavi, Y., 1981: *The UMOT-Urban Interactions.* DOT-RSPA-DPB 10/7, U.S. Department of Transportation, Washington, DC, USA, 151 pp.

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EXHIBIT F

NASA deems LAX runways safe.

Print

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Byline: Art Marroquin Staff Writer

AVIATION: L.A. mayor says study should put long-term debate to rest.

The current layout of Los Angeles International Airport's north airfield is safe and the parallel runways do not need to be separated, according to a long-anticipated report released Friday by an academic panel and NASA Ames Research Center.

The fate of LAX's northern runways have remained a contentious issue between city leaders and community activists for more than 20 years, but Los Angeles Mayor Antonio Villaraigosa said the latest study should help put an end to the debate.

"I have always said that I oppose a reconfiguration of the north airfield at LAX absent a clear demonstration that such a change is necessary to ensure the safety of passengers, workers and the surrounding community," Villaraigosa said. "Barring other findings that would indicate safety issues, we are not moving the runway."

However, the report's results did not sit well with some members of the Board of Airport Commissioners, who expressed concern that doing nothing may lead to problems down the road.

"I can't help feeling like I'm a board member sitting on the board of directors for automakers, wondering if a little widget didn't get fixed, if it could cause an accident," Airport Commissioner Joseph Aredas said.

"The chance may be minute," Aredas said. "But there's still a chance."

For now, airplanes maneuvering on LAX's north airfield must use paths that crisscross the middle of the two parallel runways, which are separated by 700 feet.

The Federal Aviation Administration has maintained that the current layout provides a tight landing space for super-sized jetliners such as the Airbus A380 and the Boeing 787 Dreamliner. Five previous reports released in 2007 by aviation consulting groups suggested that the runways be at least 1,040 feet apart to accommodate the larger planes.

When those reports were disputed by community activists, the airport commission agreed in May 2008 to pay NASA $1.4million to determine whether the runways should be separated to make room for a centerline taxiway, similar to a $333million project completed nearly two years ago at LAX's south airfield.

The move would reduce the number of near-miss collisions between departing and arriving jetliners, FAA officials said.

LAX reported eight runway incursions during the year that ended last September, a significant decline from 21 such incidents in 2007. The most serious near-miss in recent years occurred Aug. 16, 2007, when two jetliners came within 37 feet of each other on the north airfield.

"Multiple studies by airport design and layout experts have concluded that reconfiguring the south and north airfields are the best safety and efficiency solutions," said Ian Gregor, a spokesman for the Federal Aviation Administration.

"Changes to LAX's south airfield achieved their intended purpose and dramatically improved runway safety," Gregor said. "Conclusions that the north airfield is safe enough now are not an argument against doing everything possible to make it even safer."

Gregor said the FAA will review NASA's study and recommendations.

NASA and the academic panel found that separating the runways would make the north airfield safer, but the risk of ground collisions are so low that any shift would be inconsequential.

Researchers estimated that the current layout could lead to one death from a runway collision for every 150 million airline passengers. When broken down, that's a total of five deaths over the next decade, the study said.

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EXHIBIT G

... / A340 Family(aircraftfamilies/passengeraircraft/a340family/) / A340-600

A340-600

THE LARGEST A340

The A340-600 is the longest-fuselage jetliner ever built by Airbus, and the largest-capacity member of the A340 Family.

With an overall length of 75.3 metres, it has a seating capacity for 360 passengers in a three-class layout, or 419 in a two-class configuration.

This super-stretch aircraft provides operators with unrivalled standards of space, comfort and amenities in each class of service, along with twice the underfloor cargo capacity of comparable airliners.

Asset management(aircraftfamilies/asset/)

A dedicated corporate division for selling/leasing used Airbus aircraft to airlines worldwide

FLYING FARTHER

Airbus' A340-600 also is an ultra long-haul leader, with a range of 7,900 nautical miles. Equipped for the best economy on long-haul routes, the A340-600 offers unmatched operational flexibility on non-stop flights over remote areas such as oceans and mountain ranges.

The jetliner's four Rolls-Royce Trent 500 engines use only 56,000 lbs. of their certified 60,000 lbs. of thrust, resulting in longer on-wing lives. In addition, the use of four engines – as opposed to two larger powerplants – allows for a 13 per cent reduction in maintenance costs for operators.

In addition, the A340-600's four engines allow for operations that are not subject to ETOPS (Extended-range Twin-engine Operational Performance Standards) regulations. This enables airlines to fly more direct routes – even long distances over water or on segments far from airports – saving travel time and cutting fuel consumption.

A FAMILY APPROACH

The A340-600 also includes state-of-the-art technologies such as weight-saving composite structures; a fuel-saving aerodynamic design; along with pilot-friendly cockpits, flight controls and systems – all of which significantly enhance the A340-600's long-range capabilities and overall cost-efficiency.

True to Airbus' unique family concept, it also offers an exceptional degree of operational commonality with all of the company's fly-by-wire aircraft – allowing pilots to transition from one type to another with minimum training time.

EXHIBIT H

LAX Airline Market Share Summary for January 2012 to December 2012

	Revenue Pounds Landed (1000 lbs)	% of total Weight	Passenger Departures	% of Total Departures	Passenger Arrivals	% of Total Arrivals	Air Freight (tons)	% of Total Freight	Air Mail (tons)	% of Total Mail	Revenue Related Operations	% of Total Operations
ABX Air Inc	270,224	0.540 %	0	0.000 %	0	0.000 %	62,252.5	3.335 %	0.0	0.000 %	1,862	0.324 %
Aeroflot	94,938	0.190 %	46,550	0.146 %	47,568	0.149 %	707.1	0.038 %	0.0	0.000 %	478	0.083 %
Aerologic GmbH	59,225	0.118 %	0	0.000 %	0	0.000 %	10,627.9	0.569 %	2.1	0.002 %	206	0.036 %
Aeromexico	324,284	0.648 %	286,625	0.900 %	274,167	0.861 %	2,007.8	0.108 %	0.0	0.000 %	5,519	0.961 %
Aerotransporte De Carga Union S A de C A	187,915	0.376 %	0	0.000 %	0	0.000 %	46,833.1	2.509 %	0.0	0.000 %	1,274	0.222 %
Air Berlin	67,769	0.136 %	40,282	0.126 %	39,749	0.125 %	1,684.2	0.090 %	0.0	0.000 %	338	0.059 %
Air Bridge Cargo Airlines	605	0.001 %	0	0.000 %	0	0.000 %	0.0	0.000 %	0.0	0.000 %	2	0.000 %
Air Canada	569,565	1.139 %	471,020	1.479 %	468,367	1.471 %	2,563.2	0.137 %	535.2	0.553 %	9,047	1.575 %
Air China	432,446	0.865 %	152,741	0.479 %	149,569	0.470 %	19,193.5	1.028 %	0.0	0.000 %	1,480	0.258 %
Air France	503,735	1.007 %	263,811	0.828 %	272,827	0.857 %	15,844.4	0.849 %	1,201.1	1.241 %	1,770	0.308 %
Air New Zealand	604,132	1.208 %	316,255	0.993 %	295,990	0.930 %	28,372.4	1.520 %	1,866.2	1.928 %	2,230	0.388 %
Air Pacific	137,414	0.275 %	80,756	0.253 %	86,799	0.273 %	3,140.4	0.168 %	257.6	0.266 %	441	0.077 %
Air Tahiti Nui	317,320	0.635 %	179,702	0.564 %	181,913	0.571 %	7,851.7	0.421 %	0.0	0.000 %	1,502	0.261 %
Air Transport Int'l LLC	550	0.001 %	0	0.000 %	0	0.000 %	47.8	0.003 %	0.0	0.000 %	4	0.001 %
Airtran Airways Inc	219,008	0.438 %	211,470	0.664 %	209,170	0.657 %	0.0	0.000 %	0.0	0.000 %	3,422	0.596 %
Alaska Airlines	1,571,704	3.143 %	1,575,275	4.945 %	1,568,434	4.927 %	5,114.9	0.274 %	2,182.1	2.255 %	25,510	4.441 %
Alitalia Compagnia Aerea Italiana S P A	69,487	0.139 %	37,918	0.119 %	39,315	0.124 %	127.2	0.007 %	0.0	0.000 %	296	0.052 %
All Nippon Airways	374,374	0.749 %	153,025	0.480 %	153,728	0.483 %	26,226.8	1.405 %	2,197.4	2.271 %	1,464	0.255 %
Allegiant Air LLC	163,176	0.326 %	169,771	0.533 %	171,032	0.537 %	0.0	0.000 %	0.0	0.000 %	2,353	0.410 %
American Airlines	6,145,732	12.289 %	4,738,068	14.873 %	4,716,537	14.817 %	91,359.9	4.895 %	3,831.1	3.959 %	67,384	11.730 %
American Eagle	991,282	1.982 %	771,087	2.420 %	796,817	2.503 %	31.1	0.002 %	0.0	0.000 %	40,030	6.968 %
Ameriflight LLC	1,396	0.003 %	0	0.000 %	0	0.000 %	102.0	0.005 %	0.0	0.000 %	188	0.033 %
Ameristar Jet Charter	437	0.001 %	61	0.000 %	87	0.000 %	0.9	0.000 %	0.0	0.000 %	10	0.002 %
ArkeFly	5,220	0.010 %	5,172	0.016 %	4,145	0.013 %	0.0	0.000 %	0.0	0.000 %	72	0.013 %
Asiana Airlines	509,014	1.018 %	208,082	0.653 %	203,025	0.638 %	58,316.2	3.124 %	4,170.2	4.309 %	1,814	0.316 %
Astar	50,050	0.100 %	0	0.000 %	0	0.000 %	2,945.8	0.158 %	0.0	0.000 %	364	0.063 %
Atlas Air Inc	23,077	0.046 %	257	0.001 %	434	0.001 %	3,417.1	0.183 %	0.0	0.000 %	71	0.012 %
British Airways	575,070	1.150 %	273,936	0.860 %	273,864	0.860 %	21,756.6	1.166 %	1,164.3	1.203 %	1,870	0.326 %
Capital Cargo International	39,600	0.079 %	0	0.000 %	0	0.000 %	5,403.4	0.290 %	0.0	0.000 %	401	0.070 %
Cargolux Airlines International	174,714	0.349 %	0	0.000 %	0	0.000 %	25,604.9	1.372 %	291.6	0.301 %	494	0.086 %
Cathay Pacific	809,953	1.620 %	267,141	0.839 %	263,203	0.827 %	68,322.2	3.661 %	442.2	0.457 %	2,701	0.470 %
China Airlines	673,326	1.346 %	205,167	0.644 %	222,217	0.698 %	56,227.7	3.013 %	1,064.5	1.100 %	2,174	0.378 %
China Cargo Airlines LTD	200,100	0.400 %	0	0.000 %	0	0.000 %	45,608.5	2.444 %	0.0	0.000 %	696	0.121 %
China Eastern Airlines	206,424	0.413 %	102,924	0.323 %	103,089	0.324 %	6,354.4	0.340 %	0.0	0.000 %	732	0.127 %

Numbers may not add correctly due to rounding.

LAX Airline Market Share Summary for January 2012 to December 2012

	Revenue Pounds Landed (1000 lbs)	% of total Weight	Passenger Departures	% of Total Departures	Passenger Arrivals	% of Total Arrivals	Air Freight (tons)	% of Total Freight	Air Mail (tons)	% of Total Mail	Revenue Related Operations	% of Total Operations
China Southern Airlines	355,022	0.710 %	100,218	0.315 %	102,184	0.321 %	31,527.3	1.689 %	655.3	0.677 %	1,268	0.221 %
Clay Lacy Aviation Inc	2,242	0.004 %	156	0.000 %	207	0.001 %	0.0	0.000 %	0.0	0.000 %	119	0.021 %
Continental Airlines	2,045,197	4.090 %	1,739,088	5.459 %	1,710,666	5.374 %	4,438.7	0.238 %	9,687.0	10.009 %	23,632	4.114 %
Copa Airlines	107,894	0.216 %	100,092	0.314 %	103,684	0.326 %	1,375.9	0.074 %	9.5	0.010 %	1,477	0.257 %
Delta Air Lines	5,101,781	10.201 %	3,697,475	11.606 %	3,752,974	11.790 %	75,188.0	4.028 %	19,232.8	19.873 %	58,733	10.224 %
Delta Connection	4,200	0.008 %	3,559	0.011 %	3,466	0.011 %	0.0	0.000 %	0.0	0.000 %	112	0.019 %
El Al Israel Airlines Ltd	94,470	0.189 %	46,543	0.146 %	48,495	0.152 %	2,260.8	0.121 %	0.0	0.000 %	402	0.070 %
Emirates	300,244	0.600 %	133,296	0.418 %	143,765	0.452 %	7,986.8	0.428 %	16.8	0.017 %	1,160	0.202 %
Eva Airways Corporation	609,808	1.219 %	212,047	0.666 %	215,950	0.678 %	63,052.5	3.378 %	291.4	0.301 %	2,256	0.393 %
Evergreen International Airlines	1,260	0.003 %	0	0.000 %	0	0.000 %	122.4	0.007 %	0.0	0.000 %	3	0.001 %
Federal Express	1,629,654	3.259 %	0	0.000 %	0	0.000 %	368,813.9	19.760 %	0.0	0.000 %	7,962	1.386 %
Florida West International Airways	5,542	0.011 %	0	0.000 %	0	0.000 %	2,366.1	0.127 %	0.0	0.000 %	67	0.012 %
Frontier Airlines	268,579	0.537 %	260,564	0.818 %	260,309	0.818 %	1,136.3	0.061 %	0.0	0.000 %	4,135	0.720 %
Frontier Jet Express	4,244	0.008 %	0	0.000 %	0	0.000 %	0.0	0.000 %	0.0	0.000 %	0	0.000 %
Great Lakes Aviation LTD	25,976	0.052 %	9,847	0.031 %	10,236	0.032 %	0.0	0.000 %	0.0	0.000 %	3,049	0.531 %
Hawaiian Airlines	402,761	0.805 %	285,850	0.897 %	289,543	0.910 %	11,699.2	0.627 %	0.0	0.000 %	2,144	0.373 %
Horizon Air	53,010	0.106 %	50,844	0.160 %	51,050	0.160 %	4.0	0.000 %	0.0	0.000 %	1,714	0.298 %
IFL Group	11,280	0.023 %	0	0.000 %	0	0.000 %	1,514.9	0.081 %	0.0	0.000 %	389	0.068 %
Iberia Airlines of Spain	59,305	0.119 %	31,057	0.097 %	32,190	0.101 %	1,781.0	0.095 %	30.1	0.031 %	290	0.050 %
Japan Airlines	202,764	0.405 %	82,163	0.258 %	81,196	0.255 %	10,922.9	0.585 %	3,215.8	3.323 %	732	0.127 %
JetBlue Airlines	410,664	0.821 %	388,063	1.218 %	388,430	1.220 %	1,201.8	0.064 %	0.0	0.000 %	5,785	1.007 %
KLM Royal Dutch Airlines	247,701	0.495 %	114,036	0.358 %	117,044	0.368 %	6,970.1	0.373 %	225.5	0.233 %	810	0.141 %
Kalitta Air LLC	147,465	0.295 %	0	0.000 %	0	0.000 %	37,723.3	2.021 %	0.0	0.000 %	468	0.081 %
Korean Airlines	1,190,526	2.381 %	333,153	1.046 %	333,725	1.048 %	78,264.6	4.193 %	1,049.5	1.084 %	3,860	0.672 %
LACSA	136,486	0.273 %	129,362	0.406 %	123,879	0.389 %	821.8	0.044 %	114.7	0.118 %	1,816	0.316 %
Lan Airlines	135,037	0.270 %	80,407	0.252 %	81,217	0.255 %	5,448.1	0.292 %	0.0	0.000 %	806	0.140 %
Lan Peru SA	62,080	0.124 %	38,779	0.122 %	36,765	0.116 %	2,449.2	0.131 %	0.0	0.000 %	388	0.068 %
Lufthansa German Airlines	511,696	1.023 %	237,345	0.745 %	237,608	0.746 %	20,167.9	1.081 %	272.8	0.282 %	1,702	0.296 %
Lynden Air	124	0.000 %	0	0.000 %	0	0.000 %	0.0	0.000 %	0.0	0.000 %	2	0.000 %
MAS Air Cargo	187,776	0.375 %	0	0.000 %	0	0.000 %	55,771.5	2.988 %	0.0	0.000 %	1,152	0.201 %
Malaysian Airlines	90,620	0.181 %	41,576	0.131 %	42,910	0.135 %	2,800.3	0.150 %	0.0	0.000 %	394	0.069 %
Miami Air	972	0.002 %	733	0.002 %	583	0.002 %	0.0	0.000 %	0.0	0.000 %	30	0.005 %
NCA	254,614	0.509 %	0	0.000 %	0	0.000 %	53,926.8	2.889 %	685.2	0.708 %	763	0.133 %
OJSC Transaero Airlines	33,916	0.068 %	14,806	0.046 %	15,059	0.047 %	218.3	0.012 %	24.6	0.025 %	142	0.025 %

Numbers may not add correctly due to rounding.

LAX Airline Market Share Summary for January 2012 to December 2012

	Revenue Pounds Landed (1000 lbs)	% of total Weight	Passenger Departures	% of Total Departures	Passenger Arrivals	% of Total Arrivals	Air Freight (tons)	% of Total Freight	Air Mail (tons)	% of Total Mail	Revenue Related Operations	% of Total Operations
Omni Air Express	1,586	0.003 %	680	0.002 %	906	0.003 %	0.0	0.000 %	0.0	0.000 %	12	0.002 %
Philippine Airlines	255,084	0.510 %	135,670	0.426 %	141,282	0.444 %	4,921.5	0.264 %	0.0	0.000 %	854	0.149 %
Polar Air Cargo	368,298	0.736 %	0	0.000 %	0	0.000 %	95,672.4	5.126 %	0.0	0.000 %	1,107	0.193 %
Qantas Airlines	1,305,180	2.610 %	596,532	1.873 %	581,253	1.826 %	11,516.4	0.617 %	4,144.3	4.282 %	3,673	0.639 %
Ryan International Airlines	411	0.001 %	309	0.001 %	0	0.000 %	0.0	0.000 %	0.0	0.000 %	2	0.000 %
Singapore Airlines	453,780	0.907 %	161,737	0.508 %	155,423	0.488 %	12,998.5	0.696 %	217.4	0.225 %	1,248	0.217 %
Singapore Airlines Cargo	148,518	0.297 %	0	0.000 %	0	0.000 %	36,881.6	1.976 %	133.9	0.138 %	446	0.078 %
Skybird Aviation	150	0.000 %	0	0.000 %	0	0.000 %	0.0	0.000 %	0.0	0.000 %	4	0.001 %
Skywest Airlines	1,854,267	3.708 %	1,525,620	4.789 %	1,547,746	4.862 %	6.7	0.000 %	0.0	0.000 %	83,434	14.523 %
Southern Air Inc	174,541	0.349 %	0	0.000 %	0	0.000 %	48,748.2	2.612 %	8,364.5	8.643 %	590	0.103 %
Southwest Airlines	4,600,494	9.199 %	3,621,726	11.369 %	3,653,999	11.479 %	16,197.0	0.868 %	0.0	0.000 %	74,527	12.973 %
Spirit Airlines Inc	258,075	0.516 %	237,720	0.746 %	236,966	0.744 %	0.0	0.000 %	0.0	0.000 %	3,730	0.649 %
Sun Country Airlines	60,093	0.120 %	51,281	0.161 %	49,860	0.157 %	64.3	0.003 %	189.5	0.196 %	869	0.151 %
Swiss International Airlines	148,050	0.296 %	71,610	0.225 %	72,768	0.229 %	10,632.4	0.570 %	484.0	0.500 %	700	0.122 %
TACA El Salvador	104,631	0.209 %	97,774	0.307 %	101,773	0.320 %	530.4	0.028 %	66.5	0.069 %	1,362	0.237 %
TNT Airways S.A.	396	0.001 %	0	0.000 %	0	0.000 %	0.0	0.000 %	0.0	0.000 %	4	0.001 %
Tampa Cargo	1,136	0.002 %	0	0.000 %	0	0.000 %	0.0	0.000 %	0.0	0.000 %	8	0.001 %
Thai Airways International Ltd	115,220	0.230 %	50,921	0.160 %	52,062	0.164 %	2,733.6	0.146 %	7.3	0.008 %	470	0.082 %
Turkish Airlines Inc	179,208	0.358 %	98,387	0.309 %	98,523	0.310 %	5,959.4	0.319 %	0.0	0.000 %	684	0.119 %
US Airways (Formerly US Air Inc)	953,838	1.907 %	933,530	2.930 %	934,315	2.935 %	2,320.6	0.124 %	5,100.6	5.270 %	12,318	2.144 %
USA Jet Airlines Inc	981	0.002 %	254	0.001 %	238	0.001 %	2.8	0.000 %	0.0	0.000 %	17	0.003 %
United Air Lines Inc	4,623,027	9.244 %	3,300,917	10.362 %	3,231,020	10.151 %	46,817.9	2.508 %	17,321.5	17.898 %	45,814	7.975 %
United Parcel Service Co	156,128	0.312 %	0	0.000 %	0	0.000 %	30,000.3	1.607 %	4,997.2	5.164 %	962	0.167 %
V Australia	402,204	0.804 %	206,650	0.649 %	212,659	0.668 %	10,275.2	0.551 %	0.0	0.000 %	1,454	0.253 %
Virgin America Inc	1,815,102	3.629 %	1,506,910	4.730 %	1,477,811	4.643 %	0.0	0.000 %	0.0	0.000 %	25,558	4.449 %
Virgin Atlantic	387,492	0.775 %	185,623	0.583 %	181,541	0.570 %	18,965.7	1.016 %	0.0	0.000 %	1,324	0.230 %
Vision Airlines	540	0.001 %	0	0.000 %	0	0.000 %	0.0	0.000 %	0.0	0.000 %	4	0.001 %
Volaris	160,543	0.321 %	215,873	0.678 %	206,058	0.647 %	0.0	0.000 %	0.0	0.000 %	3,665	0.638 %
Volga-Dnepr	1,208	0.002 %	0	0.000 %	0	0.000 %	0.0	0.000 %	0.0	0.000 %	4	0.001 %
Westjet	195,159	0.390 %	168,083	0.528 %	169,181	0.531 %	0.0	0.000 %	0.0	0.000 %	2,969	0.517 %
World Airways Inc	92,703	0.185 %	888	0.003 %	0	0.000 %	23,758.6	1.273 %	0.0	0.000 %	287	0.050 %
XTRA AIRWAYS	1,337	0.003 %	285	0.001 %	421	0.001 %	0.0	0.000 %	0.0	0.000 %	40	0.007 %
Yangtze River Express Airlines Co Ltd	123,122	0.246 %	0	0.000 %	0	0.000 %	19,427.7	1.041 %	1,035.1	1.070 %	376	0.065 %

Numbers may not add correctly due to rounding.

LAX Airline Market Share Summary for January 2012 to December 2012

	Revenue Pounds Landed (1000 lbs)	% of total Weight	Passenger Departures	% of Total Departures	Passenger Arrivals	% of Total Arrivals	Air Freight (tons)	% of Total Freight	Air Mail (tons)	% of Total Mail	Revenue Related Operations	% of Total Operations
Grand Total	50,010,678	100.000 %	31,857,135	100.000 %	31,830,986	100.000 %	1,866,431.5	100.000 %	96,778.5	100.000 %	574,477	100.000 %

Numbers may not add correctly due to rounding.

EXHIBIT I

THE PLANE TRUTH

Air Quality Impacts of Airport Operations and Strategies for Sustainability: A Case Study of the Los Angeles World Airports

A comprehensive project submitted in partial satisfaction of the requirements for the degree Master of Arts in Urban Planning from the University of California, Los Angeles

By: Colleen Callahan

Client: The Coalition for Clean Air

With support from: Environment Now

June, 2010

COALITION FOR CLEAN AIR

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Disclaimer

Neither the University of California, the School of Public Affairs, the Coalition for Clean Air, nor Environment Now either supports or disavows the findings in the report listed herein. University affiliations are for identification only; the University is not involved in or responsible for the project.

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Table of Contents

Executive Summary

Aviation facilitates economic and cultural exchange because it is one of the fastest and most efficient ways to transport products and people.[1] Aviation is also one of the most energy intensive and polluting modes of transportation.[2] Staff at the US Joint Planning Development Office predict that air pollution emissions from the aviation sector are likely to increase by 140 to 200 percent by 2025, unless aggressive actions are taken to control and reduce aviation‘s environmental footprint.[3]

This report was commissioned by the Coalition for Clean Air (CCA) ─ a non-profit organization that works to restore California‘s air quality through advocacy, outreach, and education ─ as a first step to potentially develop a campaign to reduce air pollution from airports in the Los Angeles region. The report provides a case study of the Los Angeles World Airports (LAWA), which owns and operates Los Angeles International Airport, Van Nuys Airport, Ontario International Airport, and Palmdale Regional Airport. As such, the report explores the LAWA as the basis to explore the following: 1) aviation‘s impact on local and global air pollution, 2) the sources of air pollution related to airport operations, 3) the current regulatory landscape that governs airport emissions, and 4) strategic opportunities to reduce emissions from these main sources of air pollution. The Los Angeles International Airport (LAX) is a focus of this report because LAX is the most significant source of airport-related air pollution in Southern California. In addition, the best emission source data and travel behavior data exist for LAX.

Airport-related pollution comes from numerous sources. Nitrogen oxides─ a precursor to ozone smog─ result in local and regional health impacts. The following sources contribute to nitrogen oxide (NOx) emissions from LAX-related operations:

1) Ground access transportation for travelers and cargo accounts for approximately 43 percent of NOx emissions from all LAX-related operations.
2) Aircraft accounts for 40 percent.
3) Ground service equipment accounts for 11 percent.
4) Airport vehicles account for four percent.

5) Stationary sources, primarily from energy production, account for two percent.

Any campaign to significantly and comprehensively reduce emissions from the LAWA-related operations should seek to address these emissions sources. There are myriad ways that clean air advocates could approach such a campaign. Based on communications with experts and an extensive literature review, I summarized 10 key findings and recommended associated actions for a clean air campaign based on these findings. My criteria for evaluating and prioritizing recommendations was based on: 1) impact– the importance of the recommended action in terms of emission reduction potential over the current baseline and 2) ease of implementation– the potential feasibility of a clean air advocacy organization based in Los Angeles to move the target agency to adopt the recommended action. I ranked the following five recommended actions as a high priority.

Create a Clean Air Action Plan for the LAWA

Finding: The LAWA's various environmental data collection, programmatic, and policy efforts concentrate on LAX while often not applying to its other airports. Van Nuys Airport has the second largest number of landings and take-offs in the Los Angeles County, however, the airport is virtually ignored in the LAWA's Sustainability Plan. Furthermore, there is only limited alignment between the environmental programs at LAX and at Ontario International Airport. Even at LAX, however, the LAWA does not coordinate its various air quality measures under a comprehensive plan.

Recommendation and Target: Clean air advocates should encourage the LAWA to set a health-based emission reduction goal for all three airports and develop a plan to comprehensively target airport-related emission sources through a consistent application of programs, goals, and policies among the three airports. Such a plan should be included as part of the Southern California Association of Governments' Regional Transportation Plan.

As a starting point, the LAX Community Benefits Agreement contains commitments that should be enforceable and applied to the other airports. A comprehensive clean air action plan should also include measures to protect vulnerable populations living near the LAWA airports. Effective and relatively inexpensive air filtration systems are available on the market and have already been installed in schools near the Ports of Los Angeles and Port of Long Beach, with support from the ports and the South Coast Air Quality Management District.

Ban Lead in Aviation Gasoline

Finding: Lead is banned in all fuel in the US except aviation gasoline (avgas). Avgas is used in piston-engine, normally non-commercial aircraft that frequent generation aviation airports including Van Nuys Airport, the largest general aviation airport in the world. On a national basis, avgas is the largest single source of air-borne lead emissions.[4] The lead found in leaded avgas is a potent neurotoxin. The US Centers for Disease Control and Prevention concluded in 2005 that there is ―no safe threshold for blood lead."[5] The Federal Aviation Administration (FAA) certified a non-lead alternative, AGE85, but it is not widely used in part because the FAA has been slow to certify AGE85 for all types of small planes. On April 28, 2010 the EPA Administrator Lisa Jackson issued an ―Advance Notice of Proposed Rulemaking on Lead Emissions From Piston-Engine Aircraft Using Leaded Aviation Gasoline".[6]

Recommendation and Target: Clean air advocates should submit comments to the EPA about the high levels of lead particulate found in the areas surrounding Van Nuys Airport and other general aviation airports in Los Angeles County, as well as the number of schools located within a three-mile buffer zone of key airports (see pages 37 through 39 for this information). Clean air advocates should then track the EPA's rulemaking process and advocate for a rule that will protect the approximately three million children who attend school and the up to 16 million adults who reside in close proximity to one or more of the almost 20,000 airports in the U.S. frequented by piston-engine aircraft.

Fully Implement the LAX Community Benefits Agreement

Finding: Implementation of the LAX Community Benefits Agreement (CBA) is moving at a slow pace and the LAWA has much further to go to meet many of its commitments as part of the CBA. For example, the LAWA agreed to convert all on-airport ground service equipment (GSE) to the cleanest technology available by 2015. Currently, only approximately a quarter of LAX's tenant GSE is zero-emission.[7]

Recommendation and Target: Monitoring the LAWA's progress in implementing the LAX Community Benefits Agreement (CBA) should be a high priority for clean air advocates because most major emission sources from LAX operations are addressed in the CBA. Clean air advocates should seek to ensure that the LAWA meets its commitments.

Focus on Heavy-duty Trucks

Finding: Ontario Airport is part of an expanding freight movement system in which trucks move freight from the Port of Los Angeles and Port of Long Beach to the Inland Empire's freight loading facilities, warehouses, rail yards, and airports. Diesel trucks also deliver products to airport tenants and airliners at LAX, which ranks 13th in the world in air cargo tonnage handled.[8] However, the LAWA does not track commercial truck trips at its airports.[9] The lack of data indicates a lack of focus on this emission source.

