Environmental Issues and World Energy Use

In the coming decades, responses to environmental issues could affect patterns of energy use around the world. Actions to limit greenhouse gas emissions could alter the level and composition of energy-related carbon dioxide emissions by energy source.

Two major environmental issues, global climate change and local or regional air pollution, could affect energy use throughout the world in the coming decades. Current and future policies and regulations designed to limit energy-related emissions of airborne pollutants, are likely to affect the composition and growth of global energy use. Future policy actions to limit anthropogenic (human-caused) carbon dioxide emissions as a means of reducing the potential impacts of climate change could also have significant energy implications.

This chapter focuses on concerns about the local environmental and air quality impacts of mobile and stationary energy consumption, which have resulted in increasingly stringent regulation of air pollutants such as lead, sulfur oxides, nitrogen oxides,[16] particulate matter, and volatile organic compounds. Some countries are also considering ways to limit emissions of mercury from electric power generation to avoid the possible contamination of land surfaces, rivers, lakes, and oceans.

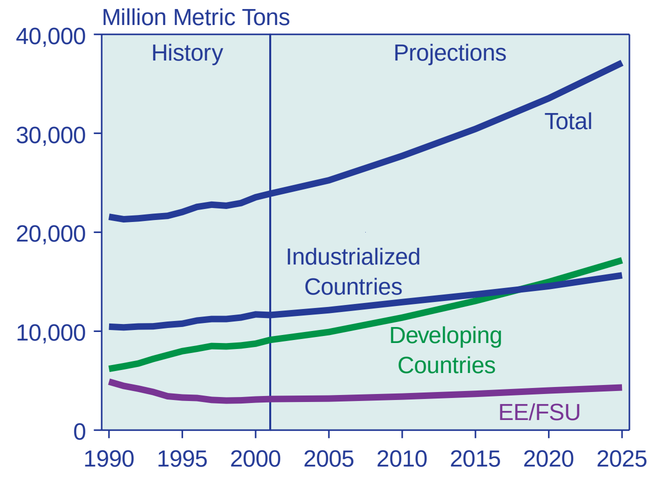
Global Outlook for Carbon Dioxide Emissions

The *International Energy Outlook 2004* (*IEO2004*) projects emissions of energy-related carbon dioxide, which, as noted above, account for the majority of global anthropogenic carbon dioxide emissions. Based on expectations of regional economic growth and dependence on fossil energy in the *IEO2004* reference case, global carbon dioxide emissions are expected to grow more rapidly over the projection period than they did during the 1990s. A projected increase in fossil fuel consumption, particularly in developing countries, is largely responsible for the expectation of fast-paced growth in carbon dioxide emissions. Because economic growth rates and population growth in the developing world are expected to be higher than in the industrialized world, accompanied by rising standards of living and fast-paced growth in energy-intensive industries, the developing nations account for the largest share of the projected increase in world energy use. Emissions are projected to grow most rapidly in China, the country expected to have the highest rate of growth in per capita income and fossil fuel use over the forecast period.

In 2001, carbon dioxide emissions from industrialized countries were 49 percent of the global total, followed by developing countries at 38 percent and the EE/FSU at 13 percent. In 2025, industrialized countries are projected to account for 42 percent of world carbon dioxide emissions, developing countries 46 percent, and the EE/FSU at 12 percent. The *IEO2004* projections suggest that carbon dioxide emissions from developing countries could surpass those from industrialized countries between 2015 and 2020 (Figure 72).

In the industrialized world, almost one-half of energy-related carbon dioxide emissions in 2001 came from oil use, followed by coal at 31 percent (Figure 73). Over the forecast period, oil is projected to remain the primary source of carbon dioxide emissions in industrialized

Figure 72. World Carbon Dioxide Emissions by Region, 1990-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

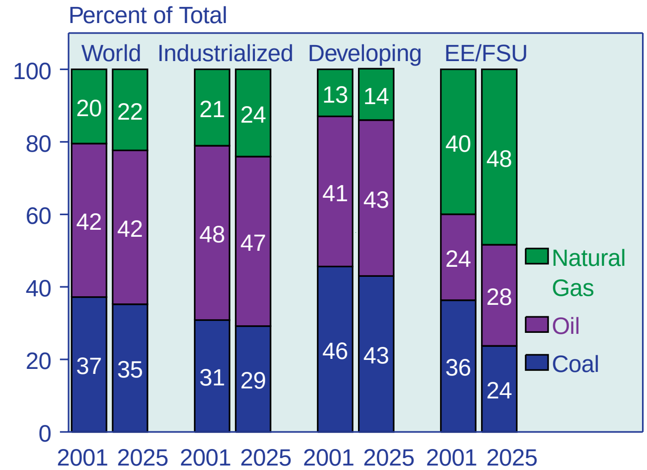
[16]Nitrogen oxides (NO_x) is the term used to describe the sum of nitric oxide (NO), nitrogen dioxide (NO_2), and other oxides of nitrogen that are short-lived atmospheric gases produced by the burning of fossil fuels and play a major role in the formation of ozone (smog). Nitrous oxide (N_2O), discussed later in this chapter, is a long-lived atmospheric gas produced primarily as a result of nitrogen fertilization of soils, mobile source combustion, and the decomposition of solid waste from domesticated animals. Nitrous oxide is also a greenhouse gas.

countries because of its continued importance in the transportation sector, where there are currently few economical alternatives. Natural gas use and associated emissions also are projected to increase, particularly for electricity generation. By 2025, the share of natural-gas-related emissions is expected to be 24 percent.

In the transitional economies of the EE/FSU region, 40 percent of energy-related carbon dioxide emissions comes from natural gas combustion. Coal production and consumption in the EE/FSU declined as a result of economic reforms and industry restructuring during the 1990s, bringing about an increase in the natural gas share of the energy and emissions mix during the period. Assuming the availability of sufficient capital for investment, further development of the vast natural gas reserves in Russia and the Caspian Sea region is expected to result in the continued displacement of coal by natural gas. Oil consumption is also projected to increase in the FSU, particularly for transportation and power generation, as Soviet-era nuclear reactors are retired in the coming years. As a result, both natural gas and oil are projected to account for increasing shares of the region's total carbon dioxide emissions, to 48 percent and 28 percent, respectively, in 2025.

With further restructuring of the coal mining industries in Poland and the Czech Republic, declines in coal production and consumption are expected to continue. Natural gas consumption is expected to double in Eastern European countries, in part because of the strict environmental standards required for membership in the European Union (EU). As a result of the projected changes in the energy mix, carbon dioxide intensity is expected to decline in Eastern Europe more than in any other region over the forecast period. Improvements in carbon dioxide intensity are expected to offset some of the growth in total energy consumption, but annual carbon dioxide emissions in Eastern Europe still are expected to increase by about 0.9 percent per year from 2001 to 2025.

Figure 73. Shares of World Carbon Dioxide Emissions by Region and Fuel Type, 2001 and 2025



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **2025:** EIA, System for the Analysis of Global Energy Markets (2004).

Compared with most of the industrialized countries, a much larger share of energy consumption in developing countries (particularly in Africa and Asia) comes from biomass, which includes wood, charcoal, animal waste, and agricultural residues (see box on page 140). Because data on biomass use in developing nations are often sparse or inadequate, *IEO2004* does not include the combustion of biomass fuels in its coverage of current or projected energy consumption, except for the United States; however, net emissions of carbon dioxide from biomass combustion are expected to be in balance in the long run with carbon sequestration by growing biomass and, therefore, are not included in the EIA estimates of greenhouse gas emissions.

Of the fossil fuels, oil and coal currently account for the majority of total energy-related carbon dioxide emissions in the developing world, and they are projected to remain the dominant sources of emissions throughout the forecast period. China and India are expected to continue to rely heavily on domestic coal supplies for electricity generation and industrial activities. Most other developing regions are expected to continue to depend on oil to meet the majority of their energy needs, especially in light of the projected increase in transportation energy demand.

Future levels of energy-related carbon dioxide emissions in many countries are likely to differ significantly from *IEO2004* projections if measures to mitigate greenhouse gas emissions are enacted, such as those outlined under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto Protocol, which calls for limitations on greenhouse gas emissions (including carbon dioxide) for developed countries and some countries with economies in transition, could have profound effects on the future fuel use of countries that ratify the protocol. Because the Kyoto Protocol has not yet come into force, the *IEO2004* projections do not reflect the potential effects of the treaty or of any other proposed climate change policy measures.

Issues in Energy-Related Greenhouse Gas Emissions Policy

International Climate Change Negotiations

The global community's effort to address climate change has taken place largely under the auspices of the

UNFCCC, which was adopted in May 1992 at the first Earth Summit held in Rio de Janeiro, Brazil, and entered into force in March 1994. The ultimate objective of the UNFCCC is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" [*1*]. The global community reaffirmed its commitment to the principles of the Framework Convention at the second Earth Summit held in Johannesburg, South Africa, in August 2002.

The implementation arm of the UNFCCC is the Kyoto Protocol, which was developed in December 1997 at the Third Conference of the Parties (COP-3). The terms of the Kyoto Protocol call for Annex I countries (including most of the industrialized countries) to reduce their overall greenhouse gas emissions by at least 5 percent below 1990 levels over the 2008 to 2012 period.[17] Quantified emissions reduction targets are differentiated by country (Table 17). The most recent COP meeting, COP-9, was held in Milan, Italy, in December 2003 (see box on page 144).

To achieve their emissions reduction targets, Annex I countries can implement domestic emission reduction measures or international "flexible mechanisms." The Kyoto Protocol includes the use of three "flexible mechanisms" (sometimes called "Kyoto mechanisms" or "market-based mechanisms") to help countries achieve their targets by allowing markets to determine the most cost-efficient way to reduce global greenhouse gas emissions.

- *International emissions trading* allows Annex I countries to transfer some of their allowable emissions to other Annex I countries, beginning in 2008, for the cost of an emission credit. For example, an Annex I country that reduces its 2010 greenhouse gas emissions level by 10 million metric tons carbon dioxide more than needed to meet its target level can sell the "surplus" emission reductions to other Annex I countries.
- *Joint implementation* (JI) allows Annex I countries, through governments or other legal entities, to invest in emission reduction or sink enhancement projects in other Annex I countries, gain credit for those "foreign" emissions reductions, and then apply the credits toward their own national emission reduction commitments.
- The *clean development mechanism* (CDM) is similar to joint implementation but the emissions reductions can occur in non-Annex I countries.

The Kyoto targets refer to overall greenhouse gas emission levels, which encompass emissions of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Hence, a country may opt for a small reduction of carbon dioxide emissions and a relatively greater reduction of other greenhouse gas emissions, or vice versa, in order to meet its Kyoto obligation. Currently, carbon dioxide emissions account for the majority of greenhouse gas emissions in most Annex I countries, followed by methane and nitrous oxide [*2*].

Different emissions may have notably different impacts on the atmosphere. Global warming potentials (GWPs) are used to compare the abilities of different greenhouse gases to trap heat in the atmosphere. GWPs are based on the radiative efficiency (heat-absorbing ability) of each gas relative to that of carbon dioxide. The IPCC is the generally accepted authority on GWPs for key greenhouse gases. In the latest IPCC assessment, published in 2001, the GWP of hydrofluorocarbon 23 is about 12,000 times that of carbon dioxide; thus, reducing emissions of hydrofluorocarbon 23 by a small amount would have a much larger impact than reducing emissions of carbon dioxide by the same amount.

The Kyoto Protocol will enter into force 90 days after it has been ratified by at least 55 Parties to the UNFCCC, including a representation of Annex I countries accounting for at least 55 percent of the total 1990 carbon dioxide emissions from the Annex I group. By the end of 2003, 119 countries and the European Union[18] had ratified the Protocol, including Canada, China, India, Japan, Mexico, New Zealand, and South Korea. A total of 31 Annex I countries, representing 44.2 percent of total 1990 carbon dioxide emissions, have signed on to the treaty (Figure 74) [*3*]. Two major Annex I countries, Australia and the United States, have announced that they will not adopt the Kyoto Protocol, leaving Russia as the deciding factor for entry into force. With its 17.4 percent of 1990 Annex I carbon dioxide emissions, Russia's ratification

[17] The Annex I nations include Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom. Turkey and Belarus, which are represented under Annex I of the UNFCCC, do not face quantified emission targets under the Kyoto Protocol. The Kyoto Protocol includes emission targets for 4 countries not listed under Annex I—namely, Croatia, Liechtenstein, Monaco, and Slovenia. Collectively, the 39 parties facing specific emissions targets under the Kyoto Protocol are commonly referred to as "Annex B parties," because their targets were specified in Annex B of the Protocol.

[18] Although the European Union (EU) ratified the Kyoto Protocol, the same group of countries was formally known as the European Community (EC) at the time the UNFCCC and Kyoto Protocol were written and is therefore referred to as the EC in most of the documents related to the UNFCCC and Kyoto Protocol.

Noncommercial Biomass Energy Use in Developing Countries

The International Energy Agency estimates that 14 percent of the energy consumed for end use throughout the world comes from noncommercial biomass fuels.[a] Noncommercial, or traditional, biomass consists mostly of solid fuels—wood, charcoal, agricultural residues, and wood and animal wastes—used in developing countries. An estimated 2.4 billion people in developing countries use biomass as their primary fuel for cooking and heating. Although more than half of the people who rely on biomass live in India and China (1.3 billion), the proportion of the population depending on biomass fuels is largest in Sub-Saharan Africa, where more than 85 percent of the population use biomass as their primary source of energy. In Latin America, only 23 percent of the population rely on biomass fuels for cooking and heating.[b]

Biomass fuels are less efficient for providing end-use energy services than are other fuels. For example, wood is less efficient than either kerosene or liquefied petroleum gas (LPG) for cooking. Although the use of biomass fuels can have negative effects on the environmental and, particularly, on human health, they are widely used because of their availability and low cost. Noncommercial biomass is available almost everywhere, and many people think of it as being "free" if they collect it themselves, or very cheap if they purchase it. In comparison, the overhead cost of acquiring kerosene or LPG stoves and bottles can discourage people from using those fuels, and even if some families can afford other fuels, the required infrastructure may not be available.[c]

Although the direct economic costs of using biomass may be small, the indirect costs in terms of agriculture, environment, and public health can be high. For example, time spent gathering fuel could be used instead for agricultural production; and biomass used for fuel, such as agricultural residues and dung, could be used instead for fertilizer. It has been estimated that, in India, dung used for fuel in 1998 would have been worth $800 million as fertilizer for use in agriculture.[d]

The use of biomass as fuel, when managed sustainably (that is, when biomass is planted or naturally replaced at the same rate it is harvested), does not harm either the local or global environment. Unsustainable harvesting of wood can, however, cause local deforestation and, potentially, loss of biodiversity. Globally, the extraction and burning of biomass releases carbon dioxide into the atmosphere; however, there is no net release of carbon dioxide if biomass is planted and harvested at the same rate, because growing plants remove and sequester carbon dioxide from the atmosphere.

Harvesting of fuelwood in developing countries is not considered to be a significant cause of large-scale deforestation. In general, people do not fell trees in their search for firewood, preferring instead to collect woody shrubs, fallen branches, or debris from cleared agricultural fields. In addition, fuelwood is rarely harvested from natural forests. Near cities with large numbers of urban poor and a lack of electrification, fuelwood or charcoal (made locally from wood) continues to be used widely as a household energy source, and the high demand for woody biomass concentrated geographically can lead to over-exploitation of forest resources near the city.

More significant adverse consequences from the use of biomass as a household energy source are associated with the indoor air pollution caused by fumes and emissions from stoves. For example, one recent study has shown that 24-hour average indoor concentrations of small particle emissions in Indian households that use solid fuels for cooking and heating can be as high as 2,000 micrograms per cubic meter[e] and can exceed World Health Organization guidelines by a factor of 10, 20, or more. For comparison, average annual outdoor concentrations of small particles (less than 10 microns in diameter) are generally less than 30 micrograms per cubic meter in U.S. cities and between 90 and 600 micrograms per cubic meter at outdoor urban monitoring stations in India.[f]

(continued on page 141)

[a]International Energy Agency, *Biomass Energy: Data, Analysis, and Trends* (Paris, France, 1998).
[b]International Energy Agency, *World Energy Outlook 2002* (Paris, France, 2002).
[c]International Energy Agency, *World Energy Outlook 2002* (Paris, France, 2002).
[d]Tata Energy Research Institute (India), Energy Research Institute (China), Wageningen Agricultural University (Netherlands), and International Institute for Applied Systems Analysis (Austria), *Potential for Use of Renewable Sources of Energy in Asia and Their Cost Effectiveness in Air Pollution Abatement, Final Report on Work Package 1* (December 1999), web site www.dow.wau.nl/msa/renewables/Downloads/workpackage1/Final_report_workpackage_1.pdf.
[e]K.R. Smith, "National Burden of Disease in India from Indoor Air Pollution," *PNAS*, Vol. 97, No. 24 (November 21, 2000), p 13285.
[f]The World Bank Group, "The Inside Story: Indoor Air Pollution Implicated in Alarming Health Problems," *Indoor Air Pollution Newsletter: Energy and Health for the Poor*, No. 1 (September 2000), web site http://wbln0018.worldbank.org/sar/sa.nsf/2991b676f98842f0852567d7005d2cba/a169d6e66c9c0c7585256990006a2631?OpenDocument.

Noncommercial Biomass Energy Use in Developing Countries (Continued)

Exposure to indoor air pollution is especially high for women and children in developing countries. Women usually have primary responsibility for cooking, and small children (under the age of five) tend to remain indoors with their mothers. One of the major health risks associated with small particle air pollution in developing countries is acute respiratory infections associated with a wide range of viruses and bacteria. In India, acute respiratory infections account for nearly three-quarters of the deaths from causes associated with indoor air pollution.[g] Chronic obstructive pulmonary disease and lung cancer have also been associated with exposure to particulate matter from indoor air pollution, as have increases in risk for cataracts (leading to blindness), tuberculosis, asthma, and adverse pregnancy outcomes (including low birth weight, prematurity, and early infant death).

Indoor air pollution affects approximately 2.4 billion people worldwide and many countries have programs to address the issue. National policy initiatives include temporary or permanent subsidies for cleaner burning, better ventilated stoves; improved delivery of energy services to the poor, particularly in rural areas; microfinancing schemes to help the poor with initial investments in improved stoves; and investments in research and development for new technologies, financing mechanisms, and exposure and health assessments.[h]

[g] K.R. Smith, "National Burden of Disease in India from Indoor Air Pollution," *PNAS*, Vol. 97, No. 24 (November 21, 2000), p 13291.
[h] The World Bank Group, "Regional Workshop on Household Energy, Indoor Air Pollution and Health," *Indoor Air Pollution Newsletter: Energy and Health for the Poor*, No. 8 (August 2002), web site http://lnweb18.worldbank.org/sar/sa.nsf/General/54F998E632F70B3685256DB70073A19A?OpenDocument.

would bring the total to 61.6 percent and enable the Kyoto Protocol to enter into force—regardless of the American and Australian decisions not to participate. Although Russia's President Vladimir Putin has announced Russia's intention to ratify the treaty, recent statements by his economic advisors suggest otherwise. Further clarification of Russia's position is unlikely until well after its March 2004 presidential and legislative elections.

A few Kyoto Protocol issues remain unresolved, some of which can be finalized only when the Protocol has entered into force. They include targets and procedures for subsequent commitment periods and the issue of technology transfer between countries to enable more rapid emissions reductions. Other unresolved issues include the accounting rules for carbon sink projects, and whether the consequences for noncompliance in meeting national emission reduction targets should be legally binding.