Recommendations and Target: First of all, clean air advocates should request that the LAWA collect and make publically available data on truck trips and their contribution to airport-related air pollution. This is important because managing a source of pollution requires the ability to measure that pollution source. Second, clean air advocates should request that the LAWA pursue a policy to phase-out the oldest and dirtiest trucks that enter onto the LAWA property. The LAWA should explore the San Pedro Ports Clean Trucks Program, already implemented at the Port of Los Angeles and Port of Long Beach, as a model program. The Clean Trucks Program progressively bans all trucks that do not meet the most recent (2007) federal emission standards by 2012.[10] The LAWA serves as a landlord at its airports and as such the LAWA should be able to set terms for the trucking companies that do business on its property.

Target Aircraft and Airports in State Implementation Plans

Finding: Although aircraft are a major source of air pollution comparable to industrial sources, they escape inclusion in State Implementation Plans, the US Environmental Protection Agency's (EPA) principal means of achieving cleaner air in air quality nonattainment areas.[11] This omission has serious consequences in efforts to both monitor and reduce air pollution.[12] In California, the Air Resources Board faces obstacles in its ability to regulate airport-related sources. However, the agency faces similar challenges in regulating the shipping and railroad industries and has found some creative ways to target emissions related to these industries.

Recommendation and Target: Clean air advocates should work with staff at the California Air Resources Board (CARB) to explore creative ways to address emissions from aircraft and other airport-related sources. In addition to exploring regulatory strategies, CARB should conduct more research about the health impacts, including cancer risk, from airports.

Introduction

REPORT CLIENT, OBJECTIVE, AND STRUCTURE

This report was commissioned by the Coalition for Clean Air (CCA). With offices in Los Angeles, Fresno, and Sacramento, the CCA is a statewide non-profit organization that since 1971 has worked to restore California‘s air quality through advocacy, outreach, and education. The report serves as a first step for the Coalition for Clean Air to potentially develop a campaign to reduce air pollution from airport operations in the Los Angeles region. Support for this research comes from Environment Now, a private non-profit foundation based in Santa Monica. Environment Now's mission is to be an active leader in creating measurably effective environmental programs to protect and restore California's environment.

The focus of this report is on the Los Angeles World Airports (LAWA), which owns and operates four airports in Southern California. The report aims to set a roadmap for staff at the CCA and other clean air advocates wanting to understand: 1) aviation‘s impact on local and global air pollution, 2) the sources of air pollution related to the LAWA operations, 3) the current regulatory landscape that governs the LAWA-related emissions, and 4) strategic opportunities to reduce emissions from these main sources of air pollution.

I begin the report by summarizing the problem of air pollution associated with airport-related emissions. Then, in the ‗Setting, Issues, and Analysis‘ chapter, I describe the regional and governing context in which the LAWA operates, introduce important environmental initiatives at the LAWA‘s airports, state the health and environmental impacts of key air pollutants, and describe what the literature reveals about air quality near airports. I then highlight the major sources of emissions from LAX operations. Finally, I analyze the state of regulations and programs that affect air pollution from the LAWA‘s operations, analyze the effectiveness of these efforts, and identify regulatory gaps and potential opportunities for additional emission reductions.

In the ‗Findings and Recommendations‘ chapter, I summarize 10 key problems and recommend associated actions that clean air advocates could encourage specific agencies to achieve. I develop these recommendations both from my review of the literature and from my communications with citizen activists, scientists, airport operations, and air regulators. My criteria for evaluating and prioritizing recommendations is based on: 1) impact– the importance of the recommended action in terms of emission reduction potential over the current baseline and 2) ease of implementation– the potential feasibility of a clean air advocacy organization based in Los Angeles to move the target agency to adopt the recommended action.

Figure 1

OVERVIEW OF THE PROBLEM

The aviation industry emits air pollution

Aircraft and the vehicles, facilities, and operations that support aviation emit many types of ―criteria air pollutants,‖[i] including nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and sulfur oxides (SOx) that cause local environmental and health problems. For example, NOx ─ combined with volatile organic compounds (VOC) in the presence of sunshine ─ is a key precursor to ground-level ozone. Ozone (smog) is a powerful oxidant that can damage the respiratory tract and induce symptoms such as coughing, chest tightness, shortness of breath, worsening of asthma symptoms, and even death.[13] The majority of our nation‘s busiest airports fall in ozone non-attainment areas.[14]

Aviation contributes approximately 0.5 percent of the total US inventory of NOx pollution.[15] According to members of the State and Territorial Air Pollution Program Administrators, NOx emissions from major airports are often greater than emissions from large stationary sources such as refineries and electrical generating facilities.[16] Table 1 shows the contributions that the nation‘s largest airports have on regional NOx inventories. Considering the myriad sources of NOx pollution, even a small percentage in the total NOx inventory represents a large amount of pollution.

Los Angeles International Airport is one of the largest sources of NOx and VOC emissions in the South Coast Air Basin.[17] The staff of the South Coast Air Quality Management District (SCAQMD) estimated that LAX contributes one percent of the Air Basin‘s annual NOx emissions. To put the airport‘s emissions in perspective, LAX‘s 6,522 tons of NOx emissions in 1993 placed it as the top emitter of this pollutant in the South Coast Air Basin, well ahead of second place Mobil Oil Corporation (2,731 tons), and third place Chevron Corporation (1,921

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[i] The U.S. Environmental Protection Agency sets National Ambient Air Quality Standards for six common air pollutants known as ―criteria pollutants" because EPA develops human health-based and/or environmentally-based criteria for setting permissible levels for these six pollutants. These pollutants are particle pollution (often referred to as particulate matter), ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. Source: U.S. Environmental Protection Agency, http://www.epa.gov/air/urbanair/.

tons). With regard to VOC, LAX's 1993 VOC emissions were almost three times the emissions from the basin's largest oil refinery and more than 10 times the VOC emissions from Santa Ana's John Wayne Airport.[18]

Table 1

Airport Contributions to NOx Inventories

Airport	National Rank (Enplanements)	Ozone Non-Attainment Status	Airport Contribution to Area NOx Inventory	Airport Contribution to Non-Road NOx Inventory
Hartsfield Atlanta International	1	Marginal	2.8%	14.1%
Chicago Nonattainment Area (ORD, MDW)	2 (ORD), 28 (MDW)	Moderate	0.8-2.0%	10.5%
South Coast California (BUR, LAX, LGB, ONT, SNA)	3 (LAX), 44 (SNA), 51 (ONT), 61 (BUR),93 (LGB)	Severe	1.5%	5.7%
Dallas/Fort Worth Air Quality Area (DFW, DAL, AFW)	4 (DFW), 53 (DAL)	Moderate	6.1%	19.9%
Houston Bush Intercontinental	8	Moderate	0.7%	3.3%

Source: Federal Aviation Administration, Office of Energy and Environment. "Aviation and Emissions: A Primer." January, 2005.
http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/aeprimer.pdf

Aircraft− just one source of airport-related emissions− is a major source of SOx pollution in the South Coast Air Basin. As illustrated in Table 2, aircraft are the fifth largest source of SOx emissions. The SCAQMD expects this ranking to jump to number three by 2014.[19] It should be noted that the most recent regional and state emission inventories do not address airport emissions cumulatively. Not included in the inventory are other sources of airport related emissions, such as the equipment that services the aircraft and the vehicles going to and from an airport. Therefore, the inventories underestimate the role that the aviation sector plays in emission inventories.

Table 2

Top 10 Sources of SOx Emissions (2002, 2014, and 2023) in the South Coast Air Basin, from Highest to Lowest

	2002	2014	2023
1	Ships & Commercial Boats	Ships & Commercial Boats	Ships & Commercial Boats
2	RECLAIM	RECLAIM	RECLAIM
3	Petroleum Refineries (non-RECLAIM)	Aircraft	Aircraft
4	Heavy-Duty Diesel Trucks	Manufacturing & Industrial Combustion	Manufacturing & Industrial Combustion
5	Aircraft	Light-Duty Passenger Cars	Light-Duty Passenger Cars
6	Trains	Light-Duty Trucks	Light-Duty Trucks
7	Off-Road Equipment	Service & Commercial Combustion	Service & Commercial Combustion
8	Light-Duty Passenger Cars	Petroleum Refineries (non-RECLAIM)	Petroleum Refineries (non-RECLAIM)
9	Manufacturing & Industrial Combustion	Waste Burning & Disposal	Waste Burning & Disposal
10	Light-Duty Trucks	Residential Fuel Combustion	Residential Fuel Combustion

Source: South Coast Air Quality Management District, "2007 Air Quality Management Plan." http://www.aqmd.gov/aqmp/07aqmp/draft/07aqmp.pdf.
A total of 48 airports were identified as having reportable operations within the District boundaries.

Aircraft is currently not one of the top ten emitters of NOx in region, but SCAQMD expects aircraft's contribution to NOx pollution in the South Coast Basin to grow significantly to the fourth top source of NOx pollution by 2023, as indicated in Table 3.[20] This is due to expected growth in air travel and reductions in other sources of emissions.

Table 3

Top Ten Sources of NOx Emissions (2002, 2014, and 2023) in the South Coast Air Basin, from Highest to Lowest

	2002	2014	2023
1	Off-Road Equipment	Heavy-Duty Diesel Trucks	Ships & Commercial Boats
2	Heavy-Duty Diesel Trucks	Off-Road Equipment	Off-Road Equipment
3	Light-Duty Passenger Cars	Ships & Commercial Boats	Heavy-Duty Diesel Trucks
4	Light-Duty Trucks	Light-Duty Trucks	Aircraft
5	Ships & Commercial Boats	Light-Duty Passenger Cars	Trains
6	Medium-Duty Trucks	RECLAIM	RECLAIM
7	Heavy-Duty Gasoline Trucks	Heavy-Duty Gasoline Trucks	Light-Duty Trucks
8	Trains	Trains	Residential Fuel Combustion
9	RECLAIM	Residential Fuel Combustion	Light-Duty Passenger Cars
10	Residential Fuel Combustion	Aircraft	Heavy-Duty Gasoline Trucks

Source: South Coast Air Quality Management District, "2007 Air Quality Management Plan." http://www.aqmd.gov/aqmp/07aqmp/draft/07aqmp.pdf.
A total of 48 airports were identified as having reportable operations within the District boundaries.

Aviation emits greenhouse gases

The Intergovernmental Panel on Climate Change concluded in 1999 that aircraft alone accounted for 13 percent of all carbon dioxide emissions (CO2) from the transportation sector and was responsible for 3.5 percent of global climate change.[21] CO2 is the greenhouse gas with the most significant impact on climate change. Airplanes emit more CO2 per passenger-mile than most other modes of transportation because of their high energy intensity.[22]

While aircraft fuel efficiencies have steadily increased over the past several decades, demand for air travel has grown more rapidly than efficiency improvements, causing CO2 and other greenhouse gases emissions to continue to increase.[23] These trends will continue under a ―business-as-usual" scenario where the global economy continues to grow over the long-term and there are no specific policies targeting aviation related greenhouse gas emissions.[24] Table 4 illustrates the growth in US world greenhouse gas emissions.

Table 4

US and World Greenhouse Gas Emissions

	Units: Millions of metric tons of CO2 equivalent	Year: 1990	Year: 2005	% Change from 1990 to 2005
World	Total Aircraft: Domestic and International	—	641.0	—
United States	Commercial, Domestic	136.7	150.4	10% increase
	General Aviation, Domestic	9.4	13.8	47% increase

Source: McCollum, D.; Gould, G.; Greene, D. "Greenhouse Gas Emissions from Aviation and Marine Transportation: Mitigation Potential and Policies." Pew Center on Global Climate Change. Dec 2009.

Air travel is down, but long-term growth will likely occur

The US aviation industry experienced turbulence during the first decade of the twentieth century. Negatively impacted by the September 11, 2001 terrorist attacks, the industry rebounded by 2006. However, unprecedented fuel prices in 2008 followed by a worsening global economic recession constrained the airline industry in 2008 and 2009.[25] In 2008, the US airline industry experienced $5.8 billion in operating losses for the year and multiple bankruptcies. Prior to the fourth quarter of 2007, the industry had experienced six consecutive quarters of operating profits totaling $11.8 billion.[26]

During the first half of the decade, the Los Angeles World Airports announced several airport projects designed to accommodate expected growth in both passenger and cargo air traffic, but since then business at these airports has decreased. Such projects at Los Angeles International Airport (LAX) and LA/Ontario International Airport are still moving forward despite passenger and cargo operations that are lower than forecasted.

LA/Ontario International Airport (ONT) exemplifies the turbulence in the airline industry during this past decade. Until recently, ONT was setting growth records. Airlines flocked to the Inland Empire airfield in what Los Angeles Mayor Antonio Villaraigosa hailed as the "great first steps" to regionalizing air travel in Southern California.[27] However, ONT has been hit harder than any other airport in Southern California by the aviation fuel and economic crisis.[28] In the fall of 2008, flights were down approximately one-third from the previous year, frustrating promises by politicians to shift some service away from LAX.[29] Officials for the Los Angeles World Airports say that ONT and LAX are particularly affected because they are neither hubs nor headquarters for major domestic airlines; when economic times are bad, airlines concentrate flights at their hubs to save money and to take advantage of their established markets.[30]

Despite the recent dip in air traffic nationwide and locally, officials at the Federal Aviation Administration (FAA) continue to forecast long-term aviation growth. Their 2009 forecast for commercial aviation anticipates a sharp decline in activity in the near- term, with a return to growth over the long-term. Specifically, this forecast predicts that the US commercial aviation industry will break a new record and carry one billion passengers by 2016.[31] At a more local level, staff at the Southern California Association of Governments (SCAG) predict that air passenger demand in the region will more than double to 170 million passengers in 2030 and that air cargo will more than triple to 8.7 million tons in 2030.[32]

As aviation traffic increases, so will the environmental impacts

Airport-related air pollution and greenhouse gas emissions are projected to grow as the demand for air travel is expected to increase more than aviation technology, operations, or other advancements over the long-term.[33] In 2005, staff at the US Department of Transportation (DOT) predicted that aircraft greenhouse emissions would increase 60 percent by 2025.[34]

Other projections are even more staggering. In 2007, experts at the US DOT Volpe Center forecasted aviation-related CO_2 globally to rise from 572 million tons in 2000 to 1,228 million by 2025, a 114 percent increase.[35] These experts also predicted that NOx pollution around airports would rise from 2.5 million tons in 2000 to 6.1 in 2025, a 144 percent increase.[36] Finally, computations provided to the US House of Representatives by staff at the Joint Planning Development Office show that aviation noise pollution and air pollution emissions are likely to increase by a whopping 140-200 percent by 2025 under future aviation growth scenarios, unless aggressive actions are taken to control and reduce aviation‘s environmental footprint.[37]

While these predictions from 2005 and 2007 are likely somewhat inflated based on the recent downturn in air travel, the timeline for reaching these projected numbers has merely shifted. Given what will likely be a long-term increase in air travel, these emission forecasts cannot be ignored. Aviation will be able to count on technology to reduce some emissions per passenger mile, but the long-term growth in air travel— both an enabler and a product of the burgeoning global economy— is likely to outpace technology efficiency gains.[38] This is at a time when other sources of pollution are decreasing. For most states and localities with major airports and seaports, aircraft and international marine vessels are the only two source sectors where emissions are projected to increase in the future.[39]

Air quality regulators and airports managers face challenges― while also missing opportunities― to reduce airport-related air pollution

Airport-related emissions are subject to a complex, multidimensional patchwork of regulations and voluntary programs. Most airport-related emission sources are independently regulated through equipment specific regulations, standards, and operational guidelines, which are established by a variety of agencies. For example, stationary sources at airports, like power boilers and refrigeration chillers, must meet independent state regulations. And the Federal Aviation Administration is responsible for enforcing aircraft emissions standards established by the US Environmental Protection Agency based on the international standards set by International Civil Aviation Organization (ICOA).

The International Civil Aviation Organization (ICAO) is a United Nations intergovernmental body responsible for worldwide planning, implementation, and coordination of civil aviation. The United States is one of 188 participating member States. Under the basic ICAO treaty established in 1944, as long as a participating nation adopts aircraft emission standards that are equal to or more stringent than the ICAO's standards, it satisfies its obligations under ICAO.[40] Therefore, the ICAO sets emission standards for jet engines that are the basis of the FAA‘s aircraft engine performance certification standards, established through the EPA‘s regulations. The ICAO has long been the forum for evaluating the environmental performance of aircraft engines.[41]

The ICAO has taken a ―technology progressing” approach, raising standards within the capabilities of proven technologies and certified products (engines and aircraft) rather than a ―technology forcing” approach, which set standards based on technology that is not yet certified, still in the development process, or may not even exist.[42] The ICAO‘s approach is based on the premise that the safety of aircraft operations restricts the use of unproven new technologies.

The FAA and the ICOA, in a sense, limit the EPA‘s jurisdiction over airport related emission sources. The EPA has historically worked with the FAA and the ICAO in the development of international aircraft emission standards. The FAA enforces the aircraft emissions standards established by the EPA in alignment with the ICAO‘s standards. The ICOA itself does not have much authority to enforce the standards that they set.

Furthermore, federal law complicates the ability of airport proprietors or state and local air regulators from setting emission standards for aircraft or otherwise regulating air carriers.[ii] Although aircraft are a major source of air pollution comparable to industrial sources, they escape inclusion in State Implementation Plans, the EPA‘s principal means of achieving cleaner air in air quality nonattainment areas. Citing the prevention of interstate commerce conflicts, Congress purposefully left the Federal Aviation Administration out of the State Implementation Process (SIP) process and thereby the regional Air Quality Management Plans (AQMPs). This omission has serious consequences in efforts to reduce air pollution.[43] Because the FAA is not directly involved in the SIP planning process and emissions from aircraft cannot be addressed in AQMPs, state and local regulators must find ways to reduce emissions elsewhere.[44]

In California, the state‘s Air Resources Board (CARB) sets and oversees on-road vehicle emissions standards, fuel specifications, and some off-road sources, yet airport emissions are not represented cumulatively in the SIP. ―Regional aircraft” is only a line item (not differentiated by airport), ―ground service equipment” is hidden in the ―off-road source” category, ―stationary sources” are lumped with similar processes, and ―ground access vehicles” are lost within the huge ―regional on-road” category.[45] While the CARB can regulate airport-related sources that do not cross state borders, because state regulators do not cumulatively consider airport emissions, state regulation often does not specifically target an airport-related source. Instead, airport-related sources are placed in broader categories with non-airport related sources. For example, the CARB lumps ground service equipment in its ―In-Use Off-Road Diesel Rule.” Due in part to the broad scope of this rule, opponents of the diesel rule challenged it and the CARB ultimately severely weakened the rule. Emissions from this source remain significant.

Transportation to and from airports (for travelers and cargo) is another major source of air pollution, yet managing this source is particularly complex. On-road vehicles, which take passengers to and from the airport, meet federal tailpipe standards set by the US Environmental Protection Agency. While airport proprietors have only indirect control of this source, they and other local/regional agencies have significant influence over the factors that incentivize passengers and employees to use less pollution-inducing forms of travel to and from airports. The ‗Setting, Issues, and Analysis‘ chapter elaborates on this point.

[ii] This does not constitute official legal analysis or counsel.

International and national leadership is lacking in efforts to reduce greenhouse gas emissions from the aviation sector

While some countries− New Zealand, Australia, and members of the European Union− have taken steps to include aviation in their domestic greenhouse gas (GHG) cap-and-trade programs, the majority of GHG emissions from aviation are unregulated. Specifically, the US does not regulate greenhouse gas emissions at a national level.

The Kyoto Protocol— a protocol to the United Nations Framework Convention on Climate Change aimed at fighting global warming— did not include GHG emission limits from international aviation, leaving the regulation of GHGs from international flights to the International Civil Aviation Organizations (ICAO). The ICOA has not set standards for either GHGs or fuel efficiency.[46] According to the Federal Aviation Administration, it is working with the ICAO to evaluate policy options to limit or reduce GHG emissions from aviation. For several years the ICAO has been evaluating voluntary approaches and market approaches, such as emission trading, to limit aviation emissions growth while allowing continued expansion of air travel. Their preliminary results show that emission-related levies are not cost effective, but voluntary arrangements and emissions trading may be cost effective in limiting or reducing greenhouse gas emissions.[47]

Due to a lack of strong leadership at the international and national levels, voluntary local and regional leadership has become increasingly important but is currently limited. Laura Zahn conducted an investigation of what airport managers are doing to reduce greenhouse gas emissions from airport-based emissions. In her study, ―Cleaner Skies, Brighter Future," she found that a limited number of airport managers— predominantly in Europe, Canada, and the United States— are taking concrete steps to reduce airport-based greenhouse gas emissions. Zahn concluded that there are opportunities for cities and city-owned airports to work together to reduce overall emissions but that two key barriers remain: no consistent way to measure the success of implemented projects and no central tool to communicate those successes to other airports. According to Zahn, future progress hinges on developing these two tools.[48]

METHODOLOGY

The Los Angeles World Airports serves as a case study in this report. The Los Angeles World Airports (LAWA) owns and operates Los Angeles International Airport, LA/Ontario International Airport, and Van Nuys Airport. The LAWA also owns Palmdale Regional Airport, but because of virtually no operations at Palmdale Regional Airport, this report addresses only the aforementioned three airports. The Los Angeles International Airport (LAX) is a particular focus in this report, both because LAX is the most significant source of airport-related air pollution in Southern California and because the best emission source data and ground access travel behavior data exists for LAX.

Through an extensive literature review and by communicating with experts, I identified and analyzed the key regional, governance, political, economic, environmental, and regulatory conditions that affect the LAWA and air pollution from its operations. Specifically, I reviewed what the literature reveals about the air quality impacts of airports and then highlighted the emission sources associated with LAX. The LAWA has direct or indirect control over these emission sources but international, federal, state, and regional agencies also play a role. Consequently, my recommendations are not focused on merely one target agency or just one emission source.

I summarized 10 key findings and recommended associated actions. My objective was to prioritize the actions that clean air advocates could strategically request the target agency to pursue to maximize emission reductions. My criteria for evaluating and prioritizing actions was based on: 1) impact— the importance of the recommended action in terms of emission reduction potential over the current baseline and 2) ease of implementation— the feasibility of a clean air advocacy organization based in Los Angeles to move the target agency to adopt the recommended action. The findings and recommendations are organized by emission source. The people who I communicated with to write this report include:

- Joe Lyou, Executive Director of the California Environmental Rights Alliance and a leading member of the LAX Coalition
- Martin Rubin, Founder and Director of Concerned Residents Against Airport Pollution
- Ken Petche, US Environmental Protection Agency
- Jim Thomson, Aviation Data Base Products

- Bill Piazza, Los Angeles Unified School District, Environmental Health and Safety
- Suzanne Paulson, University of California, Los Angeles, Department of Atmospheric and Oceanic Sciences
- Norene Hastings, Environmental Specialist, Los Angeles World Airports
- Patrick Tomcheck, Senior Transportation Engineer, Los Angeles World Airports

While this report focuses on the opportunities to reduce local criteria and toxic air pollutants, I also address greenhouse gas emissions because there is a connection between local and global air pollution. In one specific circumstance there is a tradeoff, but in general, efforts to reduce criteria pollutants will also reduce greenhouse gas emissions. Unless specified, the recommendations that I provide apply to criteria, toxic, and greenhouse gas emissions. See the pull-out box on the following page for more details about this connection.

Given the nature of this topic, this report contains many terms and acronyms. The Appendix contains a glossary of definitions and acronyms.

Criteria Pollutants and CO2 Reductions Goals: Consistency and Tradeoff

Reducing the amount of fossil fuels burned in: 1) aircraft, 2) vehicles traveling to, from, and at airports, 3) airport ground support equipment, and 4) airport operations and construction, etc., in general, results in benefits both in terms of reducing criteria and toxic emissions associated with local health effects and also reducing greenhouse gas emissions associated with global climate change. Aircraft fuel efficiency improvements are made via: 1) aerodynamic aircraft improvements, 2) weight reductions, and 3) engine developments. The first two provide consistency between criteria pollutant reduction goals and greenhouse gas emission reduction goals. The engine development method involves emission tradeoffs.

Developments that reduce airplane weight or reduce aerodynamic drag can offer all-round emission benefits for criteria, toxic and greenhouse gas pollutants. Lightweight composite materials for the majority of the aircraft structure are beginning to appear and promise significant weight reductions and fuel burn benefits. The use of winglets, fuselage airflow control devices, and laminar fuel technology (which reduces airframe drag through control of the boundary layer), can increase aerodynamic efficiency and reduce fuel consumption.

On the other hand, engine developments require a balancing of the emissions produced to both satisfy operational need (fuel efficiency) and regulatory need (NOx and CO). This tradeoff is most difficult for those engines having the highest pressure ratios (PR). Higher PRs increase the temperature of the air used for combustion, exacerbating the NOx emissions challenge. Increasing an engine's PR is one of the main options manufacturers have to improve engine efficiency. Thus, an engine may be optimized for minimum NOx emissions, at which design point the engine will burn more fuel than it might otherwise have done. However, in general, reducing local pollutants from an airport related sources will also have climate benefits.

Source: Ribeiro, K.; Kobayashi, S.; Beuthe, M.; Gasca, J.; Greene, D; Lee, D.S.; Muromachi, Y.; Newton, P.J.; Piotkin, S.; Sperling, D.; Wit, R.; Zhou, P.J. "Transport and its Infrastructure." 2007. In "Climate Change 2007: Mitigation." Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer)eds)], Cambridge University Press, Cambridge, United Kingdom and New Yorlk, NY, USA.

Setting, Issues, and Analysis

SETTING: SOUTHERN CALIFORNIA

The Los Angeles World Airports (LAWA) owns and operates Los Angeles International Airport (LAX), LA/Ontario International Airport (ONT), and Van Nuys Airport (VNY). Although these represent just three of 57 airports in the five-county region of Southern California, they are the most significant in terms of traffic and air quality impacts. LAX is the sixth busiest airport in the world in terms of number of passengers and fourth busiest in terms of number of annual takeoffs and landings.

Table 5

World's Busiest Airports by Passengers in 2008

Rank	Airport	Location	Rank Change from 2007	% Change	Total # of Passengers in 2008
1	Hartsfield-Jackson Atlanta International	Atlanta, Georgia, US	–	▲0.7%	90,039,280
2	O'Hare International	Chicago, Illinois, US	–	▼9.0%	69,353,876
3	London Heathrow	Greater London, U.K.	–	▼1.5%	67,056,379
4	Tokyo International	Ota, Tokyo, Japan	–	▼0.2%	66,754,829
5	Paris Charles de Gaulie	Roissy, France	▲1	▲1.6%	60,874,681
6	Los Angeles International	Los Angeles, California, US	▼1	▼4.7%	59,497,539
7	Dallas-Fort Worth Internat.	Dallas/Fort Worth, Texas, US	–	▼4.5%	57,093,187
8	Beijing International	Beijing, China	▲1	▲4.4%	55,937,289
9	Frankfurt	Flughafen, Germany	–	▼1.3%	50,900,000
10	Denver International	Denver, Colorado, US	–	▲2.8%	46,164,063 (Jan-Nov)

Source: Airports Council International.

Van Nuys Airport is the world's largest general aviation airport, used by non-commercial (private and government) aircraft. Table 6 and Figure 2 highlight the operations— number of annual landings and takeoffs— at LAX and Van Nuys Airport compared to other main commercial and general aviation airports in Los Angeles County.

Table 6

Number of Takeoffs and Landings in 2008 for Los Angeles County Airports

Airport	Approximate Number of Annual Takeoffs and Landings
Los Angeles International Airport	623,000
Van Nuys Airport	380,000
Long Beach Airport	300,000
Zamperini Field	150,000
Santa Monica Airport	150,000
Burbank Airport	130,000
Whiteman Airport	115,000
El Monte Airport	90,000
Hawthorne Airport	80,000
Compton Airport	65,000

Source: Federal Aviation Administration, 5010 Data: http://www.faa.gov/airports/airport_safety/airportdata_5010/ and the Los Angeles World Airports.

Figure 2

Airports In Los Angeles County
Whitman
Van Nuys
Bob Hope/Burbank
El Monte
Santa Monica
Hawthorne
Los Angeles Internatinal
Long Beach/ Daugherty Field
Compton
Zamperini Field
Pacific Ocean
N
0 4 8 16 24 32 Miles
Oregon
Nevada
California
Los Angeles County
Ten Airports
Source: UCLA Mapshare
Map by: Colleen Callahan

AIRPORT OWNERSHIP AND GOVERNANCE

Most US commercial service airports are typically owned by a local or state government, either directly or through an authority (a quasi-governmental body established to operate the airport). While Congress established a "privatization program" in 1997 under which the airport ownership could be transferred to a non-governmental entity, no airports currently participate in this program. US airports are typically managed in one of three ways:[49]

1. Management by a city, county or state. Examples of airports in this category include Atlanta, Pittsburgh, and Honolulu. In a few instances, such as Los Angeles and St. Louis, the airport is governed by an appointed commission which in turn reports to the City Council or Board.
2. Management by an airport authority. These entities are autonomous and have an appointed board that makes policy and financial decisions. Orlando, Minneapolis, and San Diego are a few examples.
3. Port Authority management. These airports are managed as part of a multi-modal entity. Examples include the Port Authority of New York and New Jersey, Seattle, and Portland.

The airport operator is responsible for the airport's long- and short-term planning, financial performance, maintenance, operation and compliance with numerous federal, state and local laws and regulations.[50] Some airports operate multiple airports within its system, such as the Los Angeles World Airports.

The Los Angeles World Airports (LAWA) is a municipal department of the City of Los Angeles. A seven-member Board of Airport Commissioners governs Los Angeles World Airports. By the Charter of the City of Los Angeles, the Board is responsible for the formulation of airport policy. The Board is composed of business and civic leaders who are appointed by the Mayor, approved by the City Council, and serve staggered five-year terms.