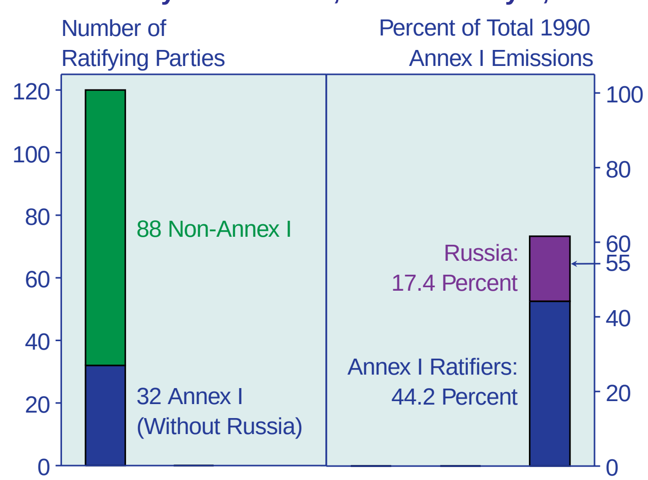
Although the Kyoto Protocol is not yet in force, many governments have been trying to reduce greenhouse gas emissions through a variety of domestic and international policies. Policies target all areas of energy use in industry, energy production, transportation, and buildings (Table 18).

The *IEO2004* reference case projections indicate that energy-related carbon dioxide emissions from the entire Annex I group of countries will exceed the group's 1990 emissions level in 2010. In addition, although energy-related carbon dioxide emissions from the group of transitional Annex I countries decreased significantly between 1990 and 2000 as a result of economic and political crises in the EE/FSU, they showed an increase from 2000 to 2001 and are projected to continue increasing over the forecast period. The combined Kyoto Protocol reduction target for the transitional Annex I countries is 10 percent below their projected 2010 baseline emissions.

Greenhouse Gas Emissions Trading

At COP-7 in Marrakech, it was established that international emissions trading under the Kyoto Protocol could start in 2008. In advance of any international emissions

Figure 74. Progress Toward Ratification of the Kyoto Protocol, as of January 1, 2004



Sources: United Nations Framework Convention on Climate Change, web site www.unfccc.int; and S. Ruth and A. Retyum, "CERA Decision Brief: Russia: Holding the Kyoto Trump Card" (Cambridge, MA: Cambridge Energy Research Associates, September 2002).

trading under the Protocol, however, some Annex I parties have established or are in the process of establishing their own internal greenhouse gas emissions trading programs. The economic rationale behind emissions trading is to reduce the costs associated with achieving a set reduction in greenhouse gases. Trading works by encouraging the covered participants with low-cost options to reduce their emission levels to below their allotted share and to make the surplus reductions available to participants whose reduction options are more costly.

One framework for emissions trading is "cap and trade," whereby a regulatory authority would establish a permanent cap on aggregate emissions for a group of emitters. The cap could, for example, be set at a fraction of the historic emissions from the group of participants. The cap would be divided into a set number of allowances, each of which would give the holder the right to emit a specified quantity of the regulated pollutant in a given compliance period. In the case of greenhouse gas emissions, each allowance could grant the holder the right to emit 1 metric ton of carbon dioxide. Once distributed among the participants, the allowances could be bought, sold, or (possibly) banked for future use. At the end of each compliance period, each participant would be required to hold allowances equal to its actual emissions or else face a penalty. Although it has not been used to achieve a mandatory large-scale reduction of greenhouse gas emissions, the cap and trade system has been used successfully in the United States since the 1990s to achieve reductions in stationary-source emissions of sulfur dioxide. In the late 1980s, New Zealand introduced an individual transferable quota system for managing fisheries, setting a total allowable catch and allocating tradable shares to individual fishermen. The system has since been emulated in more than 75 countries [*4*].

Emissions trading could also be based on concepts other than cap and trade. For example, a "credit-based" emissions trading system would include both capped and

Table 17. Quantified Emissions Reduction Targets Under the Kyoto Protocol by Country

Country	Reduction Target (Percent)	Country	Reduction Target (Percent)
Australia	+8.0	Liechtenstein	-8.0
Austria (R)	-13.0	Lithuania (R)	-8.0
Belgium (R)	-7.5	Luxembourg (R)	-28.0
Bulgaria (R)	-8.0	Monaco	-8.0
Canada (R)	-6.0	Netherlands (R)	-6.0
Croatia	-5.0	New Zealand (R)	0.0
Czech Republic (R)	-8.0	Norway (R)	+1.0
Denmark (R)	-21.0	Poland (R)	-6.0
Estonia (R)	-8.0	Portugal (R)	+27.0
European Community (R)[a]	-8.0	Romania (R)	-8.0
Finland (R)	0.0	Russia	0.0
France (R)	0.0	Slovakia (R)	-8.0
Germany (R)	-21.0	Slovenia (R)	-8.0
Greece (R)	+25.0	Spain (R)	+15.0
Hungary (R)	-6.0	Sweden (R)	+4.0
Iceland (R)	+10.0	Switzerland (R)	-8.0
Ireland (R)	+13.0	Ukraine	0.0
Italy (R)	-6.5	United Kingdom (R)	-12.5
Japan (R)	-6.0	United States	-7.0
Latvia (R)	-8.0		

(R) = Country has ratified, accepted, approved, or acceded to the Kyoto Protocol.

[a]European Union member countries renegotiated their individual targets under the EU Shared Burden Agreement, which was agreed to in 1998 and reaffirmed in the ratification of the Kyoto Protocol in 2002.

Sources: For countries in the European Union: European Environmental Agency, *Greenhouse Gas Emission Trends and Projections in Europe: 2003: Tracking Progress by the EU and Acceding and Candidate Countries Towards Achieving Their Kyoto Protocol Targets*, Environmental Issue Report No. 36 (Copenhagen, Denmark, 2003), web site http://reports.eea.eu.int/environmental_issue_report_2003_36/en/TPreport_final_draft_ 5_dec.pdf. For all other countries: "Kyoto Protocol to the United Nations Framework Convention on Climate Change," web site http://unfccc.int/ resource/docs/convkp/kpeng.pdf.

non-capped industries and entities that would trade voluntarily created, permanent emission reduction credits legally recognized by a regulator. This system would allow entities with emissions increases to obtain offsetting reductions from other entities. Other trading variants include "baseline" emissions trading systems, which would allow entities to reduce emissions below a "business-as-usual" level and then trade the emission reductions. "Rate-based" emissions trading would focus on emissions per unit of output rather than absolute emissions, allowing entities that improved their efficiency beyond target levels to trade the excess improvement with other entities. Some trading systems combine two or more methods to regulate different sectors more efficiently.

In 2003, the European Parliament and the Council of Ministers agreed on a directive establishing a scheme for trading of greenhouse gas emission allowances [*5*]. The cap and trade system will include all member states from 2005 forward but give member states the right to exempt individual sectors, activities, or installations until 2008 if comparable emission reductions are already being undertaken. In the first compliance period at least 95 percent of the allowances will be free; by the second compliance period, at least 90 percent of the allowances will be free. The first trial phase of the trading scheme will run from 2005 through 2007, regulating carbon dioxide emissions from all heat and electricity generators with more than 20 megawatts of rated thermal input capacity and from all refineries, coke ovens, iron and steel production processes, pulp and paper plants, and mineral industry installations. The proposal requires operators of such installations to hold permits as a condition for emitting greenhouse gases. Regulations can be changed and renegotiated for the second phase of the scheme, which will be concurrent with the first compliance period under the Kyoto Protocol (2008-2012). Each subsequent EU emissions trading phase will last for 5 years.

The EU member states will determine the quantity of allowances to be issued in each phase. Noncompliance sanctions will be applied to any installation that does not have enough allowances to cover actual emissions each year. The allowances, which will be tradable across the entire EU, can be banked from year to year within each phase and across phases if individual member states decide to do so.

The EU proposal is designed to be compatible with international emissions trading under the Kyoto framework; however, any other agreements recognizing third countries' emission trading schemes must be subject to

Table 18. Sample Policies and Measures To Reduce Greenhouse Gas Emissions in Annex I Countries

Regulatory Instruments	Policy Processes	Fiscal Instruments	Voluntary Agreements	Tradable Permits
United States (New Hampshire): Carbon dioxide emission reductions from existing fossil-fuel-burning steam-electric power plants to 3 percent below 1999 levels by 2006 (2002) Norway: Energy labels for household appliances Japan: Electricity suppliers to provide a specified percentage of energy from solar, wind, geothermal, biomass, and small- to medium-sized hydropower plants. Overall target is a 400-percent increase in renewable generation by 2010 Australia: Fuel consumption labels on cars (2001) United Kingdom: Renewables obligation on electricity supply	Ireland: Sustainable energy program created to promote environmentally and economically sustainable production; energy efficiency and renewable energy; and reduction of greenhouse gas emissions France: Mass media climate change campaign Denmark: Instituted labeling on cars to inform consumers of vehicle efficiency and carbon dioxide emissions Belgium: Planning to increase rail transport by 15 percent	Netherlands: "Eco-tax" exemptions for green electricity use Luxembourg: Grants for purchase of efficient vehicles (2001) Denmark: Higher energy taxes on natural gas, gasoline, diesel, diesel light, fuel oil, coal, and electricity Denmark: Reduced car registration fees for fuel-efficient vehicles	Canada: Agreement with the Aluminum Association of Canada's member companies to reduce greenhouse gas emissions from their Quebec-based facilities by approximately 200,000 metric tons by the end of 2007 France: Government-industry agreement to reduce greenhouse gas emissions; companies not achieving reduction goals in 2004 and 2007 will pay fines Netherlands: Agreement with six coal-fired power plants to reduce carbon dioxide emissions by 6 million metric tons between 2008 and 2012 Japan: Suggestion that federal, regional, and local governments deploy 10 million low-pollution vehicles and 50,000 fuel cell cars by 2010	United Kingdom: National economy-wide greenhouse gas emissions trading scheme with voluntary participants Austria: Green certificate trading (2000) Denmark: Carbon dioxide emissions trading system for electricity producers Belgium: Green certificates must be bought by grid operator for offshore wind energy, onshore wind energy, hydropower, solar energy, and biomass energy

Notes: Regulatory instruments include mandates, standards, and regulations. Policy processes include planning, information, and consultation. Fiscal instruments include taxes, tax exemptions/credits, incentives, and subsidies. Voluntary agreements are with industry/consumer groups.
Source: Energy information Administration, Office of Integrated Analysis and Forecasting.

COP-9 Climate Change Negotiations in Milan, Italy

The Ninth Session of the Conference of the Parties to the UNFCCC (COP-9) was held in Milan, Italy, from December 1 to December 12, 2003. Discussion continued on the Kyoto Protocol and the implementation of the UNFCCC. With the United States publicly stating that it will not ratify the Protocol, entry into force is dependent on ratification by Russia; however, signals from the Russian government were mixed. Early in the conference, a spokesman for the Russian treasury department stated that Russia would not ratify the Protocol. Shortly thereafter, another cabinet member expressed Russia's full intent to ratify the Protocol.

The EU has stated that it will undertake policies and measures, including a cap and trade regime, to reach the Kyoto targets regardless of Russia's final decision on ratification. It is clear, however, that the costs of reaching the targets will increase in the absence of tradable permits from Russia. By virtue of the economic collapse of the Soviet Union, Russia is below its target under the Protocol. By the end of COP-9, the Russian delegation had made explicit its calls for EU concessions on non-Protocol matters, such as trade and EU membership, as a condition for Russia's ratification.

The most important decisions reached at COP-9 pertained to rules for carbon sink projects during the first commitment period. Two years earlier, at COP-7, the parties agreed that afforestation and reforestation projects would be allowed under CDM but did not set detailed rules for such projects. The problem with establishing rules for afforestation and reforestation projects is that forests are not permanent. Before COP-9, the parties had not decided who should be liable if a sink began releasing its sequestered carbon dioxide into the atmosphere—the project developer, the host country, or the holder of emissions reductions credits for the project. At COP-9 they decided to create temporary emissions reductions credits that would be valid for only one commitment period, as well as long-term credits that could be renewed for 20-year periods. This accounting system would assign responsibility for maintaining sinks to the holder of the reduction credits, ensuring that holders could take credit only for current emission reductions. The EU delegation also sought to open discussion of the second commitment period (2012-2016), but others were not prepared to do so. The Kyoto Protocol calls for negotiations for the second commitment period to begin no later than 2005.

In addition to the official negotiations at COP-9, there were more than 100 side events hosted by various governmental and nongovernmental organizations. Participants discussed a wide array of subjects, among which the CDM was prominent. Topics in the CDM discussions included rules to help reduce poverty in the developing world and to increase private-sector involvement in CDM projects.[a] Other subjects of discussion included countries' domestic climate change policies, technical issues related to greenhouse gas inventories, directions and proposals for the climate regime after 2012, and examples of corporate responses to climate change. Although the side events were not part of the official negotiations, they were an important part of COP-9, allowing participants to share mitigation strategies, suggest ideas for future negotiations (for instance, rulemaking for the CDM), and consider the future of the UNFCCC beyond the Kyoto Protocol.

[a]United Nations Framework Convention on Climate Change, Ninth Session of the Conference of the Parties and the Nineteenth Session of the Subsidiary Bodies, 1-12 December 2003, Milan, Italy, "Side Events and Exhibits," web site: http://unfccc.int/cop9/se/se_schedule.html.

ratification of the Protocol, effectively excluding participation by non-Kyoto countries (such as Australia and the United States). Moreover, the proposal is open to the use of the Kyoto Protocol's joint implementation and clean development mechanisms, perhaps as early as the first phase, although the use of carbon "sinks" or nuclear projects may be excluded. In conjunction with the introduction of the EU trading program, several EU member countries, including Denmark, France, Germany, Ireland, the Netherlands, and the United Kingdom, are considering development of their own national trading programs. Outside the EU, Japan and Slovakia have also announced that they intend to establish trading systems.

Currently, Denmark is the only country that has instituted a mandatory cap and trade system to reduce carbon dioxide emissions from electricity producers [*6*]. The program began in 2001 with a cap of 22 million metric tons of carbon dioxide, which is to be lowered by 1 million metric tons each year during the 3-year life of the program. The cap and trade system applies only to companies that emit at least 100,000 metric tons of carbon dioxide. Eight companies, which emit more than 90 percent of the carbon dioxide from electricity generation in Denmark, are required to participate in the trading scheme. Allowances under the system were allocated on the basis of each firm's fuel consumption and actual emissions during the 1994-1998 period, excluding emissions from purchased power.

In 2001 and 2002, the average price of traded allowances under the Danish system was lower than the noncompliance penalty tax, giving companies an incentive to trade for allowances rather than simply paying the penalty [*7*]. As of late 2002, however, the number of allowances available for trading was too small to permit active trading. As a result, companies have relied on bilateral negotiations to establish contracts for the sale and purchase of allowances [*8*]. If the program is extended, its allowances are likely to be compatible with the proposed EU trading scheme.

The compatibility of the EU proposal with the United Kingdom's voluntary emissions trading program, which entered into effect in April 2002, is more questionable. The programs differ in several respects, including rules for participation, generation of allowances, and sectoral coverage. Under the British program, any company can opt to enter the trading scheme by negotiating energy efficiency targets or absolute emission reduction targets in return for incentive payments offered by the government. Companies can report on direct emissions and indirect emissions from imported energy and will earn tradable allowances for carbon dioxide reductions computed against their targets.

Also in contrast to the EU proposal, the U.K. scheme is based on voluntary targets, includes all six Protocol gases, and excludes combined heat and power generators, except for emissions from electricity that is generated and used on-site [*9*]. The scheme completed its first year of trading in December 2002, and reports show that 31 of the 32 remaining participants achieved their targets. Over 5 years, the scheme is expected to reduce carbon dioxide emissions by nearly 4 million metric tons [*10*].

In anticipation of entry into force of the Kyoto Protocol, private firms and national governments have started investing in greenhouse gas reduction projects and trading in greenhouse gas offset credits, contributing to the emergence of a nascent market in the credits. Since 1996, carbon transactions amounting to 375 million metric tons of carbon dioxide reductions have been recorded [*11*]. Major market drivers include the U.K. emissions trading scheme, the World Bank's Prototype Carbon Fund, the upcoming EU emissions trading program, and the Dutch government's programs to procure joint implementation and clean development mechanism credits. Emissions reductions purchased by the Prototype Carbon Fund average about $5 per metric ton carbon dioxide, and credits purchased by the Dutch government average just less than $7 per metric ton [*12*]. Prices in the U.K. emissions trading system have varied from $22 per metric ton in September 2002 to about $5 per metric ton in early 2003 [*13*].[19]

In general, the focus in the market is shifting from North America toward Europe, largely because of the U.S. decision not to ratify the Kyoto Protocol, the startup of the U.K. emissions trading system, and the upcoming European-wide trading scheme. Emissions trading activity in the United States could increase, however, following the December 12, 2003, opening of trading on the Chicago Climate Exchange (CCX). The CCX is a voluntary cap and trade program in which participating members will be able to buy and sell greenhouse gas credits to assist in achieving their voluntary emission reduction commitments.

Abatement of Conventional Pollutants from Energy Use

Many countries currently have policies or regulations in place that limit energy-related emissions other than carbon dioxide. Energy-related air pollutants that have received particular attention include nitrogen oxides, sulfur dioxide, lead, particulate matter, and volatile organic compounds, because of their contribution to ozone and smog formation, acid rain, and various human health problems (Table 19). Moreover, in some countries regulation of mercury emissions associated with energy combustion has recently become an issue. Countries also regulate the management of spent fuel from nuclear power generation facilities, but none of the countries with active nuclear power programs has yet established a permanent disposal system for highly radioactive waste. How countries limit energy-related emissions by legislation and/or regulation can have significant impacts on energy technology choices and energy use.

Regulated air pollutants can be attributed to a mix of mobile and stationary energy uses. Nitrogen oxide emissions come from high-temperature combustion processes, such as those that occur in motor vehicles and power plants; road transportation is generally the single largest source. Sulfur dioxide is formed during the burning of high-sulfur fuels for electricity generation, metal smelting, refining, and other industrial processes; coal-fired power plants account for the preponderance of sulfur dioxide emissions. Volatile organic compounds are emitted from a variety of sources, including motor vehicles, chemical plants, refineries, factories, consumer products, and other industrial sources. Particulate matter can be emitted directly or can be formed indirectly in the atmosphere: "primary" particles, such as dust from roads or elemental carbon (soot) from wood combustion, are emitted directly into the atmosphere; "secondary" particles are formed in the atmosphere

[19]The high prices in September 2002 probably resulted from two external factors. First, some companies had to meet an emissions reduction compliance period as of October 2003. At the same time, many companies that had bought allowances in the auction in April 2002 had not yet received them. Thus, the high price was related more to the initial market setup and external factors than to the equilibrium price of allowances in the United Kingdom.

from primary gaseous emissions. Emissions of lead usually originate from motor vehicles that burn leaded gasoline. Emissions of mercury can be attributed to coal-fired boilers, municipal waste combustors, medical waste incinerators, and manufacturing processes that use mercury as an ingredient or raw material. Coal-fired boilers contribute the largest share of mercury emissions [***14***].

With the tightening of emissions limits on combustion plants during the 1990s, sulfur dioxide emissions declined in many industrialized countries. In Europe, the shift from coal to natural gas for electricity production (most notably, in the United Kingdom and Germany) also contributed to a reduction in the region's sulfur dioxide emissions. Many industrialized countries (including Japan, the United States, and the EU) have scheduled further restrictions on sulfur dioxide emissions from stationary sources to take effect over the next 10 years.