Los Angeles Mayor Antonio Villaraigosa named five of the current members of the Los Angeles Board of Airport Commissioners on July 25, 2005. They are labor leader Joseph A. Aredas; Alan Rothenberg, an executive and business leader; Fernando Torres-Gil, associate Dean of the UCLA School of Public Affairs; attorney Michael A. Lawson; and Valeria C. Velasco, also an attorney. The mayor also reappointed Airport Commissioner Walter Zifkin. The City Council later confirmed Sam Nazarianon. President Alan Rothenberg was first elected as president on Sept. 14, 2005.[51]

REGIONALISM

The current airport management system in the Southern California region is among the most decentralized and complex in the nation, if not the world.[52] Ten separate governing bodies operate the 12 commercial airports. The organization of these bodies range from municipal departments (the LAWA and Long Beach's Public Works Department), to county agencies (Orange County's John Wayne Airport) to facilities operated as Joint Powers Authorities (Bob Hope Airport operated by the Burbank-Glendale-Pasadena Airport Authority).[53]

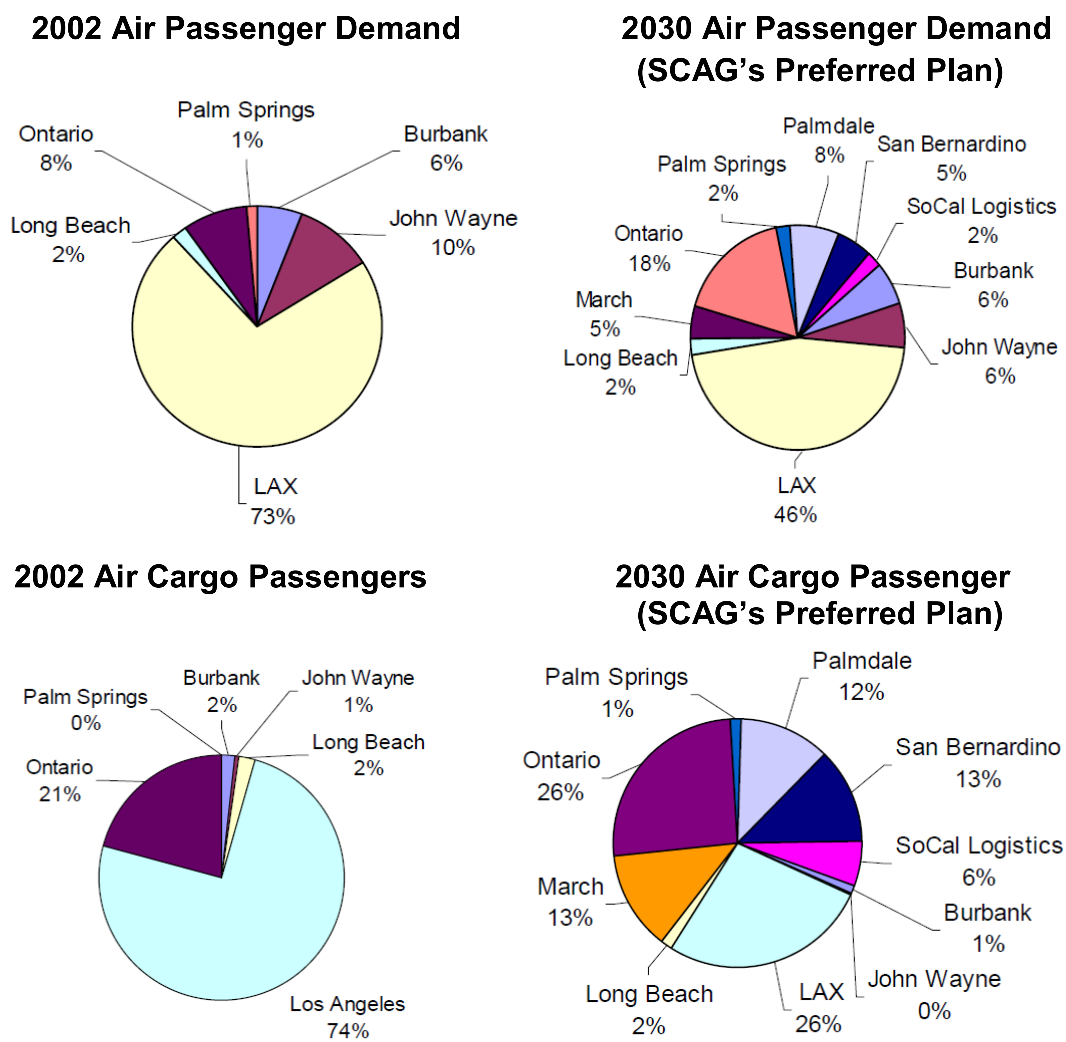
Clifton Moore, Executive Director of the Los Angeles' Department of Airports (later renamed the Los Angeles World Airports) from 1968-1992, was a strong advocate for airport regionalization. He came to argue that growing community opposition limited LAX expansion prospects and that new airport capacity was needed in outlying areas. Moore proposed the creation of a new regional airport authority to ―appropriately accommodate regional aviation demand."[54] In 1985, the Counties of Los Angeles, Riverside, San Bernardino, and the City of Los Angeles signed a joint powers agreement, officially creating the Southern California Regional Airport Authority (SCRAA). Orange County originally declined membership but in 1992 decided to join the SCRAA on the condition that each member had contractual veto power over the authority's decisions.[55]

Soon thereafter, members of the SCRAA were in conflict over battles featuring the LAX Masters Plan and a proposed commercial airport at the recently closed Marine Corps Air Station El Toro in South Orange County. The group advocating against the airport proposal consisted primarily of residents of Irvine, Lake Forest, Laguna Niguel, and other cities in proximity to El Toro. The cities opposed to the airport created a joint powers authority, the El Toro Reuse Planning Authority to oppose the project.

After Orange County voters in 2002 rejected a commercial airport at El Toro (Measure W), members of the SCRCC advocated for a proposed ―airport without runways" high speed rail system to run from Anaheim to Inland Empire airports. But by 2004 the SCRCC became dormant for a lack of a quorum when Orange and Riverside Counties withdrew because of airport development conflicts and the City of Los Angeles failed to send a representative, ostensibly because of L.A. County's use of the SCRCC to oppose the LAX Master Plan.[56]

In recent years there has been a shift in the policy focus and political tenor of aviation debates in Southern California. The focus has changed from adding capacity to making better use of capacity already available at suburban airports in a strategy termed “regionalism.” The SCAG‘s Regional Aviation Plan— part of the 2004 Regional Transportation Plan— recommends strategies for decentralizing passenger and air cargo service from congested urban airports to suburban airports. The Regional Aviation Plan also recommends a new “Regional Airport Consortium” for coordinating airport master planning, facilities construction, and ground access transportation policies and planning. Staff at the SCAG note that the SCRAA could be reinvigorated to serve as a consortium.

Figure 3



Source: Armstrong, M. “Regional Aviation Planning in Southern California.” Presentation at the 33rd Annual FA Aviation Forecast California Meeting. March 11, 2008.

THE LAWA OWNED AND OPERATED AIRPORTS

Ontario Airport

Source: Los Angeles World Airports

LA/Ontario International Airport (ONT) is an airport with commercial jet service to major US cities and international destinations. The airport is the centerpiece of one of the fastest-growing regions in the United States. ONT's service area includes a population of six million people living in San Bernardino and Riverside Counties and portions of north Orange County and east Los Angeles County. Passenger traffic at ONT has increased over the past 10 years. In 2006, 7 million passengers used the airport. ONT's has approximately 220 flights per day and a total of approximately 120,000 landings and takeoffs per year.[57]

History: The "new" Ontario International Airport opened September 27, 1998. The $270 million project included two new terminals at 265,000 square foot each, a new ground transportation center, an additional parking lot, a new roadway system, airfield improvements, landscaping, and a site storm-drain system. The new terminals are eight times larger than the former terminal and can accommodate up to 10 million passengers a year. LAWA plans to construct a third terminal when passenger traffic at ONT reaches 10 million in two consecutive years.[58]

Freight transport: ONT is part of a freight movement system that includes the airport, two railroads, and four major freeways. Although ONT is not located as close to the Ports of Los Angeles and Long Beach as many other airports in the region, it is located in proximity to the freight transfer facilities, warehouses and logistics centers where trucks and trains take freight to be loaded, organized, and distributed to its final destination. The airport moved 602,326 tons of air freight in 2006. Major US air freight carriers include Ameriflight, Federal Express, Kalitta Air, and United Parcel Service.[59]

Master Plan: LAWA is in the process of developing a new master plan for the Ontario International Airport. As such, LAWA has forecasted major growth in operations, as illustrated from the following three tables.

Table 7

Proposed Ontario Airport Master Plan Recommendation 2030

	2006	2030	Increase
Aircraft Passenger Gates	26	71	173 %
Rental Car Facilities (Acres)	26.5	73	175 %
Cargo Facilities (Acres)	100	254	154 %
Parking Spaces	6,575	30,680	366 %

Source: Los Angeles World Airports, LA/Ontario Proposed Master Plan Recommendations 2030. Master Plan and Environmental Impact Scoping Meeting. September 7, 2007.

Table 8

The LAWA's Forecast for Ontario Airport

Year	2006	2030	Increase
Annual Operations (Takeoffs and Landings)	108,191	383,987	254 %
Total Cargo Volumes (Tons)	544,600	3, 260,000	500 %
Passengers	9 million	33.4 million	271 %

Source: Los Angeles World Airports, LA/Ontario Proposed Master Plan Recommendations 2030. Master Plan and Environmental Impact Scoping Meeting. September 7, 2007.

Van Nuys Airport

Surprisingly to many Angelinos, Van Nuys Airport (VNY) ranks as the world's busiest general aviation airport. As such, VNY is dedicated to non-commercial air travel, serving a variety of private, corporate, and government aircraft.[60]

VNY averages close to 400,000 takeoffs and landings annually. The Mayor of Los Angeles signed the VNY Master Plan in 2006. The Master Plan does not add acreage to the existing 730-acre airport, but does state the LAWA's intent to establish VNY as the Southern California general aviation center for the next 20 years.[61]

Source: Los Angeles World Airports

Los Angeles International Airport

Los Angeles International Airport (LAX) is the world's busiest origin and destination (O & D) airport. O&D passengers are those beginning or ending their trips in Southern California rather than using the airport for connecting flights. Based on number of passengers, LAX is the sixth busiest airport in the world. In 2008, the airlines of LAX served 59.8 million passengers.[62]

Freight: LAX ranks 13th in the world in air cargo tonnage handled.[63] In 2008, the airlines of LAX handled 1.8 million tons of freight and mail, with more than 1,000 flights departing and arriving every day carrying cargo. The majority of the air cargo at LAX arrives and departs in the bellies of passenger aircraft, allowing airlines serving LAX to offer some of the lowest airfares to travelers. More than 50 percent of LAX air cargo activity is international in origin or destination.[64]

Economics: The annual budget for LAX was more than $524.1 million for 2008. According to the LAWA, LAX contributes $61 billion to the economy annually, and is a source of jobs.[65]

Source: Los Angeles World Airports

Regional issues: LAX handles 70 percent of the passengers and an estimated 79 percent of the air cargo for a five-county Southern California region.[66] Thirteen percent of LAX passengers come from Orange County.[67] In the 1990's and early 2000's, Orange County residents opposed proposals to build an international airport in South Orange County at the former Marine Corps Air Station, El Toro. The area is now designated as park land.

LAX Master Plan**:** In 2001, staff at the Los Angeles World Airports (LAWA) announced a new airport expansion plan. In December 2004, the Los Angeles City Council approved the LAX Master Plan and related entitlements for the future development of LAX. The LAX Master Plan provides the first major airport expansion plan since 1984. A main goal of the LAX Master Plan was to accommodate the expected growth in the number of passengers at LAX through the year 2015. Specifically, the gates would be reconfigured to accommodate larger planes and approximately 90 million annual passengers, up from its then current traffic of 61 million. In addition, the plan initially proposed doubling the airport's cargo capacity from almost two million tons to more than four million, but ultimately settled for expanding to about three million tons.[68]

The LAX Master Plan serves as a broad policy statement regarding planning for projects, such as the Bradley West Project. The draft Environmental Impact Report for this project, released in May, 2009, states that this project, consistent with the LAX Master Program, would result in ―unavoidable significant air quality impacts for construction and operations-related emissions" (1-14). [69]

In summary, the LAX Master Plan and the elements therein, are moving forward and are designed to accommodate increases in passengers and cargo. While the airport is used by residents of the entire country and beyond, the LAX-adjacent communities that suffer the daily impacts of airport operations – traffic congestion, air pollution, and noise pollution– could find those problems exacerbated with implementation of the LAX Master Plan.[70]

LAX COMMUNITY BENEFIT AGREEMENT

In 2000, Attorney Jerilyn Lopez Mendoza, who at the time worked for the nonprofit organization Environmental Defense, was monitoring the proposed LAX expansion and she suggested the obvious plan of attack for the environmental justice community: a Title VI complaint under the Civil Rights Act of 1964.[71] ―Based on LAWA‘s own analysis of the expansion—more cars, more trucks, more people—it would have a disparate impact on people of color," Lopez Mendoza said.[72] However, in April 2001, the United States Supreme Court tossed a wrench in Mendoza‘s plan with its decision in *Alexander v. Sandoval* (2001). The Supreme Court held that Title VI did not give rise to a private cause of action, which means that only public agencies (rather than private citizens) can file suits based on evidence of disparate impact. With a Title VI lawsuit no longer in the cards, Lopez Mendoza and others began to explore strategies that did not involve litigation.

In the summer of 2003, members of the Los Angeles Alliance for a New Economy (LAANE) met with community members, elected officials, and representatives from several nonprofits and churches to discuss pursuing a community benefit agreement as a way to address and mitigate LAX expansion impacts without litigation. By September 2003, the essential participants had gathered− 25 groups strong─ into the LAX Coalition, which consisted of two school districts (Inglewood Unified School District and Lennox School District), twelve community organizations, seven environmental organizations, and four labor unions.

In February 2004, LAX Coalition representatives had their first meeting with officials of the LAWA. Reverend William Smart from the LAANE led the negotiations for the Coalition. Jim Ritchie, Deputy Airport Director, was the principal negotiator for the LAWA. The LAWA staff had a powerful negotiating tactic in their communication with the Federal Aviation Administration and the revenue diversions rule, which states that airport revenue cannot be used for funding of non-airport-related purposes. Officials from the LAWA would claim that some of the measures on the LAX Coalition‘s program request list did not constitute a close enough nexus with airport operations.[73]

Although officials from the LAWA and members of the LAX Coalition often wanted different things, they both wanted an agreement. On February 15, 2005, the LAX Coalition and the LAWA signed the community benefits agreement

(CBA) and cooperation document. The cooperation document is the legally binding contract between the LAX Coalition and LAWA. The CBA serves an attachment to the cooperation agreement and describes all the programs and policies agreed on in the cooperation agreement.[74]

The Final Agreement

The CBA —sets forth a range of community benefits and impact mitigations that will be provided by the Los Angeles World Airports as part of the LAX Master Plan Program, and an ongoing role for the LAX Coalition in implementation and oversight of these benefits and mitigations."[75] The main environmental benefits and mitigations related to air pollution are as follows:[76]

1. Air quality study. Details are in a preceding section of this report.
2. Health study. The LAWA will fund a study to measure and investigate upper respiratory and hearing loss impacts for LAX operations due to the LAX Master Plan Program.
3. Air quality mitigation measures. The main components include:
   - **a.** Electrification of Passenger Gates: By 2010, 100 percent of the passenger gates shall be equipped and able to provide electricity to parked aircraft.
   - **b.** Electrification of Cargo Operations Areas: The LAWA shall ensure that unless determined operationally and/or technically infeasible, five years from the effective date of this Agreement, 100 percent of all cargo operations areas shall be equipped and able to provide electricity to parked aircraft.
   - **c.** Electrification of LAX hangars: The LAWA shall conduct an assessment of operations at LAX hangars.
   - **d.** Construction equipment: The LAWA shall require that all diesel equipment used for construction related to the LAX Master Plan Program be outfitted with the best available control devices primarily to reduce diesel emissions of PM, including fine PM, and secondarily, to reduce emissions of NOx.
   - **e.** ULSD and other fuels: All construction equipment shall use only Ultra-Low Sulfur Diesel fuel (15 parts per million or lower), as supplies allow.

f. Ground service equipment diesel emissions reduction incentive program: LAWA shall create a program providing incentives for the reduction of emissions from ground service equipment, expending at least $500,000 on the program.

g. Ground service equipment inventory: The LAWA shall prepare a study detailing all ground service equipment operated on-site.

h. Emission reductions from On-Road trucks, buses, and shuttles: LAWA shall fund a study of on-road heavy-duty vehicle traffic related to LAX operations. LAWA shall ensure that by 2010, 50 percent of the covered vehicles (on-road vehicles, including trucks, shuttles, passenger vans, and buses that are 8,500 gross vehicles weight rating or more and are used in operations related to LAX) operated by any airport contractor, airport lessee, and airport licensee are alternative-fuel vehicles or operational low NOx standard vehicles. By 2015, LAWA shall bring that percentage up to 100 percent.

i. Limits on diesel idling: LAWA shall prohibit diesel-powered vehicles from idling or queuing for more than 10 consecutive minutes on-site, unless CARB adopts a stricter standard, in which case LAWA shall enforce that standard.

j. Cleaner burning jet fuels: LAWA shall support efforts to encourage the airlines and petroleum industries to embark on a study to promote the use of jet fuels that minimize air pollutant emissions from jet engines.

4. Green building principles. LAWA agreed to incorporate Leadership in Energy and Environmental Design (LEED) building standards into the all aspect of LAX Master Plan to the extent practical and feasible.

5. Energy Conservation and Green Power.

a. LEED Building Standards: On January 22, 2007, the Board of Airport Commissioners (BOAC) adopted a policy requiring new remodeling and tenant improvement construction projects at all LAWA facilities to include design and construction elements that comply with or are substantially consistent with the highest possible Leadership in Energy and Environmental Design (LEED) standards, or their practical equivalent.

b. LAWA has agreement with the City's Department of Water and Power committing to 25 percent Green Power in all LAWA facilities.

c. Dedicated in September 1998, the LA/Ontario International Airport complex was designed with energy conservation in mind.

d. The Tom Bradley International Terminal at LAX is undergoing major renovations that will make the facility more energy efficiency. This project has been registered for LEED certification and the facility will offer a 15 percent energy savings over the ASGRAE 90.1-2001 Energy Standard.

Implementation of the CBA

Since the CBA signing, members of the LAX Coalition and officials from the LAWA continue to meet to move the implementation process forward. However, there have been several setbacks and delays. The mayoral election in 2005 affected the pace of implementation. The new mayor appointed Lydia Kennard as executive director of the LAWA and Kennard was generally less in favor of the CBA compared to the former executive director, Kim Kay.[77] The political scene was further complicated by a settlement agreement between the LAWA and the City of Inglewood, City of El Segundo, County of Los Angeles, and the Alliance for a Regional Solution to Airport Congestion, that were not partners in the CBA. According to members of the LAX Coalition, the litigation diverted valuable city staff time and slowed down implementation of the CBA.[78]

By far the biggest challenge for the LAX Coalition was the Federal Aviation Administration (FAA), which needed to approve some of the CBA's components in order to ensure that provisions did not violate the revenue diversion rule. The FAA denied the job training program as outlined in the CBA. In addition, the FAA approval of the school settlement agreement has been difficult because the FAA believed that the school districts' 1980s agreement precluded the need for an additional agreement. While approval was finally granted by the FAA, the school districts have not been awarded any mitigation funding as of the spring of 2009.[79] As a result, the schools located in the flight path of LAX continue to experience significant levels of noise and air pollution that impact student learning and the ability to participate in physical education.

Officials at the LAWA have used the economic downturn as an explanation for the slow progress in implementing many measures of the CBA.

For example, off-airport parking companies are required by the CBA to have 50 percent of their fleet run on alternative fuel by 2012, but little progress has been made. According to LAX staff, there are very few alternative fuel off-airport parking shuttles, taxicabs, door-to-door vans being used in the LAX CTA.[80] In addition, the LAWA agreed to convert all on-LAX ground service equipment to the cleanest technology available; however, only approximately 25 percent of ground service equipment is zero-emission electric.[81]

Despite setbacks and delays in implementation of the CBA, the members of the LAX Coalition continue to monitor and guide the process. Doing so until the cooperation agreement expires in 2020 requires a major commitment from the members of the LAX Coalition, many of which are nonprofit and community group with small budgets and limited staff and/or volunteer capacity.

LAX Air Quality and Source Apportionment Study

As required by the CBA, the Los Angeles World Airports is in the process of undertaking the largest and most comprehensive study ever of air quality around a major airport with the goal of fully identifying emission sources in the area around the airport and also attempting to, for the first time, scientifically and measurably apportion the contribution of ambient air quality of these sources. Efforts to initiate the LAX Air Quality and Source Apportionment Study go back nearly a decade, but were short-circuited after the events of September 11, 2001. As part of the CBA and the Stipulated Settlement as part of the LAX Master Plan, the LAWA agreed to re-initiate the Study. [82]

The effort to kick-off this project involved the development of a Technical Working Group composed of air quality scientists, researchers, and engineers from the various governmental agencies as well as representatives of the LAX Coalition and the City of El Segundo. While the LAWA retains ultimate decision-making authority and responsibility for the study, the Technical Working Group strives for consensus-based decision-making.[83]

Efforts are currently underway to complete the study, which is broken into two main components:

1. Technology and Methodology Feasibility Demonstration Project (Phases 1 & 2) - Monitoring is to be conducted at five on-airport locations to evaluate techniques.

2. Long-Term Study (Phase 3) - Using the results of the Demonstration Project, the final phase of work will evaluate and document the contribution of LAX to area emissions.[84]

The Study's Technical Working Group has reviewed the draft documentation from the Technology and Methodology Feasibility Demonstration Project (Demonstration Project) and recommended that before launching into the Long-Term Study (Phase 3), additional evaluation of the Demonstration Project data is needed. This ongoing additional evaluation of the Demonstration Project is termed ―Phase 2.5." After the work in Phase 2.5 is completed, the LAWA will then go back to the Board of Airport Commissioners with the newly developed Phase 3 scope to seek authorization and funding for the Long-Term Study.[85] Once Phase 2.5 is authorized and funded, staff at the LAWA will formulate a public outreach plan and schedule a public meeting about the project. [86]

THE LAWA'S SUSTAINABILITY EFFORTS

In 2007, Mayor Villaraigosa released "Green LA-An Action Plan to Lead the Nation in Fighting Global Warming."[87] The goal of the plan is to reduce the City of Los Angeles' greenhouse gas emissions by 35 percent below 1990 levels by 2030. Likewise, the LAWA set a target of reducing its greenhouse gas emission levels to 35 percent below 1990 levels by the year 2030. In order to quantify its emissions, identify areas for improvement, and evaluate the effectiveness of its reduction measures, the LAWA is performing a comprehensive GHG emission inventory.

In addition to the Green LA plan, Mayor Villaraigosa released his Executive Directive on sustainable practices in 2007. Echoing Mayor Villaraigosa‗s commitment, Los Angeles Councilmember Bill Rosendahl introduced a motion that requires LAX to be ―built and held to the highest green standards." In response, the Los Angeles Board of Airport Commissioners adopted the ―Los Angeles World Airports Sustainability Plan" in 2008. [88] The plan establishes the following fundamental objectives:[89]

1) Increase water conservation in all airport facilities and for all operations.
2) Increase use of environmentally and socially responsible products.
3) Increase recycling and source reduction efforts at all facilities and for all operations.
4) Reduce energy usage and increase usage of green power at all airport facilities and in all operations.
5) Reduce emissions from all operations.
6) Reduce single occupancy trips to, from, and within LAWA airports.
7) Incorporate sustainable planning, design, and construction practices into all airport projects.
8) Promote sustainability awareness to airport employees and the greater community.
9) Integrate sustainable practices into internal policies, business processes, and written agreements.

There is considerable overlap between the measures that the LAWA agreed to implement as part of the CBA and the measures that the LAWA now promotes as part of its Sustainability and Environmental Initiatives. The ‗Findings and Recommendations‗ section elucidates on this point and highlights the specific efforts that the LAWA is taking to achieve these objectives.

AIR POLLUTION

The Clean Air Act requires the EPA to set National Ambient Air Quality Standards for six common air pollutants found all over the US. They are: particulate matter, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. Airports operations emit all of these pollutants along with toxic air pollutants and greenhouse gases. I have already described some of pollutants and their impacts earlier in this report. The following section provides more detail about key pollutants related to airports in the Los Angeles region.

Lead Pollution

Lead is a metal now banned in the kerosene fuel used in commercial aircraft in the US In fact, due to its toxicity, the Clean Air Act of 1990 originally stated that all leaded fuels would be eliminated by 1996. However, the Clean Air Act of 1990 was later amended to include one exemption― for aviation gas (avgas). Avgas is a leaded fuel used in non-commercial, piston-engine aircraft (private, corporate, and government jets) that frequent general aviation and air taxi airports. Avgas contains four times more lead than leaded gasoline before it was banned from new cars in 1973.[90] Emissions of lead from avgas are the largest single source category for emissions of airborne lead in the US, comprising approximately half of the national inventory.[91]

The tetra-ethyl lead found in leaded avgas and its combustion products are potent neurotoxins. The US Centers for Disease Control and Prevention (CDC) concluded in 2005 that no ―safe threshold for blood lead has been identified."[92] Lead can adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems and the cardiovascular system.[93] The lead effects most commonly encountered in current populations are neurological effects in children and cardiovascular effects (e.g. high blood pressure and heart disease) in adults. Infants and young children are especially sensitive to even low levels of lead, which may contribute to behavioral problems, learning deficits and lowered IQ.[94] Lead exposure can occur from breathing or swallowing lead particles/dust, or by eating soil or paint chips containing lead.[95]

Figures 4 and 5 illustrate that lead levels are elevated near airports. The correlation is especially apparent near airports with high levels of general aviation operations (takeoff and landings of private, corporate, and government jets), such as Van Nuys Airports with almost 400,000 general aviation operations in

2008, Long Beach Airport with about 300,000 general aviation operations in 2008, Santa Monica Airport with approximately 150,000 general aviation operations, and Whiteman Airport with about 115,000 general aviation operations.

Figure 4

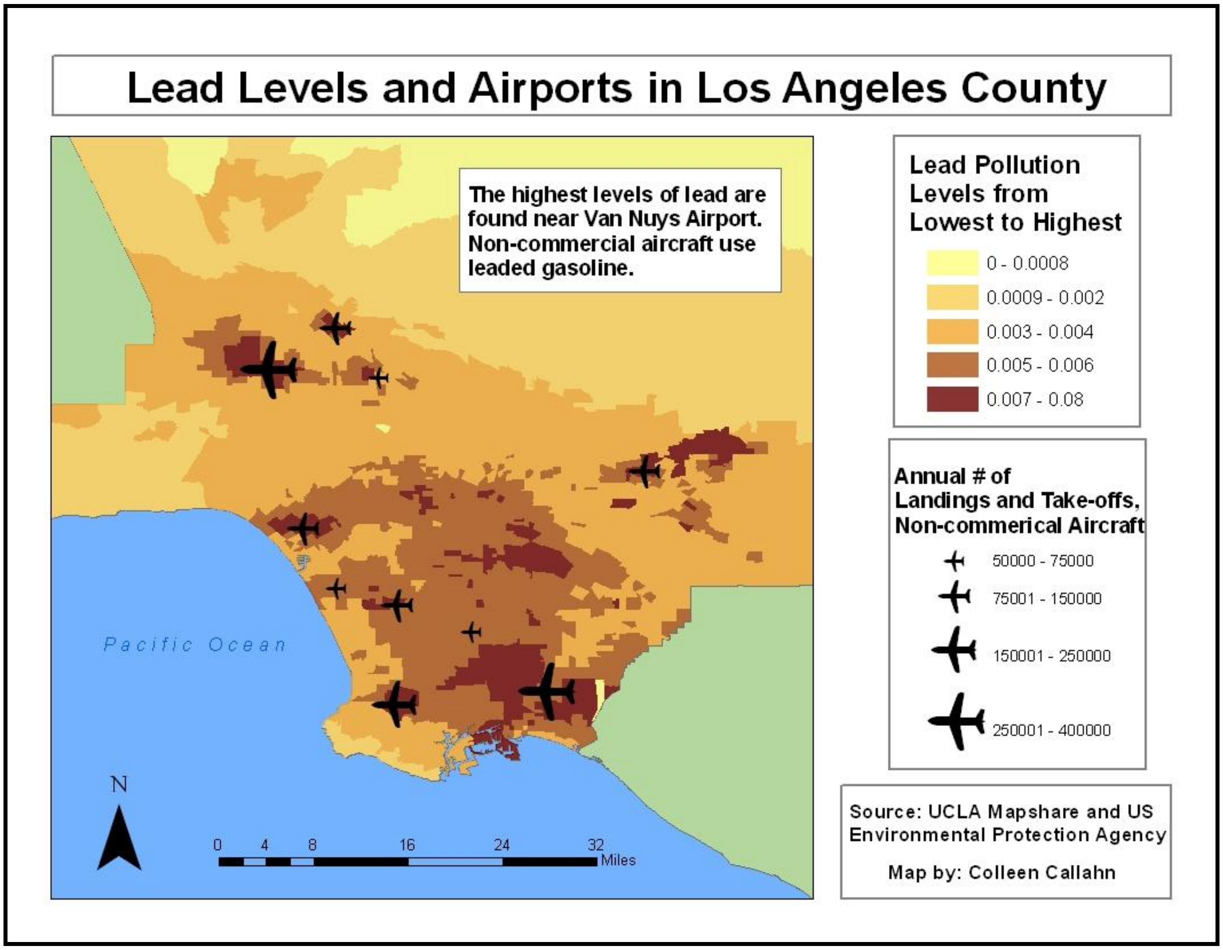
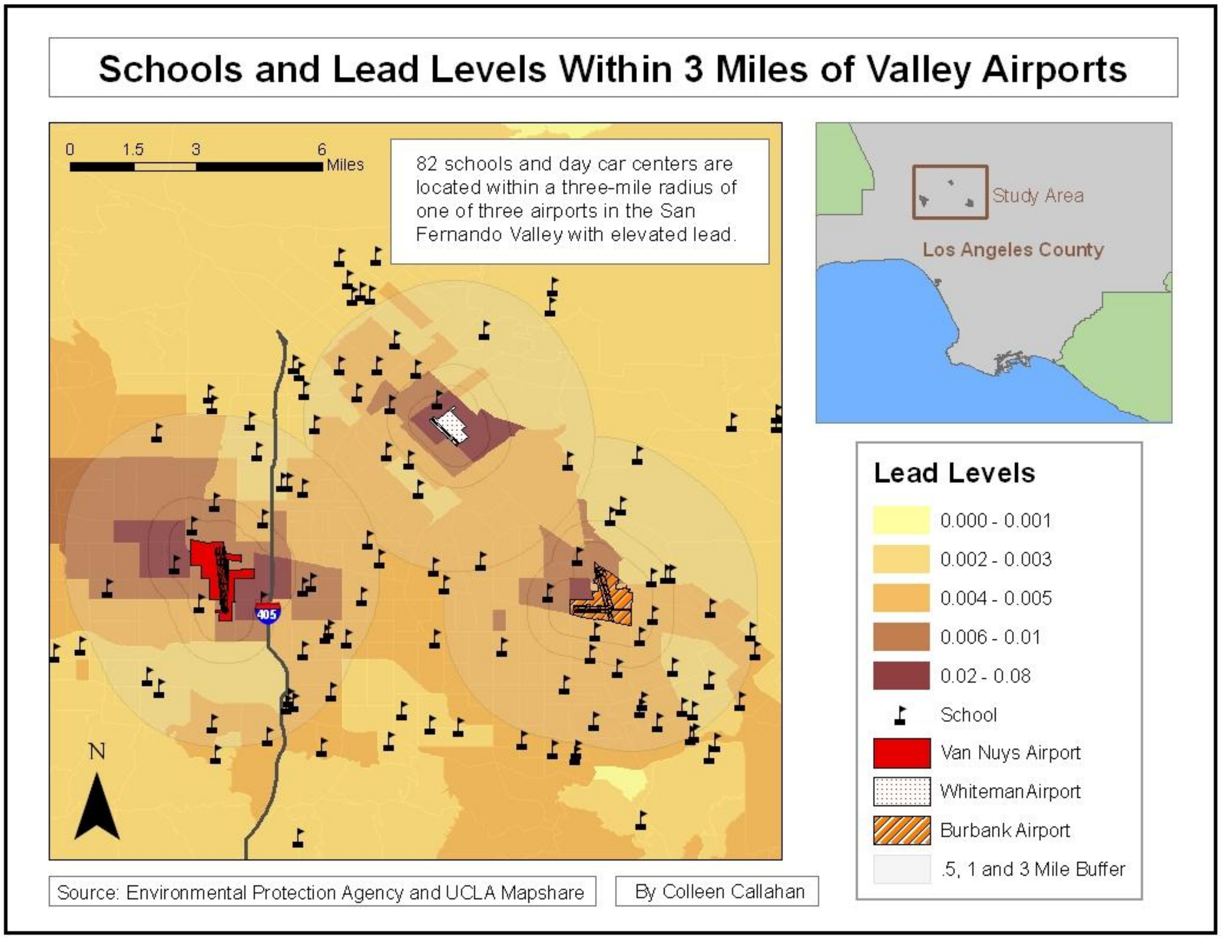


Figure 5



As illustrated in Figure 5, there are three airports within an approximately five mile area in the San Fernando Valley of Los Angeles County that are frequented by general aviation aircraft. These jets use leaded fuel. Figure 10 also illustrates a correlation between the locations of the three airports— in the middle of the three-mile buffer zones— and the highest levels of lead. There are 82 schools and day care centers within this three-mile buffer zone of an airport in the San Fernando Valley.

Particulate Pollution

Particle pollution (also called particulate matter or PM) is the term for a mixture of solid particles and liquid droplets found in the air. Some particles― such as dust, dirt, soot, or smoke― are large or dark enough to be seen with the naked eye. Others are so small that they can only be detected using an electron microscope. There are three main types of particles based on size: 1) "inhalable coarse particles” or PM10 with diameters larger than 2.5 micrometers (2.5 μm) and smaller than 10 micrometers; 2) ―fine particles” with diameters that are .1-2.5 micrometers; and 3) ultrafine/nano-particles that are less than 100 nanometers (nm). In comparison, the average human hair is about 70 micrometers in diameter – making it 30 times larger than the largest fine particle.[96]

The size of the particle is directly linked to its potential for causing health problems. Small particles pose the greatest problems because they can get deep into the lungs and even enter the bloodstream. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including:

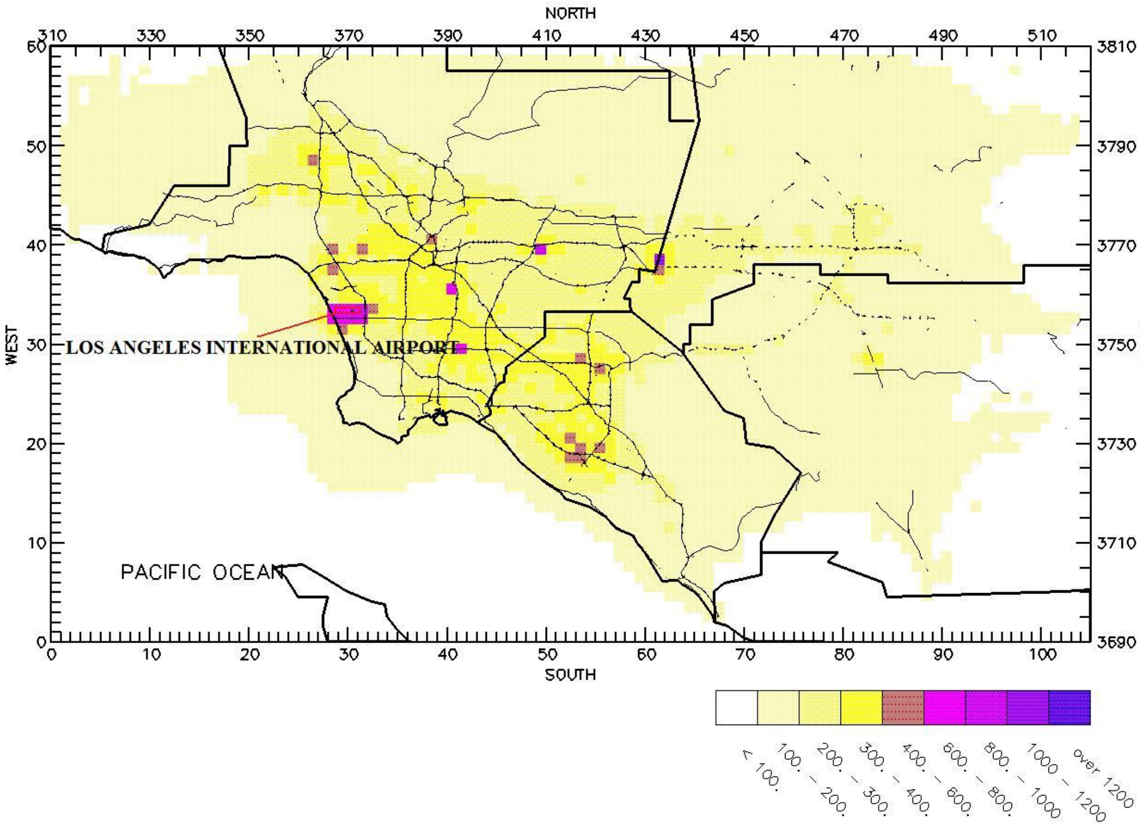
- increased respiratory symptoms
- decreased lung function
- aggravated asthma
- development of chronic bronchitis
- heart attacks
- pre-mature death in people with heart or lung disease.[97]

The study of ultrafine particles is relatively nascent compared to the study of fine particles. Early research indicates reason to be very concerned. Nanoparticles are deposited on the deep lung regions even more efficiently than fine particles.[98]

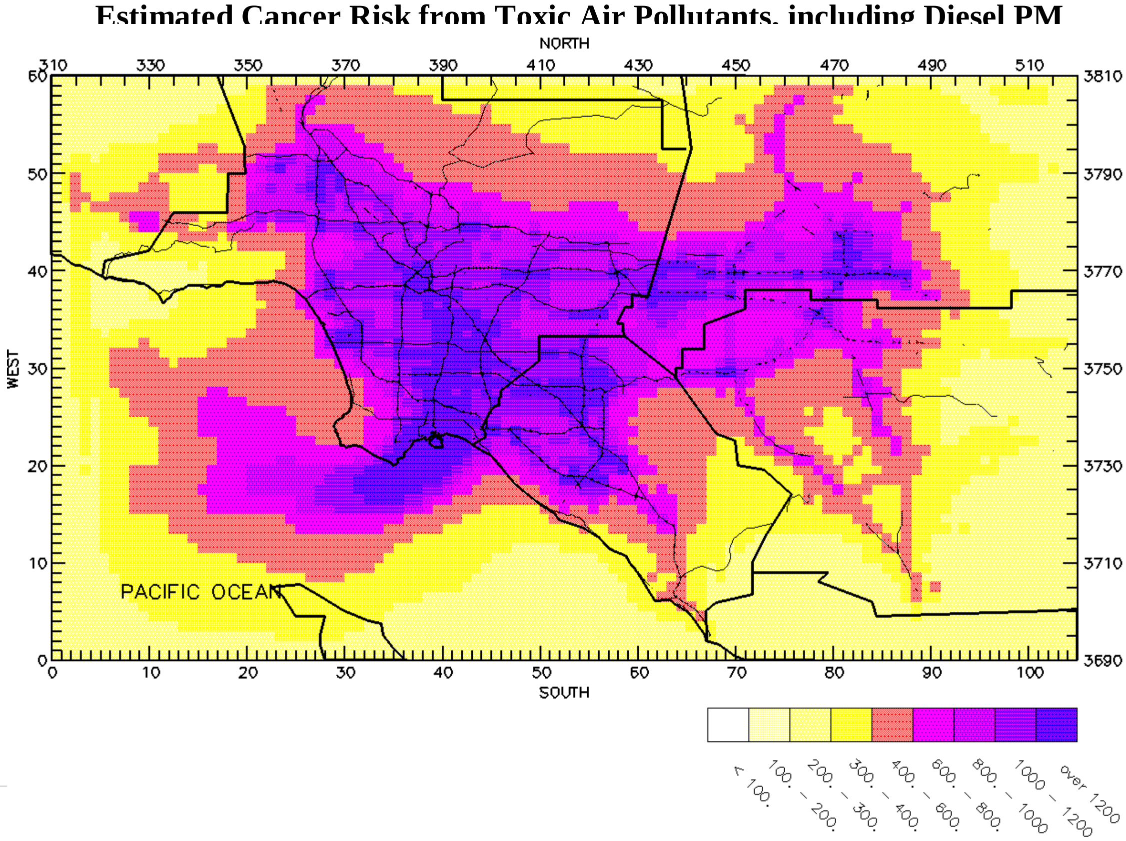
In addition to size, particles vary by composition depending on their source. Sources of particulate pollution include fires, dust, industrial processes, and fossil fuel combustion. Particulate pollution emitted from the combustion of diesel fuel is especially problematic in terms of health impacts. In 1998 the ARB identified diesel particulate matter as a toxic air contaminant, which means that it is linked to cancer.[99]

Figures 6 and 7

Estimated Cancer Risk from Toxic Air Pollutants, Without Diesel PM



Estimated Cancer Risk from Toxic Air Pollutants, including Diesel PM



Source: South Coast Air Quality Management District, MATES II Study: Multiple Air Toxics Exposure Study in the South Coast Air Basin.

Toxic Air Pollutants

Toxic air pollutants, also known as hazardous air pollutants, are known or suspected to cause cancer or other serious health effects, such as birth and reproductive effects.[100] Many toxic air pollutants are emitted in the form of volatile organic compounds (VOC) or particulates. Specific examples include benzene, which is found in gasoline, diesel particulate matter, which is emitted by diesel powered trucks, trains, and ships, and lead particulate, which is found in aviation gasoline.[101]

People are exposed to toxic air pollutants in many ways that can pose health risks, including but not limited to:

- Breathing contaminated air.
- Eating contaminated food products, such as fish from contaminated waters.
- Drinking water contaminated by toxic air pollutants.
- Ingesting contaminated soil. Young children are especially vulnerable because they often ingest soil from their hands or from objects they place in their mouths.
- Touching contaminated soil, dust, or water.[102]

People exposed to toxic air pollutants at sufficient concentrations and durations may have an increased chance of getting cancer or experiencing other serious health effects. These health effects can include damage to the immune system, as well as neurological, reproductive (e.g. reduced fertility), developmental, respiratory and other health problems. In addition to exposure from breathing air toxics, some toxic air pollutants such as mercury can deposit onto soils or surface waters, where they are taken up by plants and ingested by animals and move up through the food chain.[103]

Figures 6 and 7 (preceding page) indicate the large role that diesel particulate matter plays in cancer risk from toxic air contaminants in the South Coast Air Basin, including the area surrounding LAX. Figure 6 also illustrates elevated levels of other toxic pollution, excluding diesel PM, in the area near

LAX. Figure 8 confirms that toxic pollution levels are high in the area surrounding LAX. This map contains data from the EPA's National Scale Air Toxic Assessment, a database that provides emissions and health risk information on around 300 air toxins that present the greatest threat to public health in the largest number of urban areas.[104]

Figure 8

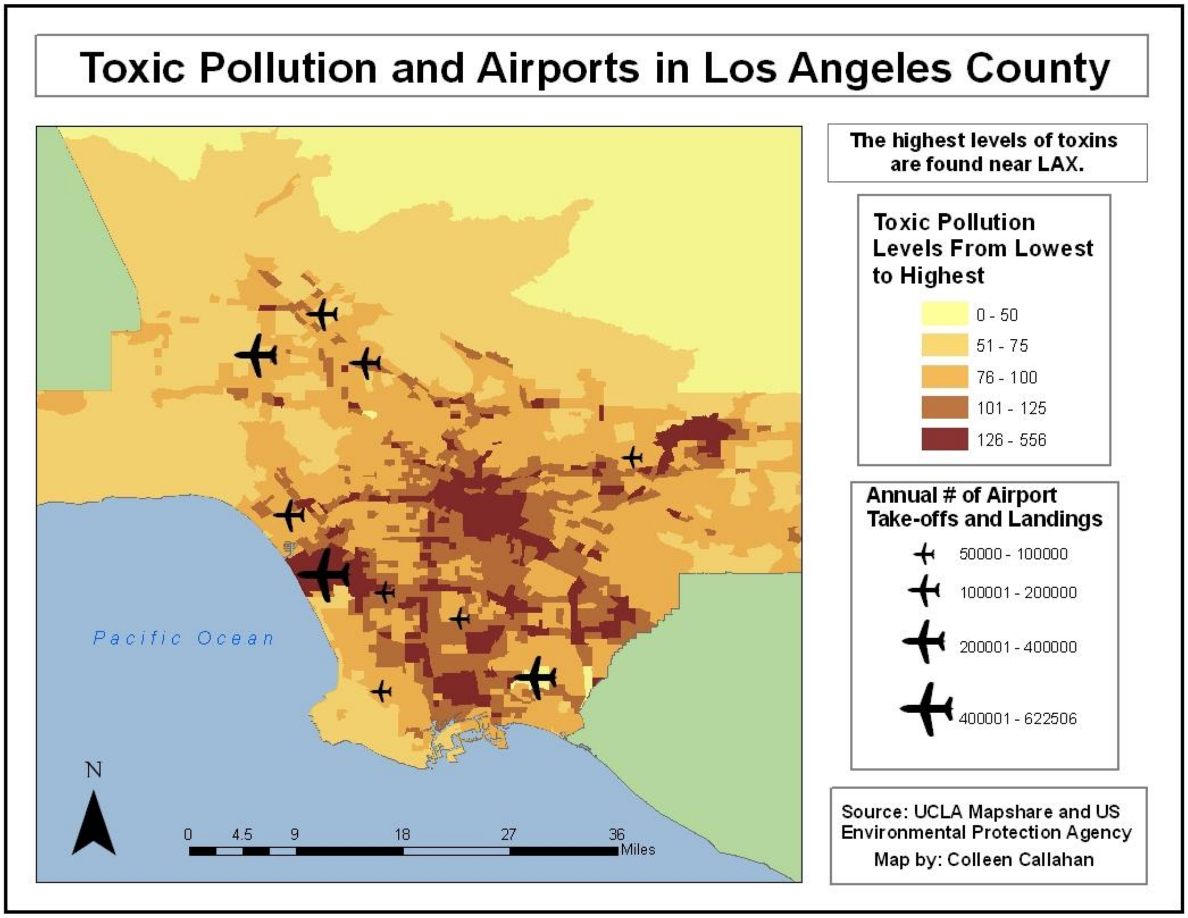
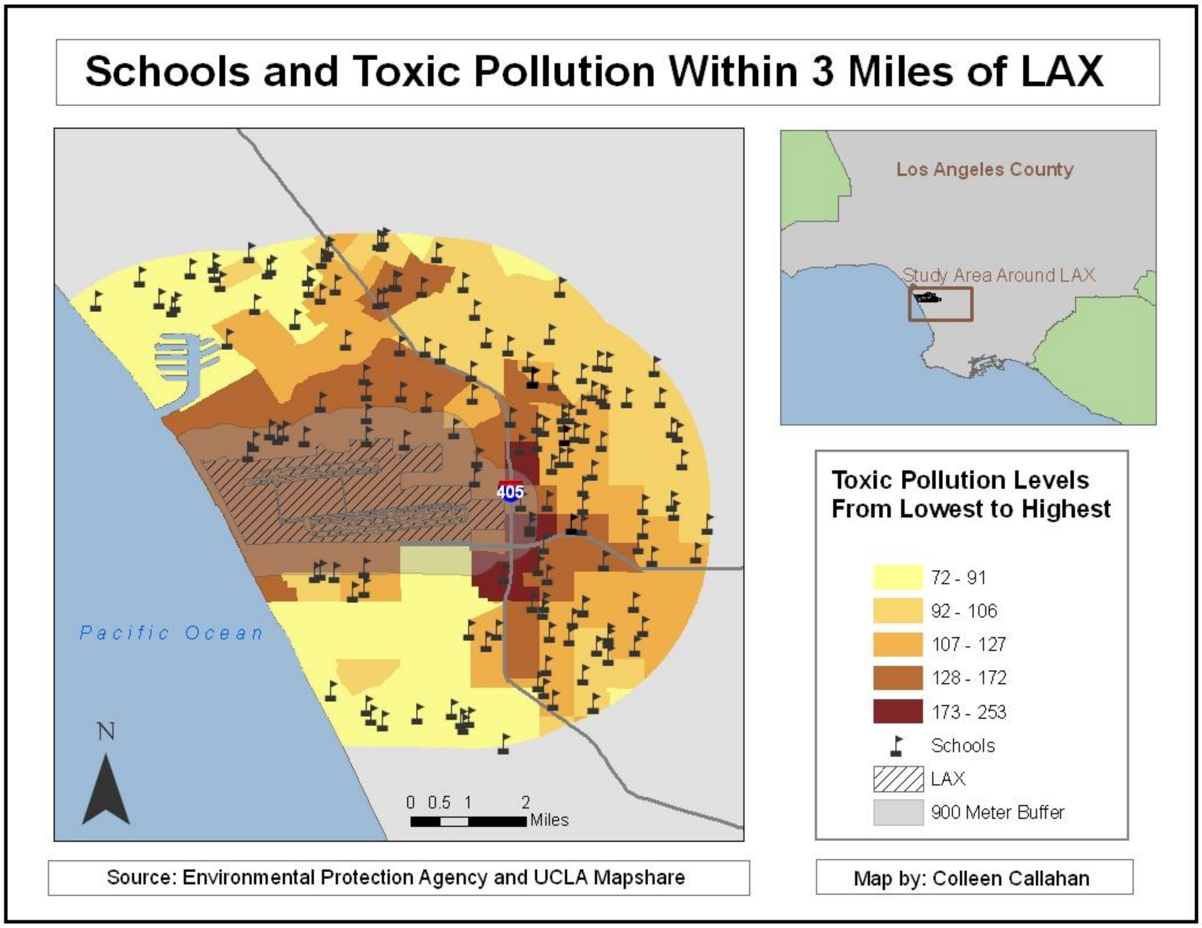


Figure 9


Schools and Toxic Pollution Within 3 Miles of LAX
Pacific Ocean
405
N
0 0.5 1 2
Miles
Los Angeles County
Study Area Around LAX
Toxic Pollution Levels From Lowest to Highest
72 - 91
92 - 106
107 - 127
128 - 172
173 - 253
Schools
LAX
900 Meter Buffer
Source: Environmental Protection Agency and UCLA Mapshare
Map by: Colleen Callahan

Climate Impacts of Non-CO2 Emissions from Aviation

The largest source of aviation-related greenhouse gas emissions are aircraft. According to the Intergovernmental Panel on Climate Change, aircraft account for 13 percent of all carbon dioxide emissions from the transportation sector, and in 1999, were responsible for 3.5 percent of global climate change.[105]

While the principal greenhouse gas related to aircraft is carbon dioxide (CO2), other non-CO2 emissions have a significant impact on radiative forcing and climate change. These include nitrogen oxides (NOx) and particulate matter. Non-CO2 emissions tend to be much shorter lived than CO2 emissions, and depending on where they occur may have a positive (warming) or negative (cooling) radiative force impact.[106] No agreement has been reached on a suitable metric for calculating the radiative forcing effects of non-CO2 emissions on an equivalent basis to CO2. This is in part due to inherent difficulty in treating long-lived (CO2) and short-lived (non-CO2) pollutants the same way.[107]

Aircraft emit significant amounts of NOx, which promotes the formation of ozone smog, a radiatively active gas with a warming effect. Yet, NOx can also accelerate the removal of atmospheric methane. Since methane has a strong warming effect, removing methane can have a cooling effect on the global climate.[108] The total radiative forcing of NOx is an area of active research.

In addition to being an air pollutant linked to severe local health effects, scientists are discovering that particulate matter in the form of black carbon (soot) ─ from burning diesel fuel ─ is a potent agent of global climate change. NASA scientists now estimate that black carbon is responsible for about 12 percent of the man-made global warming.[109] While CO2 lasts hundreds of years in the atmosphere, black carbon lasts only months or years. As a result, several climate models suggest that reducing particulate pollution can produce an immediate cooling effect on climate faster than any action on emissions like CO2.[110] According to NASA scientists, trimming black carbon represents an alternate and more immediate global warming solution for regulators stymied by the complexities of greenhouse gases such as CO2.[111] Scientists are only beginning to give attention to the climate impacts of black carbon, but this issue will likely gain in importance because reducing black carbon has both primary climate benefits and immediate secondary benefits. Therefore, reducing diesel particulate matter from airport operations can have both immediate local health benefits and global climate benefits.

AIR QUALITY IMPACTS OF AIRPORTS

Research on Air Quality and Commercial Airports

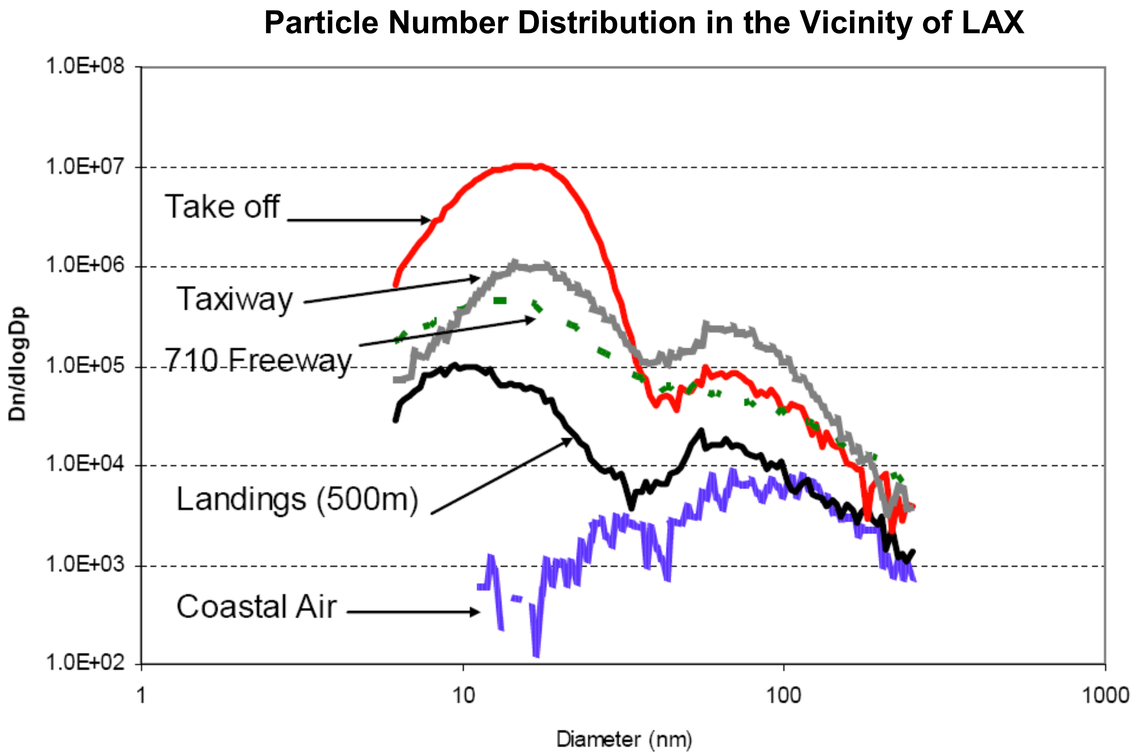
Several studies have documented seriously elevated levels of both toxic air pollutants and criteria pollutants such as nitrogen oxides and particulate matter levels near commercial airports.[112]

The Multiple Air Toxics Exposure Study of 1999 (MATES II) conducted by the South Coast Air Quality Management District involved sampling of diesel particulate matter and volatile organic compounds at 24 sites near LAX, including residential and ―ixed” location sites. The researchers of the South Coast Air Quality Management District (SCAQMD) measured high concentrations of elemental carbon (a surrogate for diesel particulates), benzene, and 1,3 butadiene at locations adjacent to LAX compared to sites further away from the airport. All key compounds are associated with mobile sources. Compounds were especially elevated at Aviation and Felton School sites, which are located near major arterials (Aviation Blvd. and 405 Freeway) and LAX. The staff at the SCAQMD contend that the higher concentrations of pollution near LAX were due primarily to the on-road vehicle activity resulting from airport operations.[113]

A study of toxic pollutants near Chicago O‘Hare Airport in 2000 also documented elevated levels of pollutants such as acetaldehyde, benzene, formaldehyde, toluene and lead.[114] Yet another study found significantly higher levels of some toxic volatile organic compounds near the Teterboro Airport in New Jersey in 2006, with spikes in pollution recorded when wind was blowing from the runway/taxiway.[115]

As part of the California Air Resources Board and University of Southern California‘s LAX and Ultrafine Particulate Matter Study, scientists performed air monitoring in the vicinity of LAX during the spring of 2003 to determine the extent of airport emissions on downwind ambient air in a mixed-use neighborhood that includes residences. The scientists found markedly higher ultrafine particulate (UFP) counts at a site 500 meters downwind of the airport, in an area that was strongly influenced by aircraft landings and where the community interfaced with airport facilities.[116] Figure 10 illustrates that particle numbers are highest in the airplane takeoff zone, an order of magnitude higher than even on the 710 Freeway. Levels are highest during takeoff, taxing, and landing when the sizes of the particles are about 20 nanometers in diameter.

Figure 10

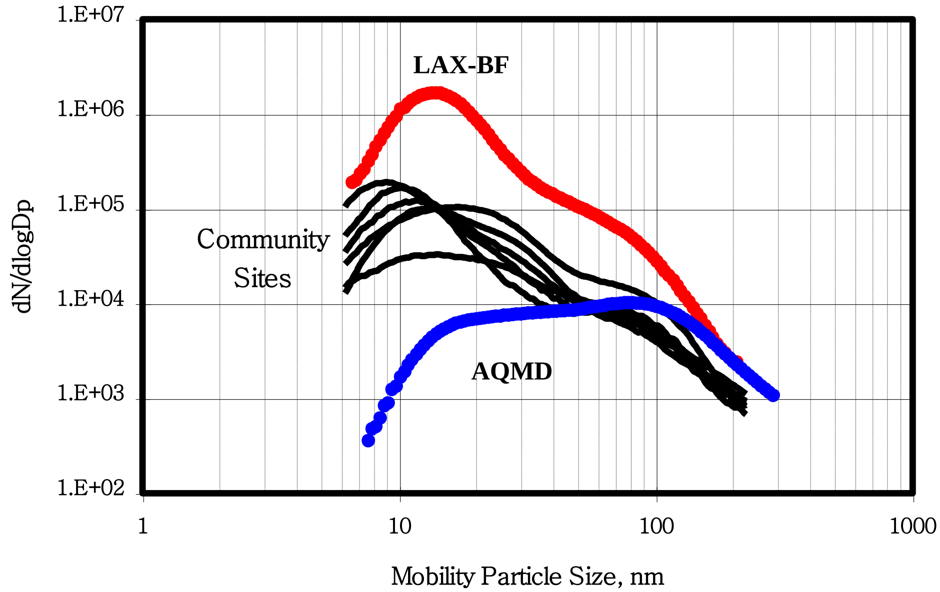


Source: Westerdahl D, Fruin S, Fine P, and Sioutas C. "The Los Angeles International Airport as a source of ultrafine particles and other pollutants to nearby communities." California Air Resources Board and the USC. Atmospheric Environment. 2008, 42: 3143-3155.