With the decrease in atmospheric concentrations of sulfur dioxide in industrialized countries, attention has shifted to ozone, nitrogen oxides, and particulates. Despite the imposition of emissions regulations, nitrogen oxide emissions rose during the 1990s in many industrialized countries as a result of continued increases in consumption of transportation fuels. In Europe, however, the decrease in coal-fired electricity generation and the introduction of catalytic converters on vehicles led to a gradual drop in nitrogen oxide emissions [***15***]. In contrast to the generally rising trend in nitrogen oxide emissions, emissions of volatile organic compounds have declined [***16***]. To continue combating ground-level ozone formation, several countries plan to tighten emissions standards for new vehicles over the coming years (Table 20). Limits on the sulfur content of gasoline and diesel fuel also are being imposed in order to ensure the effectiveness of emission control technologies used to meet new vehicle standards (Table 21).

The harmful effects of lead, especially for children, have been well established over the past three decades. As recently as 1990 leaded gasoline represented 57 percent of the global gasoline market, but as of January 1, 2004, although it was being sold in 73 countries, it accounted for less than 10 percent of the global market [***17***]. Most of the countries where leaded gasoline is still used are in Africa and the FSU, and a few are in the Middle East and Latin America (Figure 75). In countries that have not yet switched to unleaded fuel, leaded gasoline is a major source of lead pollution in urban areas, often accounting for more than 90 percent of atmospheric lead emissions [***18***] (see box on page 149).

Table 19. Possible Health and Environmental Effects of Major Air Pollutants

Air Pollutant	Nature of Pollutant	Possible Health and Environmental Effects
Nitrogen Oxides (NO_x)	Includes nitric oxide, nitrogen dioxide, and other oxides. Precursor of ozone and particulate matter.	Respiratory illnesses, haze, acid rain, and deterioration of water and soil quality.
Sulfur Dioxide (SO_2)	Family of sulfur oxides gases. Precursor of particulate matter.	Asthma, heart disease, respiratory problems, and acid rain.
Volatile Organic Compounds (VOC)	Precursor of ozone and particulate matter.	Respiratory and heart problems, acid rain, and haze.
Particulate Matter (PM)	Mixture of solid particles and liquid droplets formed by sulfur dioxide, nitrogen oxides, ammonia, volatile organic compounds, and direct particle emissions. Smaller particles (less than 2.5 microns) are more harmful to the lungs.	Respiratory and heart problems, acid rain, and haze.
Mercury (Hg)	Metallic element that, when it enters a body of water, is transformed by biological processes into a toxic form of mercury (methylmercury).	Mercury in ambient air is deposited on land surfaces or into rivers, lakes, and oceans, where it can concentrate in fish and other organisms. Exposure to methylmercury from eating contaminated fish and seafood may cause neurological and developmental damage.
Lead (Pb)	Metallic element that can be introduced to people through air, water, or ingestion. Within the body, lead is stored in bones.	Lead interferes with the development of the nervous system and is most harmful to young children and pregnant women. High levels of lead in the bloodstream can cause irreversible learning disabilities, behavioral problems, and mental retardation. Lead interferes with the metabolism of calcium and vitamin D, can damage the reproductive system and the kidneys, and can cause high blood pressure and anemia.

Sources: U.S. Environmental Protection Agency, *Latest Findings on National Air Quality: 2001 Status and Trends*, EPA 454/K-02-001 (Washington, DC, September 2003); National Research Council, *Toxicological Effects of Methylmercury* (Washington, DC, 2000); C.L. French, W.H. Maxwell, W.D. Peters, G.E. Rice, O.R. Bullock, A.B. Vasu, R. Hetes, A. Colli, C. Nelson, and B.F. Lyons, *Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units: Final Report to Congress, Volumes 1-2*, EPA-453/R-98-004a and b (Research Triangle Park, NC. February 1998).

Over the past several decades, many nations have begun to evaluate the potential adverse effects of mercury on human health and the environment. Although mercury is an element that occurs naturally throughout the world, exposure to mercury is dangerous for people and animals because their bodies neither break down nor readily excrete the metal. Mercury is a bioconcentrator: over time, mercury in the blood of animals at low trophic levels will be passed on to predators at higher trophic levels.[20] Swordfish, salmon, fish-eating birds, and seals are among the animals most affected by the bioconcentration of mercury. Although mercury exists both onshore and in the marine environment, predators in the marine ecosystem often have higher concentrations of mercury because there are more trophic levels in the aquatic ecosystem, and thus more opportunities for bioconcentration [*19*].

Mercury emissions from energy use have recently become an area of particular concern in the industrialized countries. Major anthropogenic sources of mercury emissions include stationary energy combustion, nonferrous metal production, pig iron and steel production, cement production, oil and gas processing, and waste disposal. Of these, only electricity generation, municipal solid waste combustion, and oil and gas processing are related to energy use. In the past, regulation of energy-related mercury has focused on municipal solid waste combustion; however, coal-fired boilers account for the largest remaining share of energy-related mercury

Table 20. Current and Future Nitrogen Oxide Emission Standards for New Vehicles in Selected Countries

Vehicle Type	Vehicle Class	United States		European Union		Australia	
		Limit	Date	Limit	Date	Limit	Date
Gasoline . .	Light Duty	0.60-1.53 g/mile	Current standard	0.15-0.21 g/km	Current standard	0.63-1.40 g/km	Current standard
		0.07 g/mile	Phase-in 2004-2007	0.08 g/km[b]	Starting 2005	0.22 g/km	Starting 2003
				0.1-0.11 g/km[c]	Starting 2006	0.15-0.21 g/km	Starting 2005
	Heavy Duty	4.0 g/bhp-hr	Current standard				
		1.0 g/bhp-hr[a]	Starting 2004				
		0.2 g/bhp-hr	Phase-in 2008-2009				
Diesel	Light Duty	0.97-1.53 g/mile	Current standard	0.50-0.78 g/km	Current standard	0.78-1.20 g/km	Current standard
		0.07 g/mile	Starting 2004	0.25-0.39 g/km	Starting 2005	0.50-0.78 g/km	Starting 2003
	Heavy Duty	4.0 g/bhp-hr	Current standard	5.0 g/kWh	Current standard	8.0 g/kWh	Current standard
		1.0 g/bhp-hr[a]	Starting 2004	3.5 g/kWh	Starting 2005	5.0 g/kWh	Starting 2002
		0.2 g/bhp-hr	Phase-in 2007-2010	2.0 g/kWh	Starting 2008	3.5 g/kWh	Starting 2006

[a]Combined nitrogen oxide and hydrocarbon emissions limit.
[b]For passenger cars and class I light commercial vehicles.
[c]For other light commercial vehicles.
Note: The mix of vehicle types varies by region.
Sources: **United States:** U.S. Environmental Protection Agency, Office of Mobile Sources, *Emission Facts*, EPA-420-F-99-017 (Washington, DC, May 1999). **European Union:** European Parliament, Directive 98/69/EC, Official Journal L 350 (December 28, 1998), and Directive 99/96/EC, Official Journal L 44 (February 16, 2000). **Australia:** Department of Transport and Regional Services, “Vehicle Emission Australian Design Rules (ADRs)” (August 7, 2001).

Table 21. Future Sulfur Content Limits on Motor Fuels in Selected Countries

Fuel	United States		European Union		Australia	
	Limit	Date	Limit	Date	Limit	Date
Gasoline	30 ppm	Phase-in 2004-2006	50 ppm	As of 1/1/2005	500 ppm[a]	Current Standard
					150 ppm[b]	Current Standard
					150 ppm[c]	As of 1/1/2005
Diesel	15 ppm	As of 6/1/2006	50 ppm	As of 1/1/2005	500 ppm	As of 12/31/2002
			10 ppm	As of 1/1/2009	50 ppm	As of 1/1/2006

[a]For unleaded gasoline and lead replacement gasoline.
[b]For premium unleaded gasoline.
[c]For all grades.
Sources: **United States:** U.S. Environmental Protection Agency, “Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emission Standards and Gasoline Control Requirements,” *Federal Register* (February 10, 2000). **European Union:** European Parliament, Directive 98/70/EC, Official Journal L 350 (December 28, 1998); and “E.U. Slashes Sulphur Content in Road Fuels from 2005,” Reuters News Service Planet Ark (February 3, 2003), web site www.planetark.com/dailynewsstory.cfm?newsid=19675&newsdate=03-Feb-2003. **Australia:** Attorney General’s Department, Office of Legislative Drafting, “Fuel Standards Quality Act of 2000: Fuel Standards (Diesel and Petrol)” (October 8, 2001).

[20]Trophic refers to levels in a food chain, from photosynthesizing plants at the bottom, to herbivores, to carnivores at the top of the chain.

emissions, and countries that rely heavily on coal-fired power generation are beginning to consider limits on mercury emissions from power plants [*20*] (see box on page 150).

Regional Status of Environmental Policies

Many countries around the world have enacted policies aimed at protecting the environment. In this section, environmental policies in a number of different countries are reviewed. The reviews are not intended to constitute an exhaustive list of environmental policies or countries but rather a sample of the programs that have been instituted around the world. This year, for the first time, discussions of environmental policies in Chile and Hungary are included in this section.