In another study of LAX supported by the California Air Resources Board, scientists from UCLA performed three field studies during 2005-2006. The results are compiled in a 2007 report titled ―Monitoring and Modeling of Ultrafine Particles and Black Carbon at the Los Angeles International Airport."[117] The scientists observed elevated levels of high ultrafine particle concentrations 900 meters downwind of a runway. The study authors concluded that ―airports are important sources of PM in urban air sheds, yet regulators and public health agencies have little data available to them that address the characteristics of particles emitted from aircraft and their impacts on exposure and health in adjacent communities. Toxicological research is needed to fully characterize the potential health impacts." [118]

Figure 11

Particle Size and Concentration at LAX Runway Blast Fence, Community Site near LAX, and the Regional Average



Source: Joe Lyou, Presentation on April 7, 2008 at the C40Airports and Climate Protection Workshop. Data from: Froines, J.; Fanning, E.; Chun, R.; and Lu, R. "Monitoring and Modeling of Ultrafine Particles and Black Carbon at the Los Angeles International Airport." University of California, Los Angeles. Prepared for the California Air Resources Board and the California Environmental Protection Agency. June 20, 2007.

In respect to nitrogen oxides (NOx), in 2006 scientists studied NOx in the vicinity of Heathrow Airport in England and reported elevated NOx levels more than two and a half kilometers from the airport.[119] Approximately 27 percent of the annual mean NOx in the region was due to airport operations at the downwind airfield boundary.[120]

Air Quality Studies and General Aviation Airports

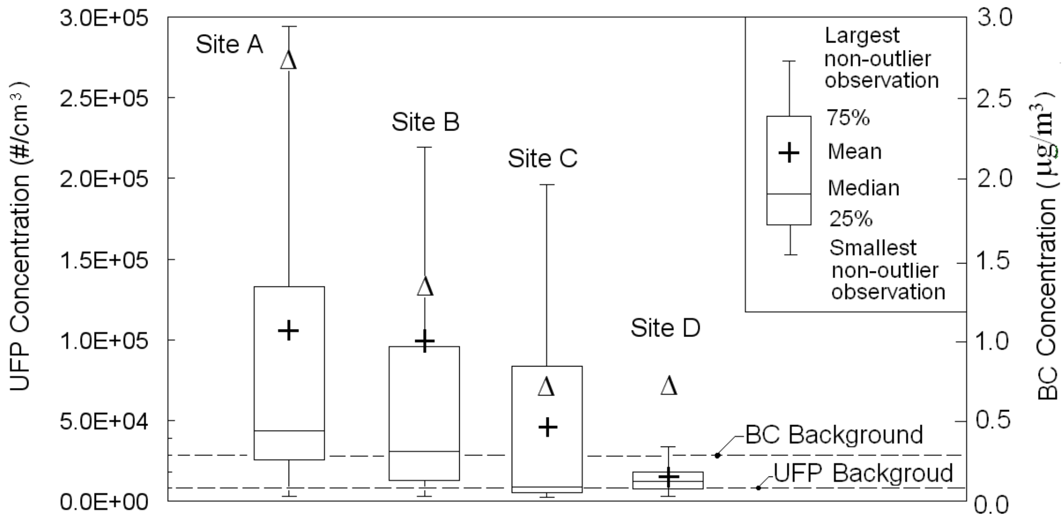
While several studies have documented poor air quality in the vicinity of major commercial airports, studies near general aviation airports− that serve private and government aircraft− are more limited. Three key studies related to general aviation airports exist from the Los Angeles region. Bill Piazza of the Los Angeles Unified School District conducted a Health Assessment of the Santa Monica Airport in 1999. He estimated that for individuals who reside in closest proximity to the airport, elevated cancer risk exists at a level of 26, 22, and 13 in a million (depending on assumptions made about the type of plane traffic). These values represent discrete elevated cancer risks associated with airport-related exposure because no background or ambient concentrations were incorporated into the risk quantification. In consideration of the Federal Clean Air Act, emissions associated with airport operations were clearly found to exceed the “acceptable risk criterion” of one in a million.[121]

In addition, scientists at the South Coast Air Quality Management District conducted a Santa Monica and Van Nuys Airports Study. The scientists recorded no discernible elevation of fine particles (with diameters that are .1- 2.5 micrometers, also called PM2.5) but did find spikes in ultrafine number concentrations associated with aircraft departures. They also observed highly elevated total suspended particulate lead at levels that were seven times higher than background levels.[122]

Most recently, in 2009, scientists at UCLA published a study titled “Aircraft Emission Impacts in a Neighborhood Adjacent to a Ground Aviation Airport in Southern California.” The scientists reported that average ultrafine particle (UFP) concentrations 600 meters downwind of Santa Monica Airport were two and a half to three times the background level, higher than typical major roadway concentrations.[123] Figure 12 illustrates that black carbon and ultrafine particles are elevated at residential sites downwind of the Santa Monica Airport. The study authors also noted that while Van Nuys Airport has a buffer zone between the airport and residences, the Santa Monica Airport does not; houses are adjacent to the runway.

Figure 12

Black Carbon Mass and Ultrafine Particles Elevated at Residential Sites East (Downwind) of the Santa Monica Airport



Source: Paulson, Suzanne. "Aircraft Impacts on Particulate Pollution Downside of Santa Monica Airport." University of California, Los Angeles and the California Air Resources Board. PowerPoint presentation, Santa Monica Airport Forum, January11, 2010.

MAIN SOURCES OF POLLUTION FROM AIRPORT OPERATIONS

Airport-related pollution comes from numerous sources. These sources include: 1) aircraft while on the ground and in the air, 2) transportation to and from the airport for travelers, employees, and cargo (called ground access transportation or regional vehicles), 3) on-airport vehicles owned by the airport, 4) ground service equipment (GSE) that services the aircraft, 5) airport infrastructure (stationary sources), and 6) auxiliary power units. The source apportionment varies depending on the type of air pollutant.

Figure 13 illustrates that aircraft is a main source of sulfur oxides (SOx) emissions at LAX while Figures 14, 15, and 16 illustrate that ground access vehicles/regional vehicles moving passengers, employees, and cargo can produce as much or even more nitrogen oxides (NOx), volatile organic compounds (VOC), and particulate matter (PM10) as planes. Missing from the source apportionment data is information about fine or ultrafine particles, which air quality monitoring and modeling studies reveal are of particular concern near airports.

The LAX emission source apportionment data illustrated in the following four graphs has policy implications. The major sources of LAX emissions serve as an organizing method used in this report to categorize, recommend, and prioritize emission reduction strategies.

Figure 13

SOx Emissions from Total LAX-related Operations

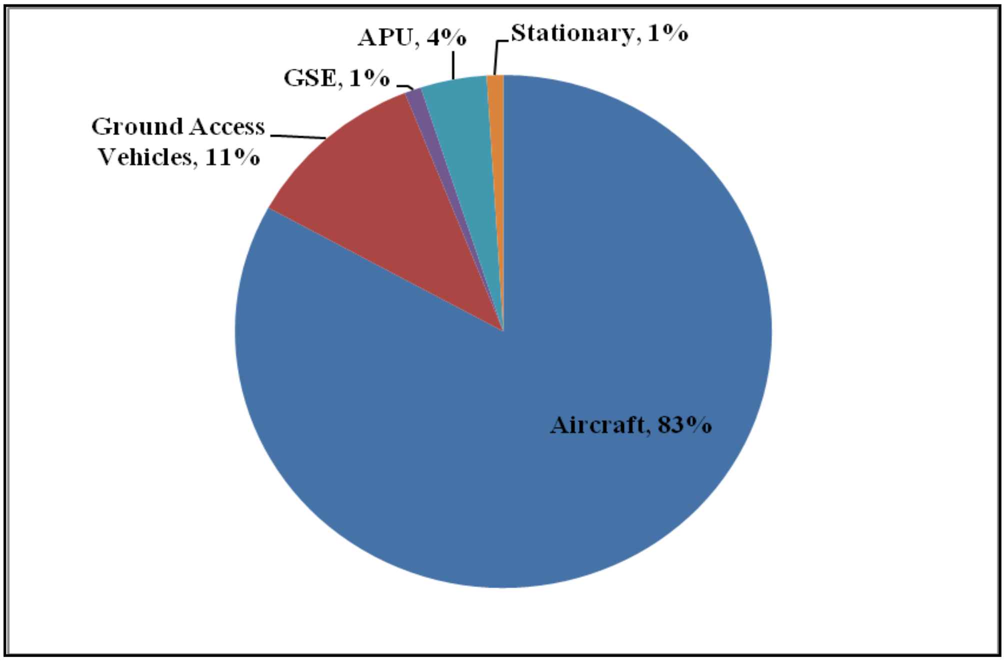


Figure 14

NOx Emissions from Total LAX-related Operations

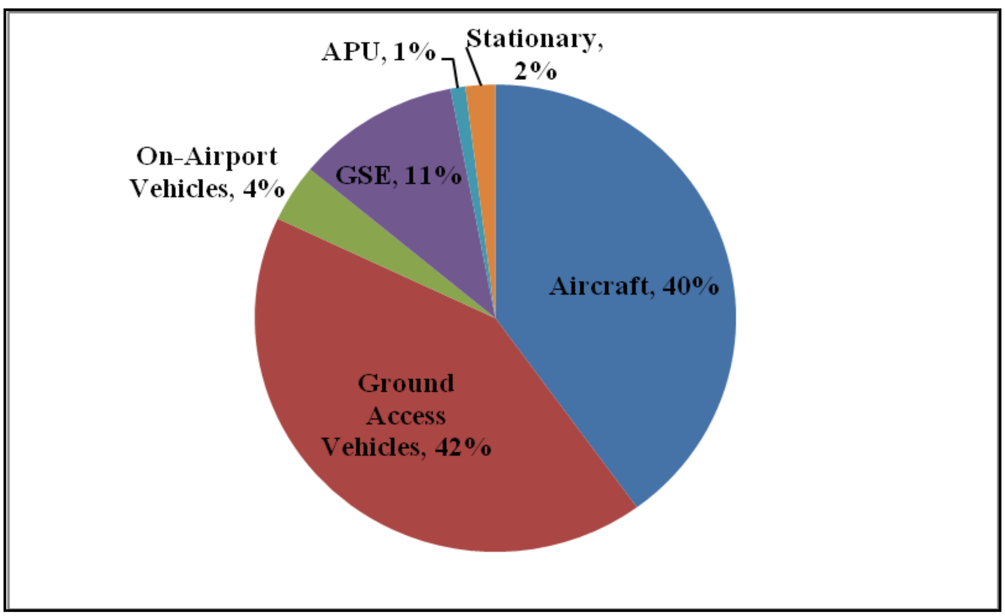


Figure 15

VOC Emissions from Total LAX-related Operations

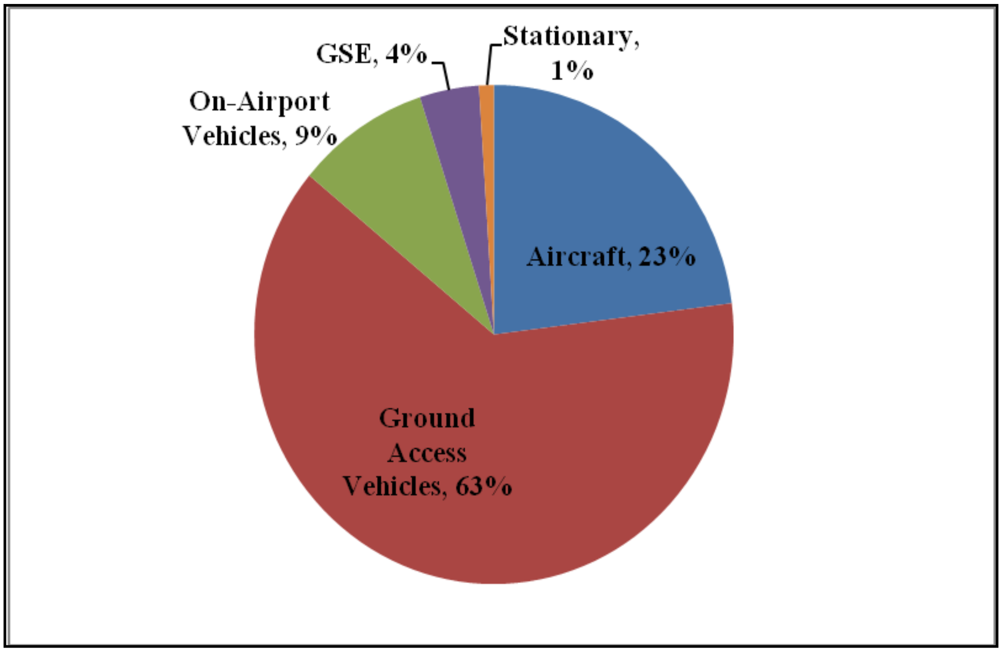
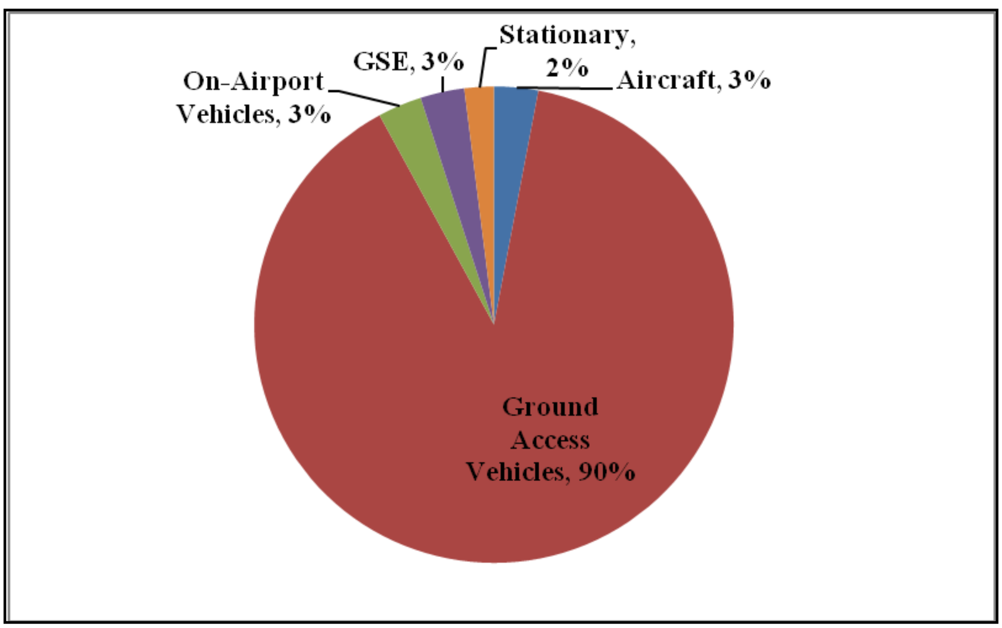


Figure 16

PM10 Emissions from Total LAX-related Operations



Source for Figures 13-16: Roger Johnson, Deputy Executive Director of the Los Angeles World Airports. "LAX Emissions by Source Category." Presentation dated February 13, 2008.

STANDARDS, REGULATIONS & PROGRAMS

Due to the many sources of emissions, types of pollutants emitted, and the difficulty in their characterization, controlling the pollutants generated by an airport‘s operations is a complex, multi-faceted issue.[124] The main air quality mitigation measures for airports and associated activities include replacing, repowering, retrofitting, refueling, and reducing idling of regional vehicles, aircraft, airport vehicles, and ground service equipment. Other mitigation measures include redirecting passengers and cargo to less congested airports or to other less polluting alternatives, such as public transit.

This section focuses on the key standards, regulations, and programs at a national, state, regional, and local level that affect the main sources of emissions related to the LAWA operations. The focus is on LAX. As previously described, particulate matter (PM) emissions are of particular concern from a local and global environment and health perspective. Therefore, the emissions sources are ordered from greatest to least effect on total LAX related PM emissions.

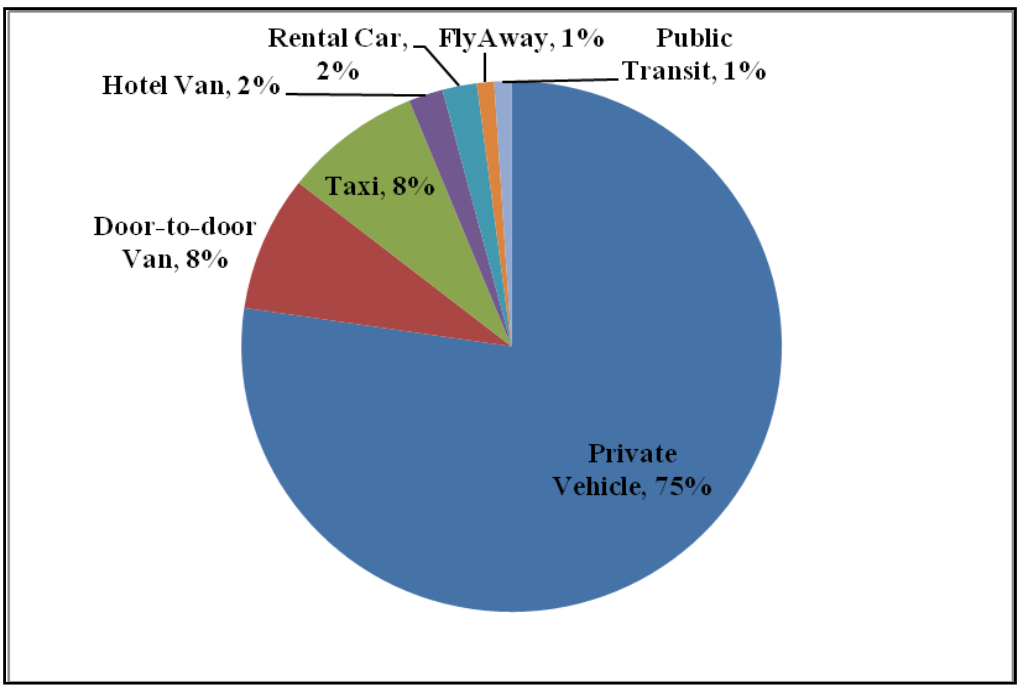
Emission Source Target: Ground Access Transportation

As previously illustrated in Figures 14, 15, and 16, ground access transportation is the most significant source of air pollution associated with airports like LAX. In fact, 90 percent of PM10 emissions are from ground access/regional vehicles. Nationally, ground access vehicles emit 56 percent of VOCs, while aircraft taking off and landing give off only 32.6% (including emissions from auxiliary power units).[125] Air pollution is emitted from private cars and trucks traveling at, to, and from the airport. These trips are generated by: 1) airport employees, 2) arriving and departing passengers, and 3) cargo and mail transport to and from the airport.[126]

A root cause of the problem is not how many people travel to the LAWA airports, but how they do so. For example, if every employee and passenger arrived to the airport on low-emission and readily available public transit and every airplane departed completely full, the pollution problem would be minimized while the travel benefits would be maximized. However, according to 2006 LAX Passenger Survey, public transit represents only one percent of mode access to/from LAX for both Southern California residents and visitors.[127] More than half of all LAX passengers (56 percent) are Southern California residents and seventy-five percent of Southern California based LAX passengers took a private vehicle to/from the airport.[128] Of those LAX passengers, over half used either the I-405 Freeway or the I-105 Freeway.[129] Based on Caltrans' 2006 traffic counts, the I-105 and the I-405 carry an annual average daily traffic volume of approximately 247,000 and 305,000 vehicles per day near LAX, respectively.[130] These volumes are among the highest in the nation. The California Department of Transportation and the Los Angeles County Metropolitan Transportation Authority (Metro) expect that peak period traffic volumes on the freeway segments near LAX will rise by 20 to 90 percent from 2006 and 2030.

Figure 17

Mode of Transportation for Southern California Residents Traveling to/from LAX



Source: Los Angeles World Airports. "2006 LAX Air Passenger Survey Final Report." December 2007. [*http://www.lawa.org/uploadedfiles/lax/pdf/2006LAXPassengerSurveyFinal.pdf*](http://www.lawa.org/uploadedfiles/lax/pdf/2006LAXPassengerSurveyFinal.pdf).

Figure 18

The LAX/Crenshaw Corridor Area

Source: Los Angeles County Metropolitan Transportation Authority

Table 9

Route Driven to LAX by Residents
Annual, 2001 and 2006

Route	2006**
Used San Diego Freeway (1-405)	37%
Used 105 freeway	25%
Did not use freeway	26%
Used both	6%
Don't know/refused to answer	6%

* 16,576 respondents.

Source: Los Angeles World Airports. "2006 LAX Air Passenger Survey Final Report." Dec 2007.
http://www.lawa.org/uploadedfiles/lax/pdf/2006LAXPassengerSurveyFinal.pdf.

As mentioned in the ‗Introduction' section, the EPA sets tailpipe standards for most vehicles, such as cars and trucks. Airport operators have virtually no direct control over emissions from the vehicles that passengers and cargo handlers drive to and from the airport. However, there are many indirect ways that airport operators and regional partners, such transportation agencies, can help maximize the number of airport passengers while minimizing the number of trips to and from the airport. The goal should be to increase the ratio of passengers to vehicles. By reducing vehicle trips, improvements in traffic flow, mass transport, and shuttle service will decrease traffic congestion, reduce emissions, and enhance the quality of life of the people who work and live near airports.

With the large number of vehicles that travel to, from, and within the three operating airports, the LAWA is in a unique position to seek efficiencies in on- and off-site transportation systems. To this end, one of the objectives in the LAWA Sustainability Plan is to reduce the number of single occupancy trips associated with its operations. Efforts to reduce pollution from ground access transportation are both ongoing and proposed.

Existing Efforts to Reduce Emissions from Ground Access Transportation

Rideshare and Carpool Program: LAWA's Rideshare Program consists of 63 vanpools, 64 carpools and free monthly transit passes, as well as marketing and advocacy activities to recruit and retain program participants. Approximately a quarter (27 percent in March 2009) percent of LAWA's employees participate in this program saving over 1,000 vehicle trips to LAWA airports every day and 7.9 billion pounds of air pollutants per year.[131]

Hotel Courtesy Shuttle Trip Reduction Program: Many airport-area hotels provide courtesy transportation from LAX terminals to hotels along the Century Boulevard corridor. In December 2006, the Board of Airport Commissioners approved a consolidated hotel courtesy shuttle operation to reduce traffic congestion in the central terminal area at LAX. The two-phase program requires hotels to set trip reduction targets and establishes financial penalties for excess trips. Phase I of the program started on July 1, 2007 and required hotels to reduce shuttle trips by at least 15 percent from a 2004 base year, with penalties of $10 per trip for non-compliance. Phase II began on February 1, 2008 and required hotels to reduce shuttle trips an additional 20 percent with penalties of $5 per trip for non-compliance.

According to the LAWA, since implementation of the program, vehicle miles traveled have been reduced by 55 percent and emissions have been reduced 65 percent over baseline years. However, more research is needed to determine the effectives of the current $5 penalty to incentivize compliance with LAX's Hotel Courtesy Shuttle Trip Reduction Program.[132]

LAX FlyAway Program: The FlyAway is a non-stop shuttle bus service operated by the LAWA that transports people to and from four locations and LAX. The LAWA is required to operate the FlyAway program as a mitigation measure of the LAX Master Plan (the stipulated settlement agreement). The FlyAway service was used by approximately 97,000 passengers in 2009, which removed approximately 1.2 million vehicle trips, reduced 133 tons of criteria pollutants, and reduced 8,540 tons of CO2 pollution.[133]

Yet, only one percent of Southern California residents take FlyAway as their mode of access to LAX.[134] The reason for this low percentage may be due in part to limited service, with only four pick-up/drop-off locations in a large region. As required by the stipulated settlement agreement, the LAWA plans to add five new FlyAway locations by 2015.[135] However, the increasing cost to ride FlyAway may be a deterrent. A trip from Union Station in downtown Los Angles to LAX costs $7 one-way or $14 round trip.[136] The newly added FlyAway line from Irvine to LAX costs $50 round trip. Fifty dollars is more expensive than paying for parking at a lot near LAX for a few days. Not surprisingly, only 84 people rode FlyAway to/from the Irvine location in 2009 after it the line opened in November.[137] Notwithstanding other issues of convenience and accessibility, taking FlyAway mostly makes economic sense for long trips.

Figure 19

Existing (Indicated by Red Circles) and Proposed FlyAway Locations

Source: Los Angeles World Airports, Presentation to the Board of Airport Commissioners, May 3, 2010. http://www.lawa.org/uploadedFiles/board_agenda/ManagementReports/boac100503z FlyAway%20Performance%20Update%20050310.pdf.

Rental Cars: In January 2003, the Board of Airport Commissioners approved on-airport concessions for 10 rental car companies at LAX. These 10 concessionaires are the only firms permitted to provide curbside pick-up and drop-off at passenger terminals. The program calls for on-airport rental car operators to reduce the number of monthly courtesy vehicles trips by at least 20 percent from a 2004 baseline year.[138]

Alternative Fuel Fleets: Two of the major contributors to vehicle traffic at LAWA facilities are passenger shuttle buses and taxis. The LAWA is working with its tenants and airport service providers to develop requirements and incentives for incorporating cleaner vehicles into their fleets. The LAWA has developed and is implementing an Alternative Fuel Vehicle (AFV) policy with a target of converting 50 percent of the larger vehicles (over 8,500 pounds gross weight) fleets to AFVs by December of 2010 and 100 percent by 2015. While it is too early to know whether LAX will meet these goals, experts are concerned that the airport will fail to reach these targets.

Consolidated Rental Car Facility (ConRac): Since 1999, LA/ONT has operated a ConRac that houses six rental car companies with tram service from the terminals to alleviate traffic congestion on the terminal roadways.

Proposed Plans to Reduce Emissions from Ground Access Transportation

Consolidated Rental Car Facility (ConRac): With the success of LA/ONT's ConRac (see immediately preceding paragraph), the LAWA plans to open a Consolidated Rental Car Facility in operation at LAX by 2015.[139]

Alternative Fuel Fleets: The LAWA plans to work with the taxi concessionaires at LA/ONT to develop a program to require that 10 percent of taxis run on alternative fuel vehicles.[140] There is no such goal at LAX and this remains an area of need. However, regulating the taxi industry at LAX has been problematic for the LAWA. Taxi services are operated by nine city-authorized taxi companies and regulated by Authorized Taxicab Supervision Inc. (ATS). City Controller Laura Chick audited ATS in Jan. 2007 and found ATS was mismanaging monies collected from passengers at LAX. Despite the audit, staff at the LAWA recommend that the Board of Airport Commissioners award a five-year concession agreement from the City to ATS.

Centralized Delivery Facility: Another significant source of vehicle traffic at LAX is the delivery of products to tenants and airlines.[141] Delivery trucks tie up passenger loading areas and increase congestion in the central terminal area. To reduce these impacts, the LAWA plans to reutilize an existing building as a centralized delivery facility, where the trucks will unload their materials and delivery trips will be consolidated.[142] The LAWA pledged to have the centralized delivery facility in operation by 2010. This will be something to monitor in the upcoming year.

Crenshaw/LAX Transit Rail Line: Over the past 40 years, the Los Angeles County Metropolitan Transportation Authority (Metro) and its predecessors have undertaken numerous plans and studies that documented the need for transportation improvements in the Crenshaw Corridor near LAX. The LAWA became an active member of the Green Line Task Force, which now also includes the California Department of Transportation, Metro, and local community groups. Their goal was to develop integrative approaches to relieve congestion around LAX with the proposed Crenshaw/LAX Transit Corridor Project.

The Draft Environmental Impact Statement (Draft EIR) for the proposed Crenshaw/LAX Transit Corridor Project analyzed two main project options− rapid bus transit and light rail along the Crenshaw Corridor− and recommended the light rail transit alternative. In December 2009, Board members of Metro adopted the light rail transit alternative as the preferred alternative, thereby allowing the final review of the Crenshaw/LAX Transit Rail Line to move forward. Metro will release the Final Environmental Impact Report in 2010. The Crenshaw/LAX Transit Rail Line would run perpendicular to the Green Line and the Expo Line (under construction).

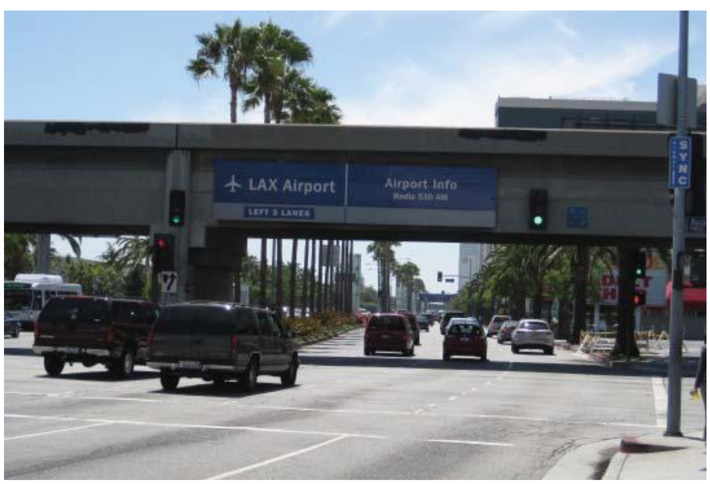
Figure 20

The Proposed Crenshaw/LAX Transit Corridor Project

Source: Los Angeles County Metropolitan Transportation Authority. Crenshaw Transit Corridor Draft Environmental Impact Statement." 2009.

The stated explanation in the Draft EIR for recommending the light rail alternative was that rail— compared to bus rapid transit— would generate the greatest travel time savings, reliability, and higher ridership as well as promote connections with other elements of the Metro rail system.[143] This argument has some merit given that the Crenshaw Corridor already has a rapid bus line plagued by slow travel speeds due to road congestion. Adding a dedicated line for bus rapid transit would mean taking away an existing road lane. This poses political and operations challenges that a rail line would help to avoid. A rail line— able to combine at grade, below grade, and aerial service— could provide faster service and more reliability.

However, the eight and a half mile rail line would not solve all problems of connectivity. The vast majority of LAX passengers live outside of the Crenshaw Corridor and the proposed rail line stops short of connecting to the Purple Line on Wilshire Boulevard and the residential and employment centers in that area. Moreover, it is unclear whether the proposed rail line would indeed provide more connectivity to LAX compared to the current Green Line, which requires a free shuttle trip to connect to LAX. The proposed rail line's Aviation Station will also not directly connect to the LAX terminal and therefore the current proposal calls for an automatic people mover along Century Boulevard, a very busy street dominated by cars, to connect the Aviation Station to LAX.



Century Boulevard and Aviation Boulevard— cross streets of the proposed Aviation Station of the LAX/Crenshaw Corridor project. The airport plans to construct an automatic people mover to provide connection to LAX terminals.

Photo source: LA County Metro.

Furthermore, any benefit of the proposed LAX/Crenshaw Corridor rail line would come at a cost. Metro staff estimate the project construction cost at $1.76 billion or approximately 207 million dollars per mile.[144] If the construction cost were divided by an estimated 50,000 riders per year for 10 years, the cost per passenger would be a whopping $3,520. This does not include operating costs, which, based on the experience from other rail lines in the Los Angeles region, will likely not be fully covered by the fares. For example, research indicates that riders of the Blue Line, a light rail line from downtown Los Angeles to Long Beach, pay a fare that covers only about eleven percent of the operating costs.[145] In comparison, local buses in Los Angeles cover close to 40 percent of the costs from the fare paid, and some crowded city routes mange to cover nearly 90 percent of their operating costs through revenue.[146] The funding that Metro is counting to build the Crenshaw/LAX Transit Corridor project will come mainly from Measure R, the half-cent local sales tax that Los Angeles County voters approved in November of 2008, and the federal government.

Analysis

The LAWA is taking significant steps to reduce air pollution associated with ground access transportation. However, none of the existing or proposed initiatives will address the fundamental issue of relative mode cost and will therefore not solve the pollution problem. The ‗kiss and fly' mode— in which a passenger is dropped-off or picked-up in a private vehicle— is the least costly ground access mode for the individual and most costly ground access mode for society because it results in four, one-way private vehicle trips instead of two or none. Through the ground access pricing system, the LAWA incentivizes the most polluting and least efficient transportation mode and creates a disincentive to take transit, FlyAway, shuttle, or taxi. For example, LAX collects $2.50 every time a cab enters the airport, but there is no charge for private vehicles to enter the LAX circle and the immediate roads into LAX.

A more efficient way to address the issue of ground access transportation would be to accurately price trips to the LAWA operated airports in order to internalize the negative externalities. The LAWA, Metro, and Caltrans could explore market based strategies in which vehicles pay a toll to enter a designated area such as the LAX driving pick-up and drop-off loop. The fee could be variable, increasing during peak travel times as a way to incentive travel during less congested times or by alternative modes. If the price was set right, the LAWA would generate income to go toward its air quality and ground transportation programs while airport passengers would be incentivized to take a less polluting mode of transportation. Tolling at LAX may be a political none-starter today. However, toll roads, like the 91 Express Lanes owned and operated by the Orange County Transportation Authority, are becoming more politically acceptable.[147]

Emission Source Target: Aircraft

Airplanes account for 90 percent of SOx, 40 percent of NOx, 23 percent of VOC, and three percent of PM10 emissions from operations at LAX. Policy, technological, and operational options are available to limit the growth in aircraft emissions. These include regulating the amount of emissions released, improving aircraft fuel efficiency via technological advancements, reducing aircraft fuel use while at airport gates, reducing congestion through either demand management strategies or operations advancements in air traffic control, and shifting from petroleum-based kerosene jet fuel to alternative fuels. The leadership to pursue most of these strategies must come from the federal government because federal law preempts states from setting emission standards for aircraft. However, airports owners may be able to employ their landlord authority to require or incentivize operations changes and the use of specific fuel while planes are on their property.

NOx standards: In 2005, the EPA amended its nitrogen oxides (NOx) emission standards for new commercial aircraft engines. These new standards are equivalent to the International Civil Aviation Organization‘s NOx emission standards (adopted in 1999 for implementation beginning in 2004) and bring the US aircraft standards into line with the international standards. The new standards reflect a 16 percent NOx reduction over the 1996 standards and a 33 percent reduction over the original standards agreed to in 1981. However, the combined effect of these standards with previously adopted standards will be a reduction in NOx emissions of only about 40 to 50 percent from new engine models relative to uncontrolled levels.[148] By comparison, emission standards and regulations set by air regulatory agencies require that other emission sources are controlled to well over 50 percent and some as high as 95 percent.[149]

The International Civil Aviation Organization‘s policy is to set ―technology supporting" rather than ―technology forcing" standards. In fact, approximately 85 percent of aircraft engines already met the standards when they were adopted by ICAO in 1999.[150] In contrast, emission standards set by air regulatory agencies for other sources of air pollution define a ―technology-forcing" performance level that goes beyond what sources are currently achieving.[151]

Further limiting the impact of the standards, aircraft engines that do not meet the new standards are not required to do so because the standards only apply to new aircraft and not to existing aircraft. The turnover of the approximately 15 percent of older engines that do meet the standards will not happen immediately due to the long fleet turn-over rate of aircraft (60 percent of aircraft are in service at 30 years of age.)[152]

Reducing fuel use through research and development: Historically, technological advances have resulted in the bulk of aviation emission reductions, but current research funding is lacking. Over the past three decades US manufacturers, with support from the US government, have invested billions of dollars in aircraft research and development. They have made significant strides in engine innovations and other technologies that save fuel and decrease emissions. The Boeing 787 aircraft, for example, achieves a 20 percent decrease in fuel use and CO2 emissions, 60 percent reduction of noise, and 28 percent less NOx than the B787 airplane that it replaces.[153]

The National Aeronautics and Space Administration (NASA) has historically been the lead US governmental agency involved with aircraft research and development. In 2004, NASA established a five-year goal to deliver technologies to reduce CO2 emissions of new aircraft by 25 percent. However, NASA's budgets for this work have declined since 2004 and, in early 2006, the agency realigned, leaving most of this proposal underfunded.[154] Manufacturers have expressed concerns that the US risks losing its global leadership in aeronautics due to reduced NASA and FAA research and development programs.[155]

There are incentives for airlines to reduce fuel use because fuel costs can over 50 percent of airline operating costs in the US[156] Investing in new aircraft is a key way for air carriers to reduce their fuel costs, but aircraft have a long product lifetime and are expensive to replace. Therefore, air carriers are employing a variety of other procedures to reduce fuel consumption, including: 1) selective engine shutdowns during ground delays, 2) cruising longer at higher altitudes and employing shorter, steeper approaches, and flying slower, 3) investing in winglets to reduce aircraft drag and reduce fuel burn, 4) experimenting with towing aircraft during some portion of travel to and from the gate, and 5) using airport power rather than onboard auxiliary power units when at the gates. [157] Several of these methods require coordination with federal agencies and airport operators; the fifth method is applicable to the LAWA and is highlighted in the following section.

Reducing fuel use at gate: Some airports, including LAX, are moving toward 100 percent electrification of airport gates. This allows planes to plug into electric power at gate instead of burning kerosene jet fuel or using an auxiliary power unit. As part of the LAX Community Benefits Agreement, LAWA agreed to equip 100 percent of passenger gates at LAX to electric power and be able to provide electricity to parked aircraft by 2010. This commitment only applies to LAX and not the other airports owned and operated by the LAWA.

Reducing airport congestion: There are three main ways to reduce airport congestion and the related energy use and air pollution without reducing overall air travel. One is to invest in infrastructure, but new runways take a considerable amount of time and money to build, plus construction periods are associated with increased congestion and emissions.[158] A second way to reduce congestion is via airport demand management, either through 1) congestion pricing 2) restrictions on airport slots.[159]

In respect to pricing, currently airlines pay land fees to airports depending only on aircraft weight. The land fees do not vary by time of day. Under congestion pricing, the landing fees paid by airlines would rise at peak hours, and in response, airlines would move some flights to off-peak hours.[160] The LAWA does not employ a timed-based congestion pricing system nor does it employ a slot system. Under a slot system, flights cannot exceed the total available number of hourly slots. One way to set up a slot system is to distribute the slots among the airlines and then allow trading. The FFA governs such as system at four congested US airports (LaGuardia, JFK, O'Hare, and Reagan-National). Another possibility is to auction the available airport slots to the airliners. In 2008, the FAA proposed a partial auction for the New York area airports, but the airliners strongly objected (they were being asked to pay for something that they now hold for free), and the FAA recently withdrew its auction proposal.[161]

A third way to reduce aviation congestion— referred to in the previous section on ‗research and development'— is through technological advancements in air traffic control. The Next Generation Air Transportation System (NextGen) is the FAA's plan to modernize the National Airspace System through 2025 while simultaneously improving safety and reducing environmental impacts. Core elements of NextGen include improving operational procedures, introducing new technology in aircraft and engines, and developing alternative fuels. For example, conversion to a satellite-based NextGen navigational system could cut emissions and delays by approximately 15 percent.[162] This system would support continuous descent arrivals, which allow aircraft to remain at cruse altitude longer and avoid excess fuel burn associated with traditional landing procedures. The NextGen navigational system is still in the development phase.

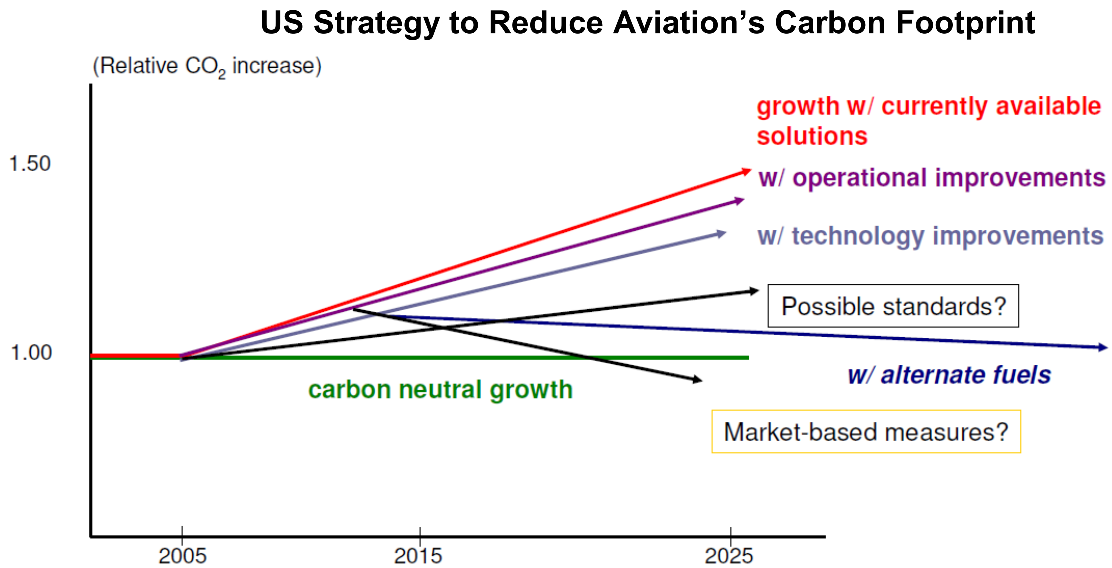
Alternative fuels: Alternative fuels are not widely used or accepted in the aviation industry, but this could change with more research and development. In partnership with the airlines, airports, and manufacturers, FAA launched the Commercial Aviation Fuels Initiative (CAAFI). CAAFI is leading efforts to develop alternative, environmentally progressive aviation fuels. Their goal is to develop a 100 percent synthetic fuel by 2010 and 100 percent bio-fuel by 2013.[163] Representatives from Boeing, the world‘s largest aircraft manufacturer, claim that bio-fuel powered aircraft could be on the market as early as 2011 and expect authorities to certify a 30 percent bio-fuel blend for commercial aircraft in the near future. [164]

But harvesting enough biomass to meet the industry‘s need remains a huge barrier to widespread adoption of the alternative fuel. The airline industry burns about 85 billion gallons of kerosene annually.[165] *The Guardian* estimates that fueling the world‘s 13,000 commercial airplanes with nothing but soybean-based fuel would require using the equivalent of the entire land mass of Europe to grow soybeans.[166] Moreover, the CO2 reduction benefits of crop-based bio-fuels are questionable when considered under a full lifecycle analysis because the entire process of growing, harvesting, and distilling the crop is quite energy and CO2 intensive.

The drawbacks of crop-based bio-fuels are one reason that Boeing is pursing algal fuels. The startup company Solazyme, based in San Francisco, has developed an algal jet fuel that behaves like kerosene. Called Solajet, this jet fuel has passed all of the eleven essential tested specifications required to meet the Jet-A1 standard.[167] It is the world‘s first microbially-derived jet fuel to do so. Another family of fuels called synthetic paraffinic kerosene− which includes those distilled from the oils of Helianthus (sunflowers) and jatropha− are close to becoming certified.[168]

The importance of bio-fuel research, development, certification, and procurement is particularly apparent when seen as part of a larger US government strategy to control aviation CO2 emissions. As Graph 21 illustrates, even with currently available solutions to control CO2 emissions from the aviation industry, operational and technological improvements, and possible CO2 standards, aviation‘s carbon footprint will continue to increase without the widespread use of alternative fuels.

Figure 21



Source: Maurice, L., US Federal Aviation Administration. "The Commercial Aviation Fuels Initiative." Presentation to the Aviation Alternative Fuels Side Event, Bonn, Germany. June 3, 2009.

In addition to use in large commercial aircraft, alternative fuels are also needed for use in small planes. As described earlier in this report, lead is banned in the kerosene fuel used in larger commercial aircraft and every other fuel in the US except the aviation gas (avgas) used in non-commercial, piston engine aircraft (private, corporate, and government jets) that frequent general aviation airports. The lead additive has been the most economical method for achieving 100-octane fuel in these high performance planes.[169] Avgas contains four times more lead than in leaded gasoline before it was banned from new cars in 1973.[170]

An alternative bio-fuel mix is available for use in some small planes. In 1999, the FAA certified a fuel known as AGE85, which is about 85 percent ethanol and contains a high-octane petroleum product and agriculturally derived ‗biodiesel' for lubrication.[171] It is unleaded and burns cleaner than avgas. However, its use is limited in part because FAA has been slow to establish a standard for the fuel and develop standards for aircraft flying with AGE85.[172]

Analysis

Aircraft is a challenging emission source for local clean air advocates and local airport operators to target. Most regulatory and standard setting authority exists at the international and national levels, but there are key ways for local clean air advocates to exert an influence. The most immediate way is to respond to the EPA‘s ‗Advanced Notice of Proposed Rulemaking on Lead Emissions from Piston-Engine Aircraft Using Leaded Aviation Gasoline.‘ More details on this rule-making and comment period can be found in the ‗Findings and Recommendations‘ chapter of this report.

Emission Source Target: Ground Support Equipment

Ground support equipment (GSE) accounts for four percent of PM10, one percent of SOx, four percent of VOC, and 11 percent of NOx emissions from LAX operations. This equipment that services aircraft include tugs, baggage loaders, catering trucks, and fueling vehicles. The main strategies for reducing emissions from this source involve federal emission standards, voluntary national and state programs, and more binding local fuel requirements.

EPA Standards for Non-Road Diesel Engines: The EPA does not specifically target ground support equipment in any of its regulations, but new ground support equipment with diesel engines that are used only on airport property will be required to meet EPA‘s Non-Road Diesel Engine Standards. The EPA is phasing in these standards from 2008 to 2014. According to the FAA, the new equipment will achieve emission performance comparable to today‘s automobiles.[173] The standards do not apply to existing ground support equipment or to non-diesel equipment, such as gasoline or other alternative fueled equipment in use at airports like LAX.

Voluntary Federal GSE Programs: The EPA, the FAA, and the Department of Energy developed a pilot program, called the Inherently Low-Emissions Airport Vehicle Pilot Program, to demonstrate air quality improvements with alternative fuel ground support equipment. These agencies recently expanded the program, now called the Voluntary Airport Low Emission Program, to increase eligibility for airport low-emission projects for commercial service airports in all air quality nonattainment areas. Through the use of funding and emission credit incentives, this voluntary program includes the conversion of ground support equipment to low emission technologies, among other emission reduction projects.[174]

United Airlines made notable progress in reducing emissions from their ground service equipment fleet, but overall industry progress has been limited. United's 1,797 alternative-fueled and zero-emitting vehicles represent nearly 25 percent of their active ground service equipment fleet.[175]

Voluntary GSE Initiative in Southern California: As part of the 1994 California State Implementation Plan (SIP) for ozone attainment, control measure M15 focused on the need for emission reductions from airports. The South Coast Air Quality Management District led the consultative process to focus on airport activities. One of the main goals of this process was to develop a Memorandum of Understanding (MOU) for ground service equipment that would be a voluntary program providing reductions in hydrocarbon (HC) and nitrogen oxide emissions beyond what is required. The MOU was developed in cooperation with the EPA, the FAA, the Air Transport Association representing the major airlines, and the five major airports in the South Coast Air Basin. It was signed in December 2002. Under the terms of the MOU, the airlines would have been exempted from new regulation of in-use programs until the MOU expired. However, the airlines chose to exercise their option to terminate the MOU, effective January 1, 2006.[176] Instead of continuing with the MOU, the airlines choose to focus their efforts and resources on new and future regulatory programs.

State Regulations that Apply to GSE: The state of California has not specifically targeted ground support equipment in its binding regulations. However, Board members of the California Air Resources Board (CARB) did adopt regulations that apply to in-use fleets, including airport ground service equipment (GSE). Those measures include the air toxic control measure for portable engines, new emission standards and fleet requirements for forklifts and other industrial equipment, and in-use requirements for off-road diesel vehicles.

This approach of using multiple broad regulations (non-industry specific) makes it challenging to focus in and analyze the effectiveness for emission reductions from ground service equipment. For example, the CARB approved the In-Use Off-Road Diesel Vehicle Regulation in July 26, 2007. This regulation applies to GSE. However, the GSE component of the regulation is caught up in the heated controversy over the entire regulation after industry opposition arose during the recent economic recession in California. As part of the 2009 California budget, the California legislature directed the CARB to make several changes to the In-Use Off-Road Diesel Vehicle Regulation. These changes in effect reduce the emission benefits associated with the rule by extending compliance deadlines and making other requirements less stringent.[177]

LAWA's GSE Conversion Program: The LAWA and its tenants have made an effort to convert GSEs to more efficient and less polluting models. As part of the LAX Community Benefits Agreement, the LAWA is committed to converting all on-LAX GSE to the cleanest technology available by 2015. Currently, only approximately a quarter (25 percent) of LAX's tenant GSEs are zero-emission vehicles.[178] This will be an area to monitor because of the potential for additional emission reductions.[179]

Analysis

Full implementation of the CARB's In-Use Off-Road Diesel Vehicle Regulation and the LAX Community Benefits Agreement could result in significant emission reductions from ground support equipment. However, the full potential of both are certainly not guaranteed and are areas that warrant monitoring and pressure from clean air advocates.

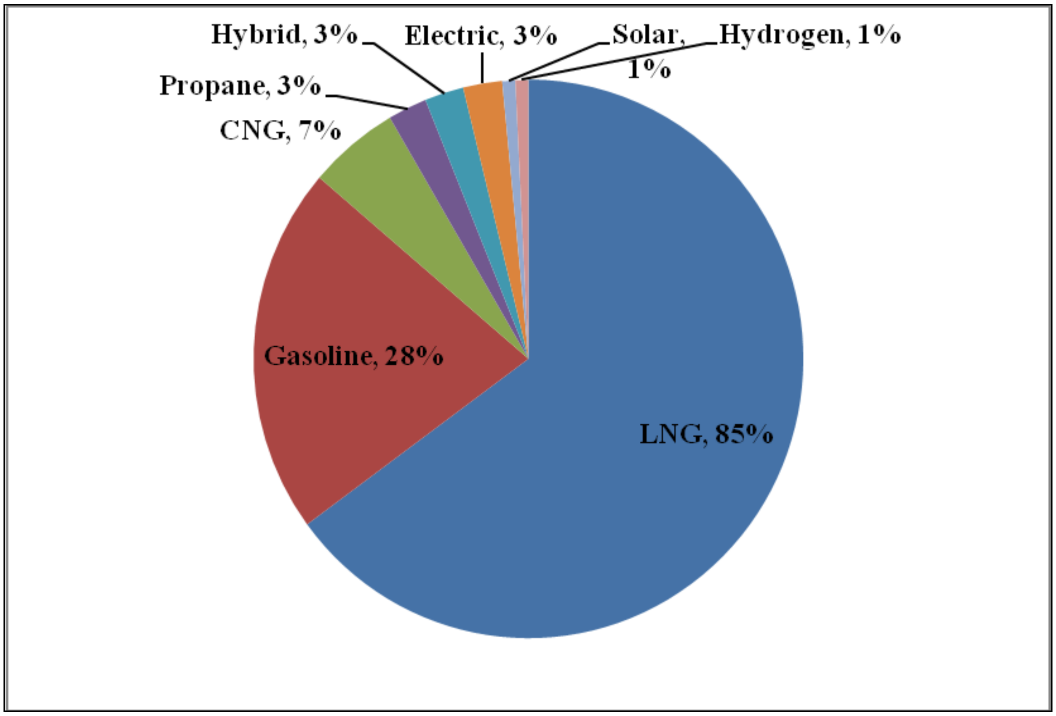
Emission Source Target: Airport Vehicles Fleet

On-airport vehicles account for three percent of particulate matter and four percent of nitrogen oxide emissions from LAX operations. The main way that airport operators are reducing emissions from airport owned vehicles is by transitioning to less polluting fuel sources. I am not aware of federal or state programs designed specifically to target airport vehicles (which is in a separate category from ground support equipment). However, the LAWA has a long history of integrating alternative fuel vehicles into its fleet. As part of the LAX Community Benefits Agreement, the LAWA agreed to expedite this transition, but it is still off its final goal of 100 percent conversion.

Figure 22 illustrates that LAX's fleet includes liquid natural gas (LNG), compressed natural gas (CNG), gasoline/electric hybrids, electric, solar, and hydrogen powered vehicles. Currently, about three-fourths of LAX's fleet is comprised of alternative fuel vehicles (AFV).[180]

Figure 22

LAX Fleet Vehicles



Source: Los Angeles World Airports. "Los Angeles World Airport Sustainability Plan." 2008.

Analysis

The LAWA has not publicized its fleet ratio for its other airports, an indication that the alternative fuel vehicle percentage of its fleets is significantly lower elsewhere. This is an area of more potential emission reductions that warrants attention. In terms of LAX, the most important effort for clean air advocates to pursue is to monitor and ensure that the LAWA fully meets its commitment to clean vehicles as part of the LAX Community Benefits Agreement.

Emission Target: Stationary Sources

Although mobile sources constitute the bulk of emissions related to airport operations, stationary sources— primarily from energy production— also certainly matter. The LAWA has a Central Utilities Plant (CUP) onsite at LAX to heat and cool the airport terminals. In November 2009, the LAWA Board of Airport Commissioners approved a new central utility plant at LAX. The existing CUP is an obsolete facility that no longer meets energy and safety codes. While the new utility plant will decrease emissions relative to current levels, the effort does not go as far as some airports— like Denver International— that are investing in on-site solar arrays. To its credit, however, in October 1999 the Board of Airport Commissioners adopted a resolution establishing the LAWA‘s participation in the City‘s Department of Water and Power‘s ―Green Power for LA" program to purchase electricity from renewable resources. LAWA purchases approximately 15 percent of its power from renewable energy resources.[181]

In addition, in January 2007, the LAWA Board of Airport Commissioners committed the LAWA to incorporate the highest possible LEED (Leadership in Energy and Environmental Design) standards in all future construction projects at the LAWA‘s airports. However, the LAWA airports lag behind some other airports in terms of LEED certification. For example, Hangar 25 at the Bob Hope Airport in Burbank was recently designated by the US Green Building Council as a "LEED Platinum" facility, the highest LEED ranking.[182] Representatives from Shangri-La Construction, the firm that created and constructed the hanger, state that Hanger 25 is the ″most sustainable airplane hangar in the world.″ The Hanger 25 building contains solar arrays that will produce 400 kWH per year of clean, renewable energy to supply 110 percent of the building‘s total energy needs.[183] Airplane process loads will be powered by solar charging carts, avoiding jet fuel consumption and improving air quality.[184]

The LAWA also strives to reduce energy consumption at its airports. The new terminal at LA/ONT includes energy efficient windows and a ceiling system that maximizes light distribution without radiating heat in the terminal. Other efforts have included retrofitting 90 percent of light fixtures at LAX for higher efficiency and installing light sensors in the LAWA administrative buildings.[185]

Analysis

The LAWA has taken steps to reduce emissions from stationary sources, but there is certainly more that the LAWA could do to invest in renewable energy and improve energy efficiency in its facilities and operations. The Board of Airport Commissioners established a target of reducing energy use by 10 percent per passenger and/or cargo tonnage by the end of 2010. In order to meet these targets, the LAWA plans to perform the following initiatives: install energy efficient light fixtures when changing burned out bulbs; install new or increase efficiency of existing heating and cooling equipment; purchase more energy efficient computer servers; install energy efficient variable speed motors during replacement; and when replacing older building-related process energy systems and equipment, upgrade with energy efficient systems.

Several of these initiatives depend on an unknown replacement schedule and/or opportunities that could be maximized during new construction projects related to the LAX Master Plan and the Ontario Master Plan. In addition, the LAWA has an unrealized potential to invest in solar and fuel cell infrastructure as renewable sources of energy.

Findings and Recommendations

After communicating with experts and conducting an extensive literature review, I summarized key findings and based on these findings, I prioritized recommended objectives for a campaign to reduce pollution from the LAWA‘s owned and operated airports. Each recommendation is assigned a suggested priority level. My criteria for evaluating and prioritizing recommendations was based on: 1) impact— the importance of the recommended action in terms of emission reduction potential over the current baseline— and 2) ease of implementation— the feasibility of a clean air advocacy organization based in Los Angeles to move the target agency to adopt the recommended action. The recommendations are listed in order of top emission sources of PM10, NOx, and VOC pollution from LAX operations.

RECOMMENDATIONS FOR OVERALL EMISSION REDUCTIONS

1) Create a Clean Air Action Plan for the LAWA

Finding: The LAWA‘s various environmental data collection, programmatic, and policy efforts concentrate on LAX while often not applying to its other airports. Van Nuys Airport has the second largest number of landings and take-offs in the Los Angeles County, however, the airport is virtually ignored in the LAWA‘s Sustainability Plan. Furthermore, there is only limited alignment between the environmental programs at LAX and at Ontario International Airport. Even at LAX, however, the LAWA does not coordinate its various air quality measures under a comprehensive plan.

Recommendation: Clean air advocates should encourage the LAWA to set a health-based emission reduction goal for all three airports and develop a plan to comprehensively target airport-related emission sources through a consistent application of environmental programs, goals, and policies among the three airports. A LAWA clean air action plan should be included as part of the Southern California Association of Governments‘ Regional Transportation Plan.

As a starting point, the LAX Community Benefits Agreement contains commitments that should be applied to the other airports. A comprehensive clean air action plan should also include measures to protect vulnerable populations living near the LAWA airports. Effective and relatively inexpensive air filtration systems are available on the market and have already been installed in schools near the Ports of Los Angeles and Port of Long Beach with support from the ports and the South Coast Air Quality Management District.

The San Pedro Bay Ports Clean Air Action Plan could serve as a general model for the LAWA to develop a plan to more comprehensively and consistently target multiple emission sources across all of its airports. The San Pedro Bay Ports Clean Air Action Plan (the CAP) targets all port-related emission sources─ ships, trains, trucks, terminal equipment and harbor craft─ to significantly reduce health risks posed by air pollution. The CAP is landmark for both its comprehensiveness and agency cooperation. It was created with participation of the South Coast Air Quality Management District, the California Air Resources Board and the US Environmental Protection Agency. The Harbor Commissioners of the Port of Los Angeles and the Harbor Commissioners of the Port of Long Beach Plan approved the CAP in a joint meeting on November 20, 2006. By doing so, the Harbor Commissioners committed the ports to an aggressive plan to reduce pollution by at least 45 percent in the next five years. The San Pedro Ports Bay Clean Air Action Plan was the culmination of years of organizing and advocacy work by residents and environmental organizations.

Clean air advocates could target the Los Angeles World Airports as the lead agency while also reaching out to the South Coast Air Quality Management District, the California Air Resources Board, and the US Environmental Protection Agency about cooperatively designing a plan, as these agencies did for the CAP.

Priority: The action ranks as a high priority. If designed properly, a comprehensive clean air plan could lead to significant emission reductions at all of the LAWA's airports. Results of the forthcoming LAX Air Quality and Source Apportionment Study may highlight the need for a comprehensive approach to reducing air pollution and will provide a forum for the public to discuss such action. In addition, as air traffic increases at LA/ONT and the Ontario Airport Master Plan moves forward, advocates will have the opportunity to weigh in on the future direction of the airport.

2) Target Aircraft and Airports in State Implementation Plans

Finding: Although aircraft are a major source of air pollution comparable to industrial sources, they escape inclusion in State Implementation Plans, the US Environmental Protection Agency's (EPA) principal means of achieving cleaner air in air quality nonattainment areas.[186] This omission has serious consequences in efforts to reduce air pollution.[187] In California, the Air Resources Board faces obstacles in its ability to regulate airport-related sources. However, the California Air Resources Board faces similar challenges in regulating the shipping, trucking, and railroad industries and has found creative ways to target emissions related to these industries.

Recommendation 2.1 and Target: Clean air advocates should work with staff at the California Air Resources Board to explore creative ways to reduce emissions from aircraft and other airport-related sources. This should involve conducting research about the health impacts, including cancer risk, from airports, as the CARB has done with rail yards.