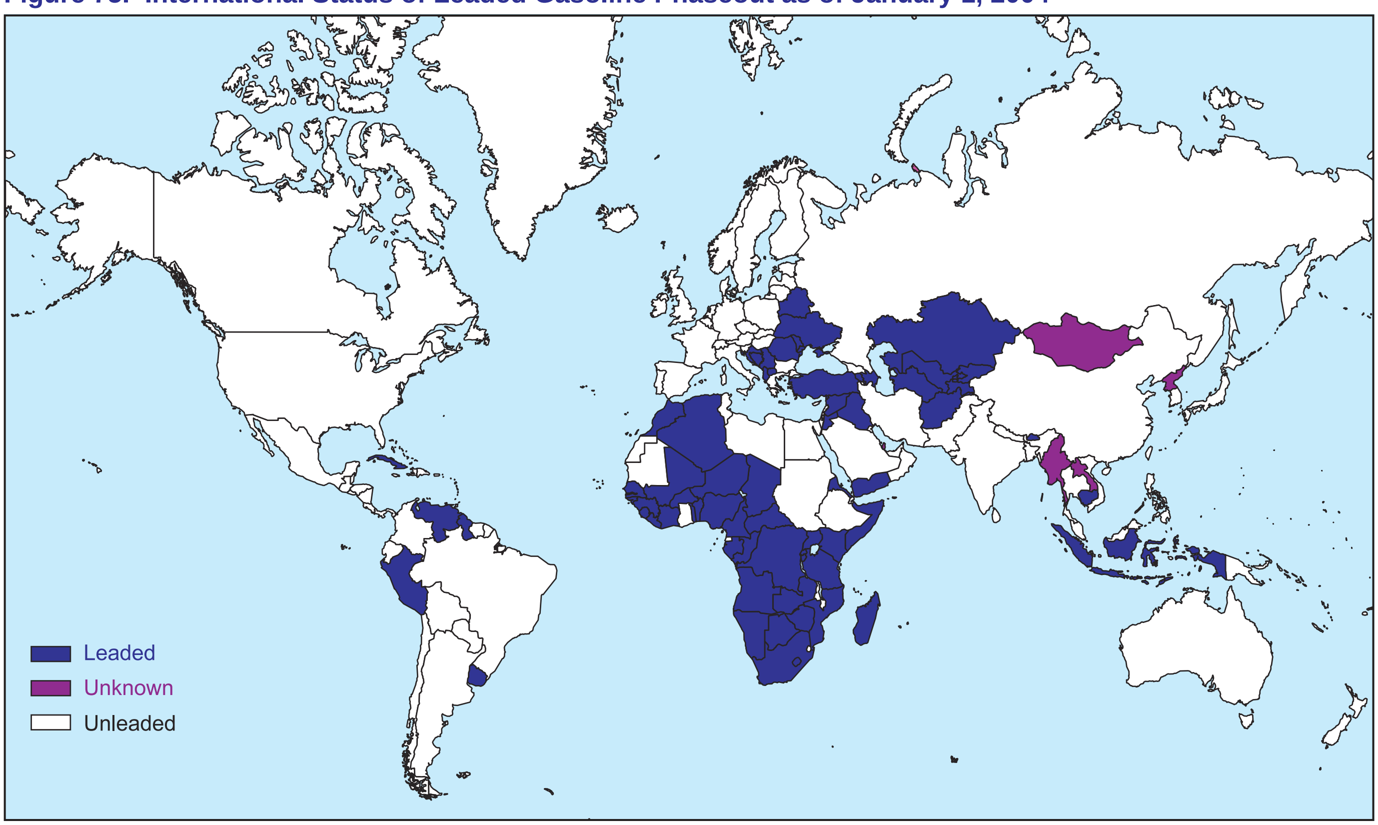
United States

The Clean Air Act of 1970 (CAA) is the comprehensive Federal law that regulates air emissions from stationary and mobile sources in the United States. It authorizes the U.S. Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to protect public health and the environment. The goal of the CAA was to set and achieve NAAQS in every State by 1975. The setting of maximum pollutant standards was coupled with directions for the development of State implementation plans (SIPs) for the regulation of emissions from local industrial sources. The CAA was amended in 1977 primarily to set new goals (dates) for the attainment of NAAQS, because many areas had failed to meet the deadlines for reducing airborne concentrations of the six "criteria pollutants" (carbon monoxide, lead, sulfur dioxide, nitrogen dioxide, ground-level ozone, and particulate matter).

The Clean Air Act Amendments of 1990 (CAAA90) addressed continuing problems associated with air emissions, including acid rain, ground level ozone, and visibility. Title IV of CAAA90, the Acid Rain Program, regulates both sulfur dioxide and nitrogen oxides. The program sets a goal of reducing annual sulfur dioxide emissions by 10 million tons below 1980 levels and annual nitrogen oxide emissions by 2 million tons below 1980 levels. In the United States in 2000, about 70 percent of annual sulfur dioxide emissions and 23 percent of nitrogen oxide emissions are produced from the burning of fossil fuels to generate electricity.

The Acid Rain Program specifies a two-phase reduction in emissions from fossil-fired electric power plants greater than 25 megawatts capacity and from all new power plants. Phase I was completed in 1999. Phase II of the program, which began in January 2000, lowered the total allowable level of sulfur dioxide emissions from all electricity generators, capping annual U.S.

Figure 75. International Status of Leaded Gasoline Phaseout as of January 1, 2004



Source: International Fuel Quality Center.

Leaded Gasoline: The Global Phaseout

Since the early 1920s, lead has been blended with gasoline to boost octane levels. In the 1970s and 1980s, however, it was established that lead is a toxin that particularly affects the neurological development of children: even low-level exposure to lead can cause reading and learning disabilities, changes in behavior, reduced attention span, and hearing loss; and greater exposure can lead to permanent mental retardation, convulsions, coma, and death.[a] As a result, many countries have banned the use of leaded gasoline—a transition that was facilitated in 1975 by the introduction of automobiles with catalytic converters that require lead-free fuel.[b]

The global phaseout of leaded gasoline has proceeded rapidly. Between 1970 and 1993, the total amount of lead added to gasoline worldwide dropped by 75 percent, from more than 375,000 tons to less than 100,000 tons.[c] Leaded gasoline made up more than 57 percent of the world gasoline market in 1990, but its share was less than 10 percent in 2003. As of January 1, 2004, 73 countries, mostly in Africa and Eastern Europe, were still using leaded gasoline (see Figure 75), and many of those countries, including Azerbaijan, Benin, Kazakhstan, Nigeria, and Uzbekistan, have plans to phase it out in the next few years.[d]

Some countries phased out lead in gasoline over relatively long periods; others did it in just 1 or 2 years. The United States moved relatively slowly, starting when the U.S. Environmental Protection Agency began to regulate the use of lead in gasoline in 1975. In 1973, the average lead content of gasoline in the United States was 2 to 3 grams per gallon, totaling about 200,000 tons of lead a year. In 1995, leaded fuel accounted for only 0.6 percent of total U.S. gasoline sales and less than 2,000 tons of lead per year. Lead was completely banned from use in on-road vehicle fuel in the United States as of January 1, 1996.[e]

In Pakistan, the phaseout was rapid by comparison. As recently as early 2001, only leaded gasoline was sold in Pakistan, but by mid-2002 its gasoline supply was virtually lead-free. The government of Pakistan partnered with the United Nations Development Programme and the World Bank in the Pakistan Clean Fuels Project to facilitate its phaseout of leaded gasoline. In July 2001, the government accelerated the phaseout by having three of the four refineries in the country begin selling only unleaded gasoline. Although environmental regulations in Pakistan still permit 0.35 grams per liter of lead in gasoline, all four of the country's refineries were producing unleaded gasoline by the end of 2003.[f]

[a]M. Lovei, *Phasing Out Lead From Gasoline: Worldwide Experience and Policy Implications*, World Bank Technical Paper No. 397: Pollution Management Series (1998).
[b]J. Lewis, "Lead Poisoning: An Historical Perspective," *EPA Journal* (May 1985), web site www.epa.gov/history/topics/perspect/lead.htm.
[c]United Nations Environmental Program, *Global Opportunities for Reducing the Use of Leaded Gasoline* (1998), web site www.chem.unep.ch/pops/pdf/lead/toc.htm.
[d]International Fuel Quality Center, *Current Status of Leaded Gasoline Phase Out Worldwide* (February 4, 2003) (updated by personal communication, October 30, 2003).
[e]U.S. Environmental Protection Agency, "EPA Takes Final Step in Phaseout of Leaded Gasoline" (Press Release, January 29, 1996), web site www.epa.gov/history/topics/lead/02.htm.
[f]International Fuel Quality Center, Asian Office, personal communication, November 5, 2003.

emissions at 8.95 million tons by 2010.[21] The sulfur dioxide regulations include a highly successful market-based regulatory program, which allows individual plant operators to reduce their emissions through any combination of strategies, including installation of scrubbers, switching to low-sulfur fuels, and trading and banking of emissions allowances. This cap and trade approach, which allows emitters to choose the most cost-effective means for limiting sulfur dioxide emissions, has led to a 24-percent decrease in sulfur dioxide emissions between 1992 and 2001 [*21*].

Specifications for reducing nitrogen oxide emissions under the Acid Rain Program also call for a two-phase approach. Phase I, beginning in 1995, aimed to reduce emissions from coal-fired electric power plants by more than 400,000 tons per year. Phase II, which began in 2000, aimed for a reduction of more than 2 million short tons per year. Unlike the sulfur dioxide reduction program, the nitrogen oxide program does not use an emissions cap and trade program. Rather, the EPA has set emission limits by boiler type. A coal-fired power plant can meet the requirements in three ways: (1) meet the standard annual emission limit for each boiler, (2) average the emissions rates of two or more boilers, or (3) apply for a less stringent alternative emission limit and use appropriate emission control technology [**22**].

The EPA has also taken two actions to address the effects of interstate transport of nitrogen oxide emissions on

[21]Because some power companies accumulated (banked) emissions allowances during Phase I of the program (1995 to 1999), the Phase II cap of 8.95 million tons per year will not be reached until the banked allowances have been exhausted.

Controlling Emissions of Mercury from Energy Use

In response to scientific research indicating potential adverse ecological and human health impacts caused by exposure to mercury, many nations are considering regulation and control of mercury emissions—including those attributed to energy use.

Recent estimates of global mercury emissions indicate that Europe and North America contribute less than 25 percent of global anthropogenic emissions (see table below). The majority of emissions originate from combustion of fossil fuels, particularly in Asian countries that rely heavily on coal for electricity generation, including China, India, and South and North Korea.[a] Other sources of mercury include processing of mineral resources at high temperatures, such as roasting and smelting of ores, kiln operations in the cement industry, incineration of waste materials, and production of certain chemicals.

Traditionally, regulation of energy-related mercury emissions has focused on municipal solid waste combustion.[b] Mercury is found in relatively higher concentrations in waste incineration exhaust gases than in the gases released from coal combustion and is thus simpler and less expensive to remove. As a result, most industrialized and many developing countries already have standards in place to control mercury levels in the exhaust gases from waste incineration facilities and in wastewater from the cleaning of their exhaust gases (see table on page 151).[c]

A number of countries, including Canada, the United States, and the European Union, are now considering standards to control mercury emissions from coal-fired electricity generators:[d]

- Under the umbrella of the Canadian Council of Ministers of the Environment, federal, provincial, and territorial governments in Canada have agreed to develop a nationwide emission standard for the coal-fired electricity generation sector by the end of 2005 and to reduce mercury emissions from coal-fired power plants by 2010.[e]
- The United States is debating various multi-pollutant legislative initiatives, with mercury as one of the targeted pollutants. In December 2002, the EPA found that it is appropriate and necessary to regulate hazardous air pollutants, including mercury from electric power plants.[f] The EPA proposed Utility Mercury Reductions in December 2003 and currently is seeking comment on two types of emissions reductions mechanisms, one based on maximum achievable control technologies (MACT) and another based on a cap and trade system. A final rule will be promulgated in December 2004.

(continued on page 151)

Emissions of Mercury from Anthropogenic Sources by World Region, 1995
(Metric Tons per Year)

Region	Source of Emissions					Total
	Stationary Combustion of Fossil Fuels	Nonferrous Metal Production	Pig Iron and Steel Production	Cement Production	Waste Disposal	
Asia	860	87	12	82	33	**1,074**
Europe	186	15	10	26	12	**248**
North America	105	25	5	13	66	**214**
Africa	197	8	1	5	—	**211**
Australia and Oceania	100	4	0	1	0	**106**
South America	27	25	1	6	—	**59**
Total	**1,475**	**166**	**29**	**132**	**111**	**1,913**

Source: See note a below.

[a]European Commission, *Ambient Air Pollution by Mercury (Hg): Position Paper* (Luxembourg: Office for Official Publications of the European Communities, 2001), web site http://europa.eu.int/comm/environment/air/background.htm.

[b]Municipal solid waste combustion is considered an energy source, because many incinerators produce steam for heating.

[c]United Nations Environment Programme, *Global Mercury Assessment. Appendix: Overview of Existing and Future National Actions, Including Legislation, Relevant to Mercury as of November 1, 2002* (Geneva, Switzerland, December 2002), web site www.chem.unep.ch/mercury/Report/Finalreport/final-appendix-1Nov02.pdf; and "Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the Incineration of Waste," *Official Journal of the European Communities*, L332/91 (December 28, 2000), web site http://europa.eu.int/comm/environment/wasteinc/newdir/2000-76_en.pdf.

[d]United Nations Environment Programme, *Global Mercury Assessment. Appendix: Overview of Existing and Future National Actions, Including Legislation, Relevant to Mercury as of November 1, 2002* (Geneva, Switzerland, December 2002), web site www.chem.unep.ch/mercury/Report/Finalreport/final-appendix-1Nov02.pdf.

[e]Canadian Council of Ministers of the Environment, "CWS for Mercury From Coal-Fired Electric Power Generation Sector," web site www.ccme.ca/initiatives/ standards.html?category_id=53.

[f]U.S. Environmental Protection Agency, "Fact Sheet: EPA To Regulate Mercury and Other Air Toxics Emissions From Coal- and Oil-Fired Power Plants" (December 14, 2000), web site www.epa.gov/ttn/oarpg/t3/fact_sheets/fs_util.pdf.

Controlling Emissions of Mercury from Energy Use (Continued)

- The European Union is in the process of developing emissions monitoring procedures and control strategies based on Best Available Technology (BAT) as part of a subsequent directive under the 1996 Air Quality Framework Directive (96/62/EC).

To address transboundary issues related to the long-range transport of mercury emissions, countries are also working under the auspices of the United Nations Environment Programme (UNEP) to develop a global assessment of mercury and its compounds. The assessment, to include options for addressing any significant global adverse impacts of mercury, was presented to the UNEP Governing Council at its 22nd session in February 2003 for further action by the global community. A meeting of UNEP's Working Group on Mercury took place in Geneva, Switzerland, in September 2002 to develop options for addressing global adverse impacts of mercury. Proposals included the creation of an international legally binding treaty to reduce or eliminate mercury use and emissions.[g]

Sample Mercury Limits on Exhaust Gases from Municipal Waste Incineration

Country	Regulated Municipal Waste Process/Technology	Maximum Mercury Concentrations in Exhaust Gases	
		Current	New
Canada	Incineration at 11% oxygen (average)	0.02 mg/m^3	
China	Incineration (average)	0.2 mg/m^3	
Croatia	Incineration with gas flow of 10 g/h or more	1 mg/m^3	
European Union	Incineration at 11% oxygen (average over period of minimum 30 minutes and maximum 8 hours)	0.05 mg/m^3	
Germany	Incineration at 11% oxygen (daily maximum average)	0.03 mg/m^3	
	Incineration at 11% oxygen (half hour average)	0.05 mg/m^3	
Norway	Incineration, facilities permitted after 1994 (average)	0.03 mg/m^3	
South Korea	Incineration (average)	5 mg/m^3	0.1 mg/m3 (January 1, 2005)
United States	Incineration at 7% oxygen (daily maximum)	0.08 mg/m^3	

Source: United Nations Environment Programme, *Global Mercury Assessment. Appendix: Overview of Existing and Future National Actions, Including Legislation, Relevant to Mercury as of November 1, 2002* (Geneva, Switzerland, December 2002), web site www.chem.unep.ch/mercury/Report/Finalreport/final-appendix-1Nov02.pdf.

[g]United Nations Environment Programme, *Global Mercury Assessment* (Geneva, Switzerland, December 2002), web site www.chem.unep.ch/mercury/Report/Finalreport/final-assessment-report-25nov02.pdf.

downwind ozone nonattainment areas. In 1998, the EPA finalized the "Nitrogen Oxides SIP Call" rules, which require 22 States[22] and the District of Columbia to revise their SIPs to control summertime nitrogen oxide emissions. The SIP Call involves a cap and trade program to reduce summertime emissions of nitrogen oxides to target levels beginning in summer 2003 [*23*].[23] After several court challenges, three States[24] were removed from the program, and the compliance date was moved to summer 2004. A similar program in the northeastern States, the NO_x Budget Program, has been reducing emissions through a cap and trade system since 1995. In 2002, States participating in the NO_x Budget Program had reduced their emissions of nitrogen oxides to 60 percent below 1990 levels [*24*].

In December 2003, the EPA released a proposal for regulations controlling both sulfur dioxide and nitrogen oxides in 29 eastern States and the District of Columbia.[25] The Interstate Air Quality proposal would reduce sulfur dioxide emissions within the regulated region by 3.6 million tons in 2010 (a cut of approximately 40 percent from current levels) and by another 2 million tons per year when the rules are fully implemented (a total cut of approximately 70 percent from current levels). Annual nitrogen oxide emissions would be cut by 1.5

[22]Alabama, Connecticut, Delaware, Georgia, Illinois, Indiana, Kentucky, Massachusetts, Maryland, Michigan, Missouri, North Carolina, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Virginia, Wisconsin, and West Virginia.

[23]Under Section 126 of the Clean Air Act, States may petition the EPA to mitigate significant regional transport of nitrogen oxides. In May 1999, the EPA established the Federal Nitrogen Oxides Budget Trading Program as the general control remedy for reducing interstate ozone transport and required 392 facilities in the Northeast to participate in the cap and trade program for nitrogen oxide emissions.

[24]Georgia, Missouri, and Wisconsin.

[25]Alabama, Arkansas, Connecticut (ozone only), Delaware, Florida (particle pollution only), Georgia, Illinois, Indiana, Iowa, Kansas (particle pollution only), Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota (particle pollution only), Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas (particle pollution only), Virginia, West Virginia, Wisconsin, and District of Columbia.

Multipollutant Control Legislation in the United States

Electric power plant operators in the United States may face new requirements to reduce emissions of sulfur dioxide, nitrogen oxides, and mercury beyond the levels called for in current regulations. Some proposed Federal legislative initiatives would also require mandatory reduction of carbon dioxide emissions. Whereas in the past each pollutant was addressed through a separate regulatory program, the new legislative initiatives focus on simultaneous reductions of multiple emissions in order to reduce the cost and administrative burden of compliance. The legislative initiatives now being considered would also modify the New Source Review requirements of the 1990 Clean Air Act Amendments for modernization at older power plants.

Three major legislative initiatives were introduced in Congress during the 107th legislative session and have been referred to committee for further consideration. A fourth was announced early in the 108th Congress. Introduced first by Senator Jim Jeffords in 2002 and later in 2003, the Clean Power Act of 2003 is the most far-reaching of the multipollutant initiatives. As shown in the table below, it covers emissions of sulfur dioxide, nitrogen oxides, mercury, and carbon dioxide. The bill proposes a cap and trade scheme for meeting sulfur dioxide, nitrogen oxide, and carbon dioxide emission targets and a MACT requirement to reduce mercury emissions. The current Clean Air Act requires the EPA to adopt a performance standard based on MACT in the next few years, with compliance required by the end of 2007. In addition, the Clean Power Act of 2003 would require every power plant to be equipped with the most recent pollution controls required for new sources by the plant's 40th year of operation or by 2014, whichever is later.

The Clear Skies Initiative, announced by President Bush in February 2002 and introduced as House and Senate bills, proposes nationwide caps for sulfur dioxide and mercury and regional (East and West) caps for nitrogen oxides. The Clear Skies Initiative differs from the proposed Clean Power Act primarily in targeted emission reductions and proposed compliance dates. The final nitrogen oxides and sulfur dioxide targets are close to those proposed in the Clean Power Act of 2003, but mercury reductions are not as stringent, and the timetable for reaching the targets is delayed by 5 to 10 years, depending on the pollutant. The Clear Skies

(continued on page 153)

Key U.S. Legislative and Policy Initiatives for Multipollutant Control

Proposal Title	Sponsor	Annual Nitrogen Oxides (NO_x) (Million Tons)	Annual Sulfur Dioxide (SO_2) (Million Tons)	Annual Mercury (Hg) (Tons)	Annual Carbon Dioxide (CO_2) (Million Metric Tons)
		Current Emission Levels from Fossil-Fueled Electricity Generation[a]			
		4.7 (2001)	10.6 (2001)	48 (2000)	2,044 (1990); 2,249 (2000)
		Proposed Reduction Goals and Timetable[b]			
Clear Skies Initiative (S. 1844)[c]	Bush Administration	2.1 million tons in 2008; 1.7 million tons in 2018	4.5 million tons in 2010; 3.0 million tons in 2018	34 tons in 2010; 15 tons in 2018	Voluntary
Clean Power Act of 2003 (S. 366)	James Jeffords (I-VT)	1.5 million tons by 2009	2.25 million tons by 2009	5 tons by 2009; 2.48 g/GWhr MACT in 2008	2,050 million metric tons by 2009
Clean Air Planning Act of 2003 (S. 843)	Tom Carper (D-DE)	1.51 million tons by 2009; 1.70 million tons by 2013	4.50 million tons by 2009; 3.50 million tons in 2013; 2.25 million tons in 2016	24 tons by 2009; 10 tons by 2013	2006 level by 2009; 2001 level by 2013
Greenhouse Gas Cap and Trade	John McCain (R-AZ) and Joseph Lieberman (D-CT)	—	—	—	2000 level by 2010[d] 1990 level by 2016

[a]Sources: Energy Information Administration, *Annual Energy Outlook 2004*, DOE/EIA-0383(2004) (Washington, DC, January 2004), for data on nitrogen oxides, sulfur dioxide, and carbon dioxide. Data on mercury obtained from Congressional Research Service, *Air Quality: Multi-Pollutant Legislation*, CRS Report No. RL31326 (Washington, DC, October 22, 2002).

[b]Source: Resources for the Future, "Legislative Comparison of Multipollutant Proposals S. 366, S. 1844, and S. 843. Version 01/22/2004," web site www.rff.org/multipollutant.

[c]S. 1844 was sponsored by Senator James Inhofe in November 2003. The exact emissions reductions differ somewhat from those proposed in the Bush Administration's original Clear Skies Initiative; however, the Administration has proposed regulatory rules similar to the provisions of S. 1844.

[d]Emissions of all six greenhouse gases would be covered (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride), and allowances would be traded in metric tons carbon dioxide equivalent. The bill would cover the transportation, industrial, and commercial sectors in addition to electricity generation.

Multi-Pollutant Legislation in the United States (Continued)

Initiative provides for market-based cap and trade programs for nitrogen oxides and sulfur dioxide and also provides for mercury emissions trading. It includes carbon dioxide emission provisions that would be voluntary only.

The third bill, the Clean Air Planning Act of 2003, was introduced by Senator Tom Carper in October 2002 and later in April 2003. Its emissions targets are generally between those of the Clean Power Act and those of the Clear Skies Initiative. The Clean Air Planning Act would establish caps on emissions of sulfur dioxide, nitrogen oxides, and mercury, but they would be phased in over a longer period than proposed in the Clean Power Act. The bill would also introduce limited caps on carbon dioxide emissions. The bill proposes to reduce carbon dioxide emissions to 2006 levels by 2009 and to 2001 levels by 2013, whereas the Clean Power Act would reduce carbon dioxide emissions to 1990 levels by 2009. The nitrogen oxide, sulfur dioxide, and mercury reduction targets and timelines included in the legislation are more aggressive than those outlined in the President's Clear Skies Initiative but less stringent than those proposed in the Clean Power Act.

In early January 2003, Senators McCain and Lieberman introduced legislation to reduce annual emissions of greenhouse gases by emitters in the electricity, transportation, industrial, and commercial sectors that produce 10,000 metric tons carbon dioxide or more per year.[a] The bill would create a system of tradable allowances allocated to emitters in each sector free of charge, with the goal of reducing greenhouse gas emissions to 2000 levels by 2010 and to 1990 levels by 2016. It does not address emissions of nitrogen oxides, sulfur dioxide, or mercury.

[a]U.S. Senator Joseph Lieberman, "Summary of Lieberman/McCain Draft Proposal on Climate Change," Press Release (Washington, DC, January 8, 2003), web site www.senate.gov/~lieberman/press/03/01/2003108655.html.

million tons in 2010 and 1.8 million tons in 2015 (a reduction of approximately 65 percent from current levels). Emissions of both pollutants would be permanently capped. The EPA is accepting public comment on the Interstate Air Quality proposal, and issuance of a final rule is planned for 2005 [***25***].

Also in December 2003, the EPA proposed a Utility Mercury Reductions rule. When implemented, it will be the first U.S. regulatory program to control mercury emissions from electricity generators. The proposed rule, using a cap and trade system, would cut mercury emissions by 70 percent after 2018, when Phase II is implemented and allowances banked before 2018 have been exhausted. The EPA is seeking comments on two proposals to reduce mercury emissions, one based on MACT and another based on a cap and trade system. The MACT approach would reduce annual mercury emissions by 14 tons (29 percent) by 2007 [***26***].

In addition to the EPA programs and initiatives discussed above, several legislative proposals introduced recently in the U.S. Congress are aimed at simultaneous reductions of multiple emissions, including sulfur dioxide, nitrogen oxides, mercury, and/or carbon dioxide (see box above).

Canada

In Canada, emissions from stationary sources are regulated under the Thermal Power Generation Emissions National Guidelines for New Stationary Sources of the 1993 Canadian Environmental Protection Act (CEPA). In January 2003, the emission guidelines for new sources of electricity generation were updated, tightening emissions limits for sulfur dioxide, nitrogen oxide, and particulate matter from new coal-, oil-, and natural-gas-fired steam-electric power plants [***27***]. The new targets would lower sulfur dioxide emissions by 75 percent, nitrogen oxide emissions by 60 percent, and emissions of particulate matter by 80 percent. With these requirements, the long-term emission performance of all fossil-fired generation is targeted to approach that of natural gas.

Additional efforts to abate sulfur dioxide emissions have focused on the seven easternmost provinces, where smog levels are on the rise and acid rain is a concern.[26] The Eastern Canada Acid Rain Program placed a region-wide cap on sulfur dioxide emissions at 2.3 million metric tons per year for 1994, mostly by restricting emissions from large industrial facilities. Recently, new measures at provincial levels were enacted to reduce nitrogen oxide emissions. Starting in 2007, fossil-fueled power plants in central and southern Ontario will face an annual cap of 39,000 tons, and emissions from plants in southern Quebec will be capped at 5,000 tons.

Addressing the problems of acid rain and ground-level ozone in Canada has required cooperation with the United States, given the transboundary flow of air

[26]The seven Canadian provinces covered under the Eastern Canada Acid Rain Program are Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Newfoundland, and Prince Edward Island.

pollutants between the two countries. The Canada-U.S. Air Quality Agreement, signed in 1991, has been amended to include additional pollutants over the past 13 years. In December 2000, one such annex set a target of cutting ozone in the U.S./Canada transboundary region by 43 percent by 2010 [*28*]. The agreement was seen as a major step toward harmonizing air quality standards for stationary and mobile sources, and negotiators have begun discussing its expansion to cover other pollutants.

Canadian regulation of mobile sources tends to mirror standards in the United States, in line with efforts to create an integrated vehicle manufacturing market in North America. Starting with the 1998 model year, regulations for light-duty vehicles were aligned with the Tier 1 standards of the United States. According to a regulation introduced in January 2003, standards for passenger cars, minivans, pickup trucks, sport utility vehicles, heavy-duty trucks and buses, and motorcycles will be subject to more stringent emissions standards [*29*].

In 1999, Canada approved a limit of 30 parts per million sulfur content in gasoline, which would take effect by January 1, 2005. The average level of sulfur in Canadian gasoline is currently 150 parts per million. Canada will also require a diesel fuel sulfur cap of 15 parts per million by June 2006, mirroring the U.S. highway diesel regulation.

Mexico

Air pollution in the large cities of Mexico is a serious concern for the country. Mexico City, Guadalajara, and Ciudad Juarez are the most polluted, and Mexico City's air quality is among the worst in the world. In addition to pollution from industrial sources, the transportation sector is a major source of emissions, accounting for 80 percent of the country's nitrogen oxide emissions, 40 percent of volatile organic compound emissions, 20 percent of sulfur dioxide, and 35 percent of small particulate matter emissions [*30*].

In the 1990s, the Mexican government implemented a number of policies that dramatically improved air quality in the Mexico City area. Catalytic converters were required for all new cars beginning in 1991, and leaded gasoline was eliminated by 1997. The government has also reduced the concentration of sulfur in diesel, introduced oxygenates into gasoline, enhanced emissions inspection programs, and introduced LPG and compressed natural gas (CNG) as alternative vehicle fuels. A "No Driving Day" (Hoy No Circula) program, introduced in the greater Mexico City region in 1989, banned 20 percent of registered cars from driving in the city on one workday of each week, rotating the ban based on the last digit of vehicle license plate numbers. The