Priority of Recommendation 2.1: Working with staff from the California Air Resources Board should be a high priority for clean air advocates. While the California Air Resources has limited control over airport-related emission sources, the state has more power and authority than local or regional agencies and the proven ability to work creatively to target major emission sources.

Recommendation 2.2 and Target: Clean air advocates should lobby US Senators to author and support legislation that would give states more ability to regulate airports— like other major sources of pollution— as part of the State Implementation Plan process. Allowing states to include control strategies for ground-level aircraft emissions in their SIPs and regional air districts to more easily control other airport-related sources in their air quality management plans would definitely help achieve air quality goals.[188] The South Coast Air Quality Management District could potentially be an ally in this effort.

Priority of Recommendation 2.2: This action ranks as a medium priority. While the action could have major impacts on reducing emissions from airport-related operations in the Los Angeles region, achieving the desired action would be particularly challenging for clean air advocates based in Los Angeles to achieve given the amount of resources needed to affect federal legislation.

SOURCE TARGET: GROUND ACCESS TRANSPORTATION

3) Increase the Viability of Alternative Ground Access Options via Cordon Pricing and Improved Public transit

Finding: Ground access transportation accounts for 63 percent of VOC emissions, 42 percent of NOx emissions, and 90 percent of PM10 emissions from LAX-related operations.[189] Nationally, ground access vehicles emit an average of 56 percent of VOCs from airport-related sources, while aircraft taking off and landing give off only 32.6% (including emissions from auxiliary power units) from airport-related sources.[190] Ground access trips are generated are generated by: 1) airport employees, 2) arriving and departing passengers, and 3) cargo and mail transport to and from the airport.[191]

A root cause of the problem is not how many people travel to LAX and other airports owned by the LAWA, but how they do so. If every employee and passenger arrived to the airport on low-emission and readily available public transit, the pollution problem from ground access transportation would be minimized while the travel benefits would be maximized. However, public transit represented only one percent of the trips to/from LAX in 2006. During this same year, three-fourth of LAX passengers who lived in Southern California took a private vehicle to LAX and more than three-fourths of these passengers were dropped-off at the curb. This ‗kiss and fly' mode is the least expensive for the individual and most expensive mode for society because it results in congestion and air pollution from four, one-way vehicle trips. Through its ground access pricing system, the LAWA incentivizes the most polluting and least efficient mode of transportation while creating disincentives to take less polluting modes like transit, FlyAway, and shared shuttle. A more efficient way to address the issue of ground access transportation would be to accurately price trips to the LAWA operated airports in order to internalize the negative externalities.

Recommendation 3.1 and Target: Clean air advocates should ask the LAWA and other regional partners to explore cordon pricing in which private vehicles would be accessed a toll to enter an airport pick-up and drop-off circle. If the price was set right, the LAWA would generate income to go toward its air quality and ground transportation programs while airport passengers would be incentivized to use a less polluting mode of ground access transportation.

Priority of Recommendation 3.1: This action ranks as a medium priority. While ground access is the most significant source of air pollution from LAX operations and pricing could have the most significant impact on mode choice, road pricing is currently not particularly politically viable at this time. However, toll roads— like the 91 Express Lanes owned and operated by the Orange County Transportation Authority— are becoming more acceptable and therefore, the political calculation could shift in the future.[192] Regardless, clean air advocates would need to be willing to risk supporting a controversial measure.

Recommendation 3.2 and Target: Clean air advocates should ensure that the Los Angeles County Metropolitan Transportation Authority (Metro) properly designs the proposed Crenshaw/LAX Transit light rail line, which would run past LAX and connect the Green Line with the Expo Line. If properly designed, this eight and a half mile rail line could lure some passengers and employees to take public transit to LAX versus driving. However, access and convenience to LAX will impact the viability of this proposed transit option. The current plan calls for a transit station at Century Boulevard and Aviation Boulevard— a busy intersection about a mile outside of LAX— and the construction of a people mover between this station and LAX terminals. The location of this transit station in a non-pedestrian friendly area and the distance from LAX could serve as a barrier to attracting riders. Clean air advocates should request that Metro address concerns with LAX connectivity and safety at the proposed LAX transit station.

Priority of Recommendation 3.2: This action ranks as a medium but urgent priority. The project planning is well underway and clean air advocates will want to meet with Metro staff member as soon as possible. The Final Environment Impact Study/Environment Impact Report could be ready by the end of 2010, with the line scheduled to open in 2018.

4) Focus on Heavy-duty Trucks

Finding: Ontario Airport is part of an expanding freight movement system in which trucks move freight from the Port of Los Angeles and Port of Long Beach to the Inland Empire's freight loading facilities, warehouses, rail yards, and airports. Diesel trucks also deliver products to airport tenants and airliners at LAX, which ranks as the 13th in the world in air cargo tonnage handled.[193] However, while the LAWA tracks some commercial vehicle traffic, it does not track commercial truck trips at any of its airports.[194] This lack of data indicates a lack of focus on this emission source.

Recommendation and Target: First of all, clean air advocates should request that the LAWA collect and make publically available data on cargo-handling trucks. Managing a source of pollution requires the ability to measure that pollution source. Second, clean air advocates could request that the LAWA pursue a policy to phase-out the oldest and dirtiest trucks that enter onto the property of the LAWA. The model that the LAWA should explore is the Clean Trucks Program at the Port of Los Angeles and Port of Long Beach. The Clean Trucks Program progressively bans all trucks that do not meet the most recent emission standards by 2012.[195] Like at the Port of Los Angeles, the City of Los Angeles serves as a landlord at its airports and as a landlord, the City can set terms for companies that do business on its property.

Priority: These two interrelated actions rank as a medium and potentially high priority. Without good data, it is hard to know how significant cargo handling vehicles are to air pollution related to the LAWA's operations. Obtaining this data is important and could help determine next steps.

SOURCE TARGET: AIRCRAFT

5) Ban Lead in Aviation Gasoline

Finding: Studies of emissions near airports in Los Angeles County demonstrate highly elevated levels of lead particulate. Lead is banned in all fuel in the US except aviation gasoline (avgas). Avgas is used in non-commercial, piston-engine aircraft that frequent generation aviation airports including Van Nuys Airport, the largest general aviation airport in the world. On a national basis, emissions of lead from aircraft engines using leaded avgas are the largest single source category for emissions of lead to air, comprising approximately half of the national inventory in 2005.[196] The tetra-ethyl lead found in leaded avgas and its combustion products are potent neurotoxins. The US Centers for Disease Control and Prevention (CDC) concluded in 2005 that no “safe threshold for blood lead has been identified.”[197] The Federal Aviation Administration (FAA) certified a non-lead alternative, AGE85, but it is not widely used in part because the FAA has been slow to certify AGE85 for all types of small planes.

On April 28, 2010 the EPA Administrator Lisa Jackson issued an Advance Notice of Proposed Rulemaking on Lead Emissions From Piston-Engine Aircraft Using Leaded Aviation Gasoline. Until June 28, 2001, the EPA will accept comments on the “data available for evaluating lead emissions, ambient concentrations, and potential exposure to lead from the continued use of leaded avgas in piston-engine powered aircraft,” as well as “additional information that will inform future action.”[198]

Recommendation 5.1 and Target: Clean air advocates should submit comments to the EPA— prior to the June 28th, 2010 comment period deadline— about the high levels of lead particulate found in the areas surrounding Van Nuys Airport and other general aviation airports in Los Angeles County, as well as the number of schools located within a three mile buffer zone of these airports (see pages 37 to 39 for this information). Clean air advocates should then track the EPA‘s rulemaking process and advocate for the removal of lead in avgas.

Priority of Recommendation 5.1: This action ranks as a high and urgent priority given that the EPA is in the beginning of their rulemaking process and there is the potential to affect regulation that could protect the public from lead exposure from avgas.

Recommendation 5.2 and Target: Airport owners and operators, such as the LAWA, could potentially structure their lease agreements with users of their airport to require the use of non-leaded fuel while on their airport property. More legal research would be required to determine exactly how such a lease agreement could be structured. Clean air advocates in conjunction with legal experts should pursue more legal research on this topic.

Priority of Recommendation 5.2: Additional legal research is a high but not urgent priority given that clean air advocates may first want to strategically concentrate on the EPA rulemaking process.

6) Restore Research Funding to Develop Clean and Efficient Aviation Technology

Finding: Historically, most of the aviation environmental gains have come from new technologies, with the National Aeronautics and Space Administration (NASA) as a lead agency in this process. In 2004, NASA established a five-year goal to deliver technologies that reduce CO2 emissions of new aircraft by 25 percent. However, NASA‘s budgets have declined since 2004, leaving this specific proposal underfunded and the goal unmet.

Recommendation and Target: Clean air advocates should ask federal legislators to restore research funding for cleaner aviation technology development. Funding criteria should be performance based and meant to accelerate breakthroughs in and commercialization of clean and efficient aviation technology. Funding could come from reinstating the Aviation Trust Fund. Revenue that was once collected through a 10 percent domestic ticket tax could instead be collected through an aviation fuel tax, thus providing an incentive to increase airline operational efficiency and to modernize the aging fleet with more efficient airframes and engines.[199]

Priority: This action ranks as a low priority for clean air advocates based in the Los Angeles region. Impacting funding at a national level would be a challenge for clean air advocates in Southern California and perhaps outside the scope of a campaign to target emission from operations at the LAWA owned and operated airports. However, doing so could be very important. The International Civil Aviation Organization (ICAO) sets emission standards for aircraft engines that the EPA adopts. The ICAO‘s policy is to set ―technology supporting” rather than ―technology forcing” standards, which means that research and development of cleaner aircraft engines is critical.

SOURCE TARGET: GROUND SUPPORT EQUIPMENT

7) Ensure Implementation of the LAX CBA

Finding: Ground service equipment account for four percent of VOC emissions, two percent of PM10 emissions, and 11 percent of NOx emissions. As part of the LAX Community Benefits Agreement (CBA), the LAWA agreed to convert all on-airport ground service equipment (GSE) to the cleanest technology available by 2015. Currently, only approximately a quarter of LAX's tenant GSE are zero-emission.[200]

Recommendation and Target: Clean air advocates should monitor and ensure that the LAWA meets its commitments in the CBA.

Priority: This action ranks as a high priority. Significant resources are required to monitor and put pressure on the LAWA to meet its commitment to clean GSE and other air quality components as part of the CBA. Yet doing so is important because of the potential for significant emission reductions and the logic in fully implementing an existing agreement rather than developing new and potentially duplicative policies.

8) Defend California's On-Road Diesel Regulation and/or Advocate for a New Regulation that Targets GSE

Finding: The state of California does not specifically target ground support equipment (GSE) in any of its binding regulations. While the CARB's In-Use Off-Road Diesel Vehicle Regulation applies to GSE, among many other emission sources, as part of the 2009 California budget, the California legislature directed the CARB to make several changes to the rule that reduce the emission reduction and health benefits associated with the rule by extending compliance deadlines and making other requirements less stringent.[201]

Recommendation and Target: Clean air advocates should work with the CARB to defend this important rule. If the CARB does not strengthen the rule, clean air advocates should encourage the CARB to develop a separate rule that specifically and aggressively addresses airport GSE.

Priority: This action ranks as a medium priority. An effective statewide rule could have significant emission reduction potential, but strengthening or creating a new rule to effectively target emissions from GSE at airports would be challenging given the current political and regulatory climate

TARGET SOURCE: AIRPORT VEHICLE FLEETS

9) Ensure that the LAWA Meets its Commitment to Cleaner Airport Vehicles and Extend the Commitment to Ontario and Van Nuys Airports

Finding: Airport-owned vehicles contribute nine percent of VOC emissions, four percent of NOx emissions, and three percent of PM10 emissions from LAX-related operations. As part of the LAX Community Benefits Agreement, the LAWA agreed that 100 percent of its fleet vehicles would be alternative fueled, or vehicles with comparable emissions, by 2015. Currently, the LAX fleet is comprised of approximately 72 percent alternative fuel vehicles (AFV). LAWA has not publicized its fleet ratio for its other airports, an indication that the AFV rate is significantly lower elsewhere.

Recommendation 9.1 and Target: Clean air advocates should monitor and ensure that the LAWA meets its commitment to a 100 percent transition of its LAX fleet to alternative fuel vehicles, or vehicles with comparable emission reductions, as part of the LAX Community Benefits Agreement.

Priority for Recommendation 9.1: In general, monitoring the LAWA's progress in implementing the LAX Community Benefits Agreement (CBA) should be a high priority for clean air advocates.

Recommendation 9.2 and Target: The commitment to alternative fueled vehicles via the CBA should be extended to Ontario Airport and Van Nuys Airports. Although the LAWA is behind in its original schedule for the Ontario Master Plan due to the recent downturn in air travel, the LAWA will likely move forward with development plans for Ontario Airport at some point in the future. Clean air advocates could use that opportunity to ensure that the LAWA is maximizing opportunities for emission reductions from its vehicle fleet as part of any plan to expand.

Priority of Recommendation 9.2: This action ranks as a low to medium priority. While creating something like a community benefits agreement for Ontario Airport could result in significant emission reductions, doing so would take a significant amount of resources and a comprehensive clean air action plan, per recommendation number one, is the preferred strategy.

TARGET: STATIONARY SOURCES

10) Go Solar at the LAWA Airports

Finding: Although mobile sources constitute the bulk of emissions related to airport operations, stationary sources— primarily from energy production— account for two percent of both NOx and PM10 emissions from LAX operations. In November 2009, the LAWA Board of Airport Commissioners approved a new central utility plant at LAX that will decrease emissions relative to current levels. However, the effort does not go as far as some airports— like Denver International— that are investing in onsite solar arrays.

Recommendation and Target: Clean air advocates should ask the Los Angeles World Airports and the Los Angeles Department of Water (DWP) to invest in solar panels at every airport owned and operated by the LAWA. In particular, the LAWA and the DWP should follow through with the proposal to build a large solar facility on unused land on Palmdale Airport property.

Priority: This action ranks as a medium priority. Stationary sources are not the most significant source of criteria air pollution from airport operations, but reducing emissions associated with airport energy use would be achieved simply by shifting to more solar power. The LAWA certainly has the space to install solar panels on its properties and doing so could help meet the City of Los Angeles' renewable energy goals and advance the City's Solar Plan.

Table 10

Recommended Actions	Emission Source Target	Suggested Priority
Create a clean air action plan for the LAWA	Several sources	High
Target aircraft and airports in State Implementation Plans	Several sources	Medium to high
Increase the viability of alternative ground access transportation via cordon pricing and improved public transit	Ground access	Medium
Focus on heavy-duty trucks	Ground access	Medium to high
Ban lead in aviation gasoline	Aircraft	High and urgent
Restore research funding to develop clean and efficient aviation technology	Aircraft	Low
Ensure implementation of the LAX Community Benefits Agreement, in particular the commitment to clean GSE	Several, including ground service equipment	High
Defend California's On-Road Diesel Regulation and/or advocate for a new regulation that targets GSE.	Ground service equipment	Medium
Ensure that the LAWA meets its commitment to cleaner airport vehicles and extend the commitment to Ontario and Van Nuys Airports	Airport vehicles	High
Go solar at the LAWA airports	Stationary	Medium

Conclusion

Aviation is one of the most rapidly growing sources of both criteria pollutants and greenhouse gas emissions. This trend will continue if the long-term demand for air travel increases without policy, technology, and operational changes. Fortunately, many opportunities exist for emission reductions that clean air advocates can pursue. A combination of international, national, state, regional, and local entities have a role in reducing emissions from a variety of sources at the Los Angeles World Airports (LAWA). These emission sources include: ground access transportation, aircraft, airport fleet vehicles, ground support equipment, and stationary sources.

Any campaign to significantly reduce emissions from the LAWA's airports should seek to move the LAWA to develop a comprehensive plan to reduce emissions from all airport-related emission sources through a consistent application of air quality goals and policies at all of the LAWA's airports. While not simple, designing a successful clean air campaign is important given significant air quality and health impacts of airports.

Appendix 1

GLOSSARY OF TERMS AND ACRONYMS

air carriers — airlines holding a certificate issued under section 401 of the Federal Aviation Act of 1958 that operate aircraft designed to have a maximum seating capacity of more than 60 seats or a maximum payload capacity of more than 18,000 pounds or conduct international operations. There are four different types of air carriers: major, national, large regional, and medium regional. Their annual operating revenues are, respectively, greater than $1 billion, $100 million to $1 billion, $20 million to $100 million, and up to $20 million.

air taxis — planes that 1) perform at least five round trips per week between two or more points according to flight schedules that specify the times, days of the week, and places between which such flights are performed or 2) transport mail pursuant to a current contract with the US Postal Service.

airport operations — the number of arrivals and departures from the airport at which the airport traffic control tower is located.

AFV — alternative fuel vehicle

attainment area — an area considered to have air quality as good as or better than the national ambient air quality standards as defined in the Clean Air Act. An area may be an attainment area for one pollutant and a nonattainment area for others. See also **nonattainment area**.

CARB — California Air Resources Board

CBA — community benefits agreement

commercial aircraft — the sum total of air carrier and air taxi flights.

CO2 — carbon Dioxide

criteria pollutant — The US Environmental Protection Agency sets National Ambient Air Quality Standards for six common air pollutants, which are known as

—criteria pollutants” because EPA develops human health-based and/or environmentally-based criteria for setting permissible levels. These pollutants are particle pollution (often referred to as particulate matter), ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead.

day-night sound level (DNL) ─ a level of noise derived by measuring average sound levels in a 24-hour day, in decibels. Night time noise, between the hours of 10:00 p.m. and 7:00 a.m. is "weighted"; that is, given an additional 10 decibels to compensate for sleep interference and other disruptions caused by loud nighttime noise. For airport noise exposure purposes, an annual average of the daily day-night average sound levels is used. 65 dB DNL is the noise threshold at which the FAA defines areas as "compatible" with residential use; areas at or above 65 dB DNL are designated as "incompatible" with residential use.

decibel (dB) ─ a unit of sound measurement. A sound doubles in loudness for every increase of ten decibels.

emission ─ pollution discharged into the atmosphere from smokestacks, other vents, and surface areas of commercial or industrial facilities; from residual chimneys; and from motor vehicle, locomotive, or aircraft exhausts.

EPA ─ Environmental Protection Agency

EU ─ European Union

general aviation ─ all aviation that is not commercial or military.

GHG ─ greenhouse gas

GSE ─ ground service equipment

hazardous air pollutants (HAP) ─ also known as toxic air pollutants, are those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects. See also **toxic air pollutants**.

HC ─ hydrocarbon

ICAO ─ International Civil Aviation Organization

IPCC ─ International Panel on Climate Change

FAA ─ Federal Aviation Administration

LA ─ Los Angeles

LAWA ─ Los Angeles World Airports

LAX ─ Los Angeles International Airport

landing and takeoff cycle (LTO) ─ the basis of ground-level aircraft emissions calculations. The components of an LTO are approach, taxi/idle-in, taxi/idle-out, take-off, and climb-out. LTO cycle calculations include only the emissions planes create within 3,000 feet of the earth's surface, all of which affect ground-level air quality.

MOU ─ memorandum of understanding

National Ambient Air Quality Standards (NAAQS) ─ air quality standards established by EPA that apply to outside air throughout the country.

nitrogen oxide (NOx) ─ a product of combustion from transportation and stationary sources, a major contributor to acid deposition and the formation of both ground level and upper tropospheric ozone.

non-attainment area ─ geographic area that does not meet one or more of the National Ambient Air Quality Standards for ozone, nitrogen dioxide, carbon monoxide, particulates, sulfur dioxide, and lead.

ONT ─ Ontario International Airport

ozone (O3) ─ a form of oxygen found in two layers of the atmosphere: the stratosphere and the troposphere. This report refers to ozone in the troposphere─ the layer extending up seven to 10 miles from the earth's surface. Ozone is a chemical oxidant and major component of photochemical smog. Ozone can seriously affect the human respiratory system and is one of the most prevalent and widespread of all the criteria pollutants for which the Clean Air Act required EPA to set standards. Ozone in the troposphere is produced through complex chemical reactions of nitrogen oxides, hydrocarbons, and sunlight.

PM ─ particulate matter

RTP ─ Regional Transportation Plan

SCAG ─ Southern California Association of Governments

SCAQMD ─ South Coast Air Quality Management District

SCRAA ─ Southern California Regional Airport Authority

SIP (State Implementation Plan) ─ EPA-approved state plans for the establishment, regulation, and enforcement of air pollution standards. States that violate federal air quality standards for carbon monoxide, nitrogen dioxide, ozone, PM10 (particulate matter smaller than 10 microns), lead or sulfur dioxide must prepare SIPs.

smog ─ air pollution caused by chemical reactions of various pollutants emitted from different sources.

sulfur dioxide (SO2) ─ a pungent, colorless gas formed primarily by the combustion of fossil fuels; becomes a pollutant when present in large amounts.

sulfur oxides (SOx) ─ the entire group of sulfur oxides that include SO2 and the less common SO3. EPA's National Ambient Air Quality Standard for SO2 is designed to protect against exposure to the entire group of sulfur oxides. Emissions that lead to high concentrations of SO_2 generally also lead to the formation of other SOx. Control measures that reduce SO_2 can generally be expected to reduce people's exposures to all gaseous SOx.

Toxic air pollutants ─ also known as hazardous air pollutants, are those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects. The EPA is working with state, local, and tribal governments to reduce the release of 188 toxic air pollutants.

Toxic Release Inventory (TRI) ─ a national database of information on toxic chemical releases and transfers, administered by the EPA.

US ─ United States

VNY ─ Van Nuys Airport

volatile organic compound (VOC) ─ any organic compound that participates in atmospheric photochemical reactions except for those designated by EPA as having negligible photochemical reactivity.

Sources for definitions:

—Glossary of Environmental Terms," Environmental Protection Agency. Last updated December 1997. http://www.epa.gov/OCEPAterms/.

"Air Traffic Activity Data System," Federal Aviation Administration. Last updated July, 2009. http://aspmhelp.faa.gov/index.php/Glossary.

Appendix 2

LABOR DYNAMICS

Traditionally, the airline industry has provided middle-class jobs. However, job quality may have decreased in the industry in part due to economic concessions and contracting policies that have driven down wages and benefits.[202] Labor costs have been a major focus for the industry's cost-cutting.[203] According to the *Wall Street Journal*, airlines have cut wages and benefits so much that they are having problems with attracting and retaining workers.[204] Major network carriers cut more than 170,000 workers, or 38 percent of the total workforce, between August 2001 and October 2006, according to the Air Transport Association.[205]

In Los Angeles, labor issues have been a focus of airport oriented organizing efforts. The Los Angeles Alliance for a New Economy was the lead organization behind the community benefits (CBA) agreement reached with the Los Angeles World Airports. The main labor related components of the CBA are as follows:[206]

1. <u>Job training</u>. The LAWA committed to providing $3 million per year for five years to fund job training, with funding priority given to low-income individuals, special needs individuals, and individuals working in airport jobs or aviation-related jobs. Programs include job readiness programs, skills development, and career ladder programs.
2. <u>First source hiring program</u>. This program is geared toward low-income individuals who have lived in the project impact area for at least one year and special needs individuals given priority for available airport jobs. Second priority is given to low-income individuals living in the city.
3. <u>Living wage, worker retention, and contractor responsibility</u>**.** The City's Living Wage Ordinance applies to all Airport Contractors, Lessees, and Licensees.

Appendix 3

OTHER AIRPORT-RELATED ENVIRONMENTAL IMPACTS

In January 1995, the nonprofit organization the Natural Resources Defense Council (NRDC) undertook a study and survey of airports throughout the country to determine the most important environmental issues connected with airports.[207] The NRDC found that while airports vary in terms of size and geographical characteristics, significant environmental impacts were common to most of the airports in their survey. These impacts included: noise pollution, air pollution, climate/energy impacts, and water pollution and use. The following two sections are a summary of the findings and policy implications in respect to noise pollution and water pollution impacts from airport operations.

Noise pollution

The bulk of the research on the health effects of airport operations have focused on noise pollution. Research suggests that aircraft noise affects millions of people every day in a variety of ways both short-term and long-term, both obvious and difficult to gauge.[208] Research proves that noise affects one's ability to concentrate and can cause hearing loss and sleep deprivation, resulting in potentially deleterious effects on health and well-being.[209]

A myriad of studies have also found that community exposure to aircraft noise is associated with hypertension (high blood pressure).[210] For example, in 2001, M. Rosenlund evaluated aircraft noise exposure for 2,959 adults and found an association between the increase in raised blood pressure and a continuous 24 hour aircraft noise level above 55 dB and at maximum levels above 72 dB.[211] Eriksson *et al*. studied 2,037 men in the 40 to 60 year age group over a 10 year period and found that exposure to aircraft noise above 50 dB was associated with a significant 20 percent increase in the risk of hypertension.[212] The HYENA study of 4,861 adults aged 45 to 70 years living in the close vicinity of six European airports, reported that a 10 dB increase in the continuous night-time noise level was found to be significantly associated with a 14 percent increase in the probability of being diagnosed with hypertension.[213] The largest study of medication use was performed in the vicinity of Cologne/Bonn Airport in

Germany).[214] The study revealed significant relationships between the intensity of aircraft noise and the number of antihypertensive medications prescribed per patient. Antihypertensive medications for women were prescribed 27 percent more often at for women exposed to continuous aircraft noise at a level of 40 to 45 dB and 66 percent more often at level of 46 to 61 dB.

Research also links airport noise to an increased risk of stroke and heart disease. A recent (2010) study commissioned by Germany's Federal Environment Agency studied data from public health insurers on more than 1 million Germans ages 40 and over who live near Cologne-Bonn Airport in western Germany. According to the study, men who are exposed to jet noise have a 69 percent higher risk of being hospitalized for cardiovascular disease.[215] Women living under flight paths fare even worse, logging a 93 percent higher rate of hospitalization with cardiovascular problems, compared with their counterparts in quiet residential areas.[216] The study also found that women who are exposed to jet noise (of about 60 decibels) during the day are nearly two-times as likely to suffer a stroke as women not exposed jet noise.[217]

Policy Implications

These studies clearly demonstrate that health effects are seen at levels below 65 db DNL. The FAA's threshold of 65 dB for residential use is problematic because: 1) it is based on an averaging of noise, rather than the loud "single event" noise that specifically characterizes aircraft noise, and 2) the threshold of 65 dB significantly underestimates the level at which many people are impacted by aircraft noise.[218] The most recent studies on noise and health have been conducted mostly in Europe rather than the United States. This is due, at least in part, to the current limited role of the US Environmental Protection Agency (EPA) in the field of aircraft noise.[219] More research in the US is needed to perhaps revisit safe noise levels. While most airports have some type of program in place to lessen noise for their neighbors (such as using flight paths farther away from residential areas at night), a fundamental key to good aircraft noise policy lies in setting appropriate land uses adjacent to airports.[220]

Water Pollution

The presence of snow, ice, or slush on runways or aircraft frequently causes hazardous conditions that can contribute to aircraft accidents, delays, and flight cancellations. Consequently, deicing or anti-icing (preventing the formation of ice) of aircraft and runways is a necessary part of operations at most US airports in winter months. The most common method of controlling ice is through the use of chemicals, particularly ethylene or propylene-based glycol mixtures with additives. Given that many, if not most, of the country's largest airports are sited along waterways, the control disposal of deicing chemicals and other chemicals, solvents, and metals used at airports constitute a significant water pollution issue. In addition, the use of deicing chemicals (particularly ethylene glycol) and other toxic substances at airports may present threats to human health, particularly to airport workers. Ethylene glycol and the issue of worker health and safety needs to be further addressed.[221]

Revisions to the Clean Water Act revisions in 1987 recognized storm water run-off for the first time under federal law. The result was a national storm water permit system. However, the run-off management system that airports are required to implement under the national storm water system is problematic because of gaps in the areas of effluent standards, enforcement, and monitoring.

Policy Implications

Currently, aircraft deicing is not subject to a traditional effluent guideline permitting process.[222] The EPA could reinstate aircraft deicing in its Transportation Cleaning effluent guidelines. The FAA could revise its Advisory Circular on Airport Winter Safety and Operations (AC 150/5200-30A) to include information on the latest, least environmentally-damaging deicing procedures that also meet safety requirements.[223] In addition, more research should be conducted and information made available on the health effects of and the alternatives to chemicals for deicing.[224]

Appendix 4

OTHER ENVIRONMENTAL INITIATIVES OF THE LOS ANGELES WORLD AIRPORTS

The LAWA's environmental programs— beyond the air quality related initiatives highlighted in the body of this report— include the following:[225] [226]

1) Hazardous Materials Management Programs

   a. The LAWA technicians removed 2,200 pounds of mercury in old instruments from the LAX Central Utilities Plan and replace them with mercury-free electronic transmitters.

2) Noise Management Program

   a. Residential Soundproofing Program. The number of eligible dwelling around LAX is approximately 8,200. (The LAWA has not revealed how many have actually been soundproofed, which probably means a lower number). The Van Nuys Airport Residential Soundproofing Program encompasses 1,054 dwelling units that are scheduled to be completed by 2010.

   b. Land Use Mitigation Program. This program is designed to administer, monitor, and expedite the LAWA funding for noise mitigation programs, including land acquisition and soundproofing in impacted areas around LAX and within the cities of Inglewood, El Segundo, and unincorporated areas of Los Angeles County as well as areas surrounding ONT.

   c. Voluntary Residential Acquisition and Relocation Program. This program involved relocating approximately 1,400 unit owners who voluntarily requested the LAWA to acquire their residential properties and provide relocation assistance to owners and renters.

   d. Federal Aviation Regulations, Part 161 Studies. LAWA initiated a study in 2005 that was intended to restrict departures between midnight and 6:30 am over the communities east of the airport. (Residents note that the flight restrictions are not enforced to a manner that significantly limits night flights). The goal of the VNY Part 161 Study is to implement seven noise control measures. The scope of the work has expanded and additional restrictions proposed include the phase-out of Stage 2-type corporate jet aircraft and expanding the existing curfew to 9 am and weekends.

e. LA/Ontario Airport Noise Advisory Committee and LAX Community Noise Roundtable.

3) Source Reduction and Recycling Program

a. LAWA recycled and reused more than 64 percent of trash it generated in 2007.

b. LAWA also uses recycled materials in its construction projects. More than 75 percent of the construction and demolition waste from the LAX Tom Bradley International Terminal Renovation Project will be recycled or salvaged.

4) Water Conservation and Management Programs

a. All LAWA toilets and sinks use low-flow devices.

b. Presently, 35 percent of all landscaped areas at LAX are irrigated by reclaimed water, saving approximately 40.2 million gallons per year.

5) Storm-water Monitoring

a. Prevention. LAWA staff conducts state-mandated storm-water management programs at LAX, ONT, and VYN.

b. Inspection. Airport tenant sites are inspected annually to ensure compliance with storm-water regulations.

c. Training. LAWA holds storm-water training sessions annually.

6) Wildlife and Habitat Conservation Programs

a. LAX Sand Dunes Restoration.

b. Palos Verdes Peninsula Land Conservancy.

Appendix 5

WORKS CITED

[1] Zhan, L. “Cleaner Skies, Brighter Future: Opportunities and Obstacles to Reduce Airport-based Greenhouse Gas Emissions.” June 2, 2008.

[2] McCollum, D.; Gould, G.; Greene, D. “Greenhouse Gas Emissions from Aviation and Marine Transportation: Mitigation Potential and Policies.” Pew Center on Global Climate Change. Dec 2009.

[3] U.S. House of Representatives, Committee on Transportation and Infrastructure, Subcommittee on Aviation staff. U.S. House of Representatives hearing on “Aviation and the Environment: Emissions.” May 5, 2008.

[4] U.S. Environmental Protection Agency Electronic Report on the Environment. Updated in December 2009 using the 2005 National Emissions Inventory. http://cfpub.epa.gov/eroe.

[5] Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) (2007) Interpreting and managing blood lead levels <10 ug/dL in children and reducing childhood exposures to lead: Recommendations of CDC's Advisory Committee on Childhood Lead Poisoning Prevention. Morbidity and Mortality Weekly Report. 56(RR-8). November 2, 2007.

[6] U.S. Environmental Protection Agency. “Advance Notice of Proposed Rulemaking on Lead Emission from Piston-Engine Aircraft Using Leaded Aviation Gasoline.” Federal Registry. Vol. 75, No 81, April 38, 2010.

[7] Los Angeles World Airports. “Los Angeles World Airport Sustainability Plan.” 2008.

[8] Los Angeles World Airports. LAX Airport General Description. http://www.lawa.org/welcome_lax.aspx?id=40.

[9] Hastings, Norene. Communication with Environmental Specialists at the Los Angeles World Airports. Nov. 9, 2009.

[10] Port of Los Angeles and Port of Long Beach. http://www.cleanairactionplan.org/about_caap/clean_trucks.asp.

[11] State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials. Letter to the U.S. Environmental Protection Agency. Docket No. OAR-2002-0030. December 15, 2003.

[12] *Ibid.*

[13] California Air Resources Board and the American Lung Association of California. ―Recent Research Findings: Health Effects of Particulate Matter and Ozone Air Pollution.” November, 2007. http://www.arb.ca.gov/research/health/fs/pm_ozone-fs.pdf.

[14] U.S. House of Representatives, Committee on Transportation and Infrastructure, Subcommittee on Aviation staff. U.S. House of Representatives hearing on ―Aviation and the Environment: Emissions.” May 5, 2008.

[15] Federal Aviation Administration, Office of Energy and Environment. ―Aviation and Emissions: A Primer.” January, 2005. http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/aeprimer.pdf

[16] State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials. Letter to the U.S. Environmental Protection Agency. Docket No. OAR-2002-0030. December 15, 2003.

[17] Ton, M. K. Ecos Consulting. ―Plane Smog: An Assessment of the Sources and Effects of LAX Air Pollution on the Local and Global Environment.” January, 2001. Data from South Coast Air Quality Management District, 1997.

[18] *Ibid.*

[19] *Ibid.*

[20] Source: South Coast Air Quality Management District, ―2007 Air Quality Management Plan.” http://www.aqmd.gov/aqmp/07aqmp/draft/07aqmp.pdf.

[21] Intergovernmental Panel on Climate Change (IPCC). ―Aviation and Climate Change.” 1999.

[22] Natural Resources Defense Council. ―Flying Off Course: Environmental Impacts of America's Airports.” October, 1996. http://www.rcaanews.org/nrdc_FOC.pdf.

[23] McCollum, D.; Gould, G.; Greene, D. ―Greenhouse Gas Emissions from Aviation and Marine Transportation: Mitigation Potential and Policies.” Pew Center on Global Climate Change. Dec 2009.

[24] *Ibid.*

[25] U.S. Department of Transportation. ―Aviation Industry Performance: A Review of the Aviation Industry in 2008.” May 6, 2009.

[26] *Ibid.*

[27] Weikel, D. & Pae, P. ―A dizzying descent at airport.” *LA Times*, August 6, 2008.

[28] *Ibid.*

[29] *Ibid.*

[30] *Ibid.*

[31] U.S. Department of Transportation, Federal Aviation Administration. “Aerospace Forecast: Years 2006-2025.” 2009. http://www.faa.gov/data_research/aviation/aerospace_forecasts/2009-2025/media/2009%20Forecast%20Doc.pdf.

[32] Southern California Association of Governments. “General Aviation Plan for the 2004 Regional Transportation Plan.” April 2004.

[33] Zhan, L. “Cleaner Skies, Brighter Future: Opportunities and Obstacles to Reduce Airport-based Greenhouse Gas Emissions.” June 2, 2008.

[34] Federal Aviation Administration, Office of Energy and Environment. “Aviation and Emissions: A Primer.” January, 2005. http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/aeprimer.pdf.

[35] Fleming, G.; Malwitz, A.; Balasubramanian, S.; Roof, C.; Grandi, B.K.; Usdrowski, S.; Elliff, T.; Eyers, C.; and Lee, D. “Trends in Global Noise and Emissions from Commercial Aviation for 2000 through 2025.” Paper submitted to the 7th USA /Europe Air Traffic Management R&D Seminar, Barcelona. DOT Volpe Center, Wyle Laboratories, Inc., EUROCONTROL, QinetiQ, and Manchester Metropolitan University. 2007.

[36] *Ibid.*

[37] U.S. House of Representatives, Committee on Transportation and Infrastructure, Subcommittee on Aviation staff. U.S. House of Representatives hearing on “Aviation and the Environment: Emissions.” May 5, 2008.

[38] Zhan, L. “Cleaner Skies, Brighter Future: Opportunities and Obstacles to Reduce Airport-based Greenhouse Gas Emissions.” June 2, 2008.

[39] State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials. Letter to the U.S. Environmental Protection Agency. Docket No. OAR-2002-0030. December 15, 2003.

[40] *Ibid.*

[41] Federal Aviation Administration, Office of Energy and Environment. “Aviation and Emissions: A Primer.” January, 2005. http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/aeprimer.pdf.

[42] *Ibid.*

[43] *Ibid.*

[44] *Ibid.*

[45] Humphries, J. –Aviation Air Quality 101: Airport Operations in Air Quality Plans." PowerPoint presentation at the Airport Air Quality Symposium. March 12-14, 2003.

[46] Ribeiro, K.; Kobayashi, S.; Beuthe, M.; Gasca, J.; Greene, D; Lee, D.S.; Muromachi, Y.; Newton, P.J.; Piotkin, S.; Sperling, D.; Wit, R.; Zhou, P.J. 2007. –Transport and its Infrastructure." In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Metz, M.; Davidson, O.R.; Bosch, P.R.; Dave, R.; Meyer, L.A. (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[47] Federal Aviation Administration, Office of Energy and Environment. –Aviation and Emissions: A Primer." January, 2005. http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/aeprimer.pdf .

[48] Zhan, L. –Cleaner Skies, Brighter Future: Opportunities and Obstacles to Reduce Airport-based Greenhouse Gas Emissions." June 2, 2008.

[49] Information from this section taken from: Air Transport Association. http://www.airlines.org/customerservice/airports/Airports_QandA.htm. Viewed on February 20, 2010.

[50] Information from this section taken from: Air Transport Association. http://www.airlines.org/customerservice/airports/Airports_QandA.htm. Viewed on February 20, 2010.

[51] Los Angeles World Airports. http://www.lawa.org/welcome_LAWA.aspx?id=682. Accessed on March 6, 2010.

[52] Southern California Association of Governments. –General Aviation Plan for the 2004 Regional Transportation Plan." April 2004.

[53] Erie, S.; Mckenzie, A.; NacJebsue, S.; Shaler, S. –Regional Airport Management Study." Prepared for the Southern California Association of Governments by CitiGroup Technologies Corporation. September 2005.

[54] *Ibid.*

[55] *Ibid.*

[56] *Ibid.*

[57] Los Angeles World Airports. Ontario Airport General Description. http://www.lawa.org/welcomeONT.aspx.

[58] *Ibid.*

[59] *Ibid.*

[60] Los Angeles World Airports. Van Nuys Airport General Description. http://www.lawa.org/welcome_VNY.aspx?id=92.

[61] *Ibid.*

[62] Los Angeles World Airports. LAX Airport General Description. http://www.lawa.org/welcome_lax.aspx?id=40.

[63] *Ibid.*

[64] *Ibid.*

[65] *Ibid.*

[66] *Ibid.*

[67] Los Angeles World Airports. LAWA Air Passenger Survey Report. http://www.lawa.org/uploadedfiles/lax/pdf/2006LAXPassengerSurveyFinal.pdf.

[68] LAX Master Plan Supplement to the Draft Environmental Impact Report/ Environmental Impact Statement, Executive Summary table ES-1, Summary of Activity, Comparison of Alternatives, p. ES-2.

[69] LAX Bradley West Project Draft Environmental Impact Report. Executive Summary, p. 1-10. May 2009.

[70] Kaye, Laurie and Lopez Mendoza, Jerilyn. ―Everybody Wins: Lessons Learned from Negotiating Community Benefit Agreements in Los Angeles.” Environmental Defense. 2008.

[71] *Ibid.*

[72] *Ibid.*

[73]*Ibid.*

[74] *Ibid.*

[75] Community Benefits Agreement: LAX Master Plan Program. Page 1.

[76] LAX Community Benefits Agreement. 2005. http://www.ourlax.org/cb_CBA_Exhibits.cfm.

[77] Kaye, Laurie and Lopez Mendoza, Jerilyn. ―Everybody Wins: Lessons Learned from Negotiating Community Benefit Agreements in Los Angeles.” Environmental Defense. 2008.

[78] *Ibid.*

[79] Joe Lyou. Personal communication. October 15, 2009.

[80] Jacobs Consultancy. Letter to LAX SAS File re: Commercial Vehicles Using Alternative Fuel in the LAX Central Terminal Area. Sep. 9, 2008.

[81] Los Angeles World Airports. ―Los Angeles World Airport Sustainability Plan.” 2008.

[82] Los Angeles World Airports. http://www.lawa.org/welcome_LAX.aspx?id=1066. November 1, 2009.

[83] *Ibid.*

[84] *Ibid.*

[85] Joe Lyou. Personal communication. October 15, 2009.

[86] Los Angeles World Airports. http://www.lawa.org/welcome_LAX.aspx?id=1066. November 1, 2009.

[87] Los Angeles World Airports. 2008. ―Environmental Overview.”

[88] *Ibid.*

[89] *Ibid.*

[90] Visser, Ben. ―Visser‘s Voice: ‗Knock, Knock: Who‘s there? Unleaded avgas.‘” *General Aviation*. August 29, 2003. http://www.generalaviationnews.com/editorial/articledetail.lasso?-token.key=7813&-token.src=column&-nothing.

[91] U.S. Environmental Protection Agency Electronic Report on the Environment. Updated in
December 2009 using the 2005 National Emissions Inventory. http://cfpub.epa.gov/eroe.

[92] Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) (2007) Interpreting and managing blood lead levels <10 ug/dL in children and reducing childhood exposures to lead: Recommendations of CDC's Advisory Committee on Childhood Lead Poisoning Prevention. Morbidity and Mortality Weekly Report. 56(RR-8). November 2, 2007.

[93] U.S. Environmental Protection Agency. –Advance Notice of Proposed Rulemaking on Lead Emission from Piston-Engine Aircraft Using Leaded Aviation Gasoline.” Federal Registry. Vol. 75, No 81, April 38, 2010.

[94] *Ibid.*

[95] U.S. Environmental Protection Agency. –Lead.” http://www.epa.gov/lead/.

[96] U.S. Environmental Protection Agency. –Particulate Matter.” http://www.epa.gov/air/particlepollution/basic.html. Viewed on February 21, 2010.

[97] Environmental Protection Agency. –Particulate Matter, Health and Environment.” http://www.epa.gov/air/particlepollution/health.html. Viewed on February 21, 2010.

[98] Jovasevic-Stoganovic, M. –Some Issus of Risk From Exposure to Nanoparticules from Different Sources.” Radiation and Environmental Protection Department, Institute Vinča, Begrade, Serbia. Report presented at the South Coast Air Quality Management District, Ultrafine Particle Conference, April 30-May 2, 2006.

[99] California Air Resources Board. –History.” http://www.calepa.ca.gov/about/History01/PDF/9arb.pdf.

[100] Environmental Protection Agency. –About Air Toxics.” http://www.epa.gov/ttn/atw/allabout.html. Viewed on May 8, 2010.

[101] *Ibid.*

[102] *Ibid.*

[103] *Ibid.*

[104] *Ibid.*

[105] Intergovernmental Panel on Climate Change (IPCC). –Aviation and Climate Change.” 1999.

[106] McCollum, D.; Gould, G.; Greene, D. –Greenhouse Gas Emissions from Aviation and Marine Transportation: Mitigation Potential and Policies.” Pew Center on Global Climate Change. Dec 2009.

[107] *Ibid.*

[108] *Ibid.*

[109] Begley, S. –The Evolution of an Eco-Prophet.” *Newsweek*. Nov 9, 2009.

[110] *Ibid.*

[111] Fischer, Douglas. “Cleaning the Air Helps Cool Planet.” *Environmental Health News*: Dec. 12, 2008.

[112] Hu S, Fruin S, Kozwa K, Mara, S, Winer A, and Paulson S. “Aircraft Emission Impacts in a Neighborhood Adjacent to a General Aviation Airport in Southern California.” *Environ. Sci. Technol.* 2009, 43, 9839-8045.

[113] Coel, D. and Pourzand, H. “Staff Report: Rule 1194 Commercial Airport Ground Access.” South Coast Air Quality Management District. August 2000.

[114] Fine, P. March 5, 2008. PowerPoint at the Fling Green Conference. http://airquality.ucdavis.edu/pages/events/2008/flying_presentations/FINE.pdf.

[115] *Ibid.*

[116] Westerdahl D, Fruin S, Fine P, and Sioutas C. “The Los Angeles International Airport as a source of ultrafine particles and other pollutants to nearby communities.” California Air Resources Board and the University of Southern California. *Atmospheric Environment*. 2008, 42: 3143-3155.

[117] Froines, J.; Fanning, E.; Chun, R.; and Lu, R. “Monitoring and Modeling of Ultrafine Particles and Black Carbon at the Los Angeles International Airport.” University of California, Los Angeles. Prepared for the California Air Resources Board and the California Environmental Protection Agency. June 20, 2007.

[118] *Ibid.*

[119] Carslaw D, Beevers S, Ropkins K, and Bell M. C. “Detecting and quantifying aircraft and other on-airport contributions to ambient nitrogen oxides in the vicinity of a large international airport.” *Atms. Environ*. 2006, 40, 5424-5434.

[120] Hu, S; Fruin S.; Kozwa, K.; Mara, S.; Winer. A.; and Paulson, S. “Aircraft Emission Impacts in a Neighborhood Adjacent to a General Aviation Airport in Southern California.” *Environ. Sci. Technol.* 2009, 43, 9839-8045.

[121] Piazza, B. "Santa Monica Municipal Airport: A Report on the Generation and Downwind Extent of Emissions Generated from Aircraft and Ground Support Operations." Los Angeles Unified School District. Prepared for the Santa Monica Airport Working Group. June, 1999.

[122] Fine, P. “Community-Scale Air Toxics Monitoring- Sun Valley Neighborhood and General Aviation Airport.” U.S. EPA Air Toxics Data Analysis Workshop Presentation: Chicago, IL, 2007.

[123] Hu, S.; Fruin, S.; Kozawa, K.; Mara, S. and Paulson, S. “Aircraft Emission Impacts in a Neighborhood Adjacent to a Ground Aviation Airport in Southern California.” University

of California, Los Angeles, University of Southern California, and the California Air Resources Board. Environ. Sci. Technol. 2009, 43, 8039-8045.

[124] Ton, M. K. Ecos Consulting. “Plane Smog: An Assessment of the Sources and Effects of LAX Air Pollution on the Local and Global Environment.” January, 2001. Data from South Coast Air Quality Management District, 1997.

[125] Holzman, D. “Plane Pollution.” Environmental Health Perspectives. Volume 105, Number 12, December 1997. http://ehp.niehs.nih.gov/qa/105-12focus/focus.html.

[126] U.S. Department of Transportation, Research and Innovative Technology Administration. “Airport Ground Access Planning Guide.” Lead author: Lee, Chimini. 1995. http://ntl.bts.gov/DOCS/AGAPP.html.

[127] Los Angeles World Airports. “2006 LAX Air Passenger Survey Final Report.” December 2007. http://www.lawa.org/uploadedfiles/lax/pdf/2006LAXPassengerSurveyFinal.pdf.

[128] *Ibid.*

[129] *Ibid.*

[130] Los Angeles County Metropolitan Transportation Authority. “Crenshaw Transit Corridor Draft Environmental Impact Statement.” 2009.

[131] Johnson, R. “Sustainability and Environmental Initiatives at Los Angeles World Airports.” Presentation on March 4, 2009.

[132] Los Angeles World Airports. “Los Angeles World Airports Sustainability Plan.” April 2008.

[133] Los Angeles World Airports, Presentation to the Board of Airport Commissioners, May 3, 2010. http://www.lawa.org/uploadedFiles/board_agenda/ManagementReports/boac100503zFlyAway%20Performance%20Update%20050310.pdf.

[134] Los Angeles World Airports. “2006 LAX Passenger Survey Final Report.” December, 2007.

[135] Los Angeles World Airports. “Los Angeles World Airports Sustainability Plan.” April 2008.

[136] Weikel, D. “FlyAway Bus Fare to LAX to Rise.” *LA Times*. June 11, 2009. http://latimesblogs.latimes.com/lanow/2009/06/flyaway-bus-fare-to-lax-to-rise.html.

[137] Los Angeles World Airports, Presentation to the Board of Airport Commissioners, May 3, 2010.

http://www.lawa.org/uploadedFiles/board_agenda/ManagementReports/boac100503zFlyAway%20Performance%20Update%20050310.pdf.

[138] Los Angeles World Airports. “Los Angeles World Airports Sustainability Plan.” April 2008.

[139] *Ibid.*

[140] *Ibid.*

[141] *Ibid.*

[142] *Ibid.*

[143] Los Angeles County Metropolitan Transportation Authority. “Crenshaw Transit Corridor Draft Environmental Impact Statement.” 2009.

[144] *Ibid.*

[145] Wachs, M. 1993. “Learning from Los Angeles: Transport, Urban Form, and Air Quality.” Kluwer Academic Publishers.

[146] *Ibid.*

[147] Orange County Transportation Authority. http://www.91expresslanes.com/.

[148] State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials. Letter to the U.S. Environmental Protection Agency. Docket No. OAR-2002-0030. December 15, 2003.

[149] State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials. Letter to the U.S. Environmental Protection Agency. Docket No. OAR-2002-0030. December 15, 2003.

[150] *Ibid.*

[151] *Ibid.*

[152] Ribeiro, K.; Kobayashi, S.; Beuthe, M.; Gasca, J.; Greene, D; Lee, D.S.; Muromachi, Y.; Newton, P.J.; Piotkin, S.; Sperling, D.; Wit, R.; Zhou, P.J. “Transport and its Infrastructure.” 2007. In “Climate Change 2007: Mitigation.” Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer)eds)], Cambridge University Press, Cambridge, United Kingdom and New Yorlk, NY, USA.

[153] *Ibid.*

[154] U.S. House of Representatives, Committee on Transportation and Infrastructure, Subcommittee on Aviation staff. U.S. House of Representatives hearing on “Aviation and the Environment: Emissions.” May 5, 2008.

[155] *Ibid.*

[156] U.S. House of Representatives, Committee on Transportation and Infrastructure, Subcommittee on Aviation staff. U.S. House of Representatives hearing on “Aviation and the Environment: Emissions.” May 5, 2008.

[157] *Ibid.*

[158] Brueckner, J. “Airport Congestion Management: Prices or Quantities?” *Access*. 35: Fall 2009; 10-15.

[159] *Ibid.*

[160] Brueckner, J. “Airport Congestion Management: Prices or Quantities?” *Access*. 35: Fall 2009; 10-15.

[161] *Ibid.*

[162] U.S. House of Representatives, Committee on Transportation and Infrastructure, Subcommittee on Aviation staff. U.S. House of Representatives hearing on “Aviation and the Environment: Emissions.” May 5, 2008.

[163] Maurice, L., U.S. Federal Aviation Administration. “The Commercial Aviation Fuels Initiative.” Presentation to the Aviation Alternative Fuels Side Event, Bonn, Germany. June 3, 2009. http://www.icao.int/icao/en/atb/meetings/2009/Env_SideEvent_Bonn/5_CAAFI.pdf.

[164] Demergjian, D. “Boeing Says that Aviation Biofuels Just Three Years Away.” Wired. Nov 6, 2008. http://www.wired.com/autopia/2008/11/boeing-says-thr/.

[165] *Ibid.*

[166] *Ibid.*

[167] Solarzyme. http://www.solazyme.com/market/fuels. Viewed on May 8, 2010.

[168] *Ibid.*

[169] U.S. Environmental Protection Agency. “Advance Notice of Proposed Rulemaking on Lead Emission from Piston-Engine Aircraft Using Leaded Aviation Gasoline.” Federal Registry. Vol. 75, No 81, April 38, 2010.

[170] Visser, Ben. “Visser‘s Voice: ‘Knock, Knock: Who‘s there? Unleaded avgas.‘” *General Aviation*. August 29, 2003.

http://www.generalaviationnews.com/editorial/articledetail.lasso?-token.key=7813&-token.src=column&-nothing.

[171] At Last, A Low-Cost Aviation Gasoline That Gets the Lead Out.” University of North Dakota, Energy & Environmental Research Center. July, 20, 1999. www.sciencedaily.com/releases/1999/07/990720083151.htm

[172] Fulton, S. ―Alternative Fuel: Your Next Engine Upgrade.” Aviator‘s Guide. 2005. http://www.aviatorsguide.com/planetalk/0906/index.htm.

[173] Federal Aviation Administration, Office of Energy and Environment. ―Aviation and Emissions: A Primer.” January, 2005. http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/aeprimer.pdf.

[174] Federal Aviation Administration, Office of Energy and Environment. ―Aviation and Emissions: A Primer.” January, 2005. http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/aeprimer.pdf.

[175] United Airlines. ―Our Environment.” http://www.united.com/page/article/0,6867,53165,00.html?jumpLink=%2Fenvironment. Viewed on February 20, 2010.

[176] California Air Resources Board. ―Ground Service Equipment.” http://www.arb.ca.gov/msprog/offroad/gse/gse.htm. Viewed on February 20, 2010.

[177] California Air Resources Board. ―In-Use Off-Road Diesel Vehicle Regulation.” http://www.arb.ca.gov/msprog/ordiesel/ordiesel.htm. Viewed on February 20, 2010.

[178] Lo s Angeles World Airports. ―Los Angeles World Airport Sustainability Plan.” 2008

[179] *Ibid.*

[180] Los Angeles World Airports. ―Los Angeles World Airport Sustainability Plan.” 2008.

[181] *Ibid.*

[182] Business Wire. Dec. 9, 2008. http://www.businesswire.com/portal/site/home/permalink/?ndmViewId=news_view&newsId=20081209005491&newsLang=en.

[183] Shangri-LA Construction. Website of Hanger 25. http://3030nclybournavenue.com/

[184] *Ibid.*

[185] Los Angeles World Airports. ―Los Angeles World Airport Sustainability Plan.” 2008.

[186] State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials. Letter to the U.S. Environmental Protection Agency. Docket No. OAR-2002-0030. December 15, 2003.

[187] *Ibid.*

[188] Natural Resources Defense Council. ―Flying Off Course: Environmental Impacts of America's Airports.” October, 1996. http://www.rcaanews.org/nrdc_FOC.pdf.

[189] Johnson, Roger, ―LAX Emissions by Source Category.” Presentation by the Deputy Executive Director of the Los Angeles World Airports. Feb.13, 2008.

[190] Holzman, D. ―Plane Pollution.” Environmental Health Perspectives. Volume 105, Number 12, December 1997. http://ehp.niehs.nih.gov/qa/105-12focus/focus.html.

[191] U.S. Department of Transportation, Research and Innovative Technology Administration. ―Airport Ground Access Planning Guide.” Lead author: Lee, Chimini. 1995. http://ntl.bts.gov/DOCS/AGAPP.html.

[192] Orange County Transportation Authority. http://www.91expresslanes.com/.

[193] Los Angeles World Airports. LAX Airport General Description. http://www.lawa.org/welcome_lax.aspx?id=40.

[194] Hastings, Norene. Communication with Environmental Specialists at the Los Angeles World Airports. Nov. 9, 2009.

[195] Port of Los Angeles and Port of Long Beach. http://www.cleanairactionplan.org/about_caap/clean_trucks.asp.

[196] U.S. Environmental Protection Agency Electronic Report on the Environment. Updated in
December 2009 using the 2005 National Emissions Inventory. http://cfpub.epa.gov/eroe.

[197] Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) (2007) Interpreting and managing blood lead levels <10 ug/dL in children and reducing childhood exposures to lead: Recommendations of CDC's Advisory Committee on Childhood Lead Poisoning Prevention. Morbidity and Mortality Weekly Report. 56(RR-8). November 2, 2007.

[198] U.S. Environmental Protection Agency. ―Advance Notice of Proposed Rulemaking on Lead Emission from Piston-Engine Aircraft Using Leaded Aviation Gasoline.” Federal Registry. Vol. 75, No 81, April 38, 2010.

[199] Natural Resources Defense Council. ―Flying Off Course: Environmental Impacts of America's Airports.” October, 1996. http://www.rcaanews.org/nrdc_FOC.pdf.

[200] Los Angeles World Airports. ―Los Angeles World Airport Sustainability Plan.” 2008.

[201] California Air Resources Board. “In-Use Off-Road Diesel Vehicle Regulation.” http://www.arb.ca.gov/msprog/ordiesel/ordiesel.htm. Viewed on February 20, 2010.

[202] Broines, C. and Myers, Holly. “Shortchanged: How Airlines Can Repay Taxpayers for Billions in Subsides by Improving Jobs, Security, and Services.” Los Angeles Alliance for a New Economy, July, 2008, pg iii.

[203] Trottman, M. and Carey S., “Unfriendly Skies: As Pay Falls, Airlines Struggle to Fill Jobs,” *Wall Street Journal,* May 16, 2007, p. A1.

[204] *Ibid.*

[205] Broines, C. and Myers, Holly. “Shortchanged: How Airlines Can Repay Taxpayers for Billions in Subsides by Improving Jobs, Security, and Services.” Los Angeles Alliance for a New Economy, July, 2008.

[206] LAX Community Benefits Agreement. 2005. http://www.ourlax.org/cb_CBA_Exhibits.cfm.

[207] Natural Resources Defense Council. “Flying Off Course: Environmental Impacts of America's Airports.” October, 1996. http://www.rcaanews.org/nrdc_FOC.pdf.

[208] *Ibid.*

[209] *Ibid.*

[210] Kaltenbach M, Maschke C, Klinke R. “Health consequences of aircraft noise.” *Dtsch Arbetl Int*. 2008; 105(31-32): 548-556. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2696954/.

[211] Rosenlund M, Berglund N, Pershagen G, Järup L, Bluhm G. “Increased prevalence of hypertension in a population exposed to aircraft noise.” *Occup. Environ Med.* 2001; 58: 769–773.

[212] Eriksson C, Rosenlund M, Pershagen G, Hilding A, Ostenson C-G, Bluhm G. “Aircraft noise and incidence of hypertension.” *Epidemiology.* 2007; 18: 716–77.

[213] Jarup L, Babisch W, Houthuijs D, et al. “Hypertension and exposure to noise near airports - the HYENA study.” *Environmental Health Perspectives*. 2008; 116: 329–333.

[214] Kaltenbach M, Maschke C, Klinke R. “Health consequences of aircraft noise.” *Dtsch Arbetl Int*. 2008; 105(31-32): 548-556. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2696954/.

[215] Moore, T. “Study: Airport Noise Increases Risk of Strokes.” Time, Dec. 15, 2009. http://www.time.com/time/specials/packages/article/0,28804,1929071_1929070_1947782,00.html#ixzz0ZsznAk62.

[216] *Ibid.*

[217] *Ibid.*

[218] Natural Resources Defense Council. ―Flying Off Course: Environmental Impacts of America's Airports.” October, 1996. http://www.rcaanews.org/nrdc_FOC.pdf.

[219] *Ibid.*

[220] *Ibid.*

[221] Paragraph taken from: Natural Resources Defense Council. ―Flying Off Course: Environmental Impacts of America's Airports.” October, 1996. http://www.rcaanews.org/nrdc_FOC.pdf.

[222] *Ibid.*

[223] *Ibid.*

[224] *Ibid.*

[225] Johnson, R. March 4, 2009. ―Los Angeles World Airports‘ Sustainability and Environmental Initiatives.” PowerPoint presentation.”

[226] Los Angeles World Airports. 2008. ―Environmental Overview.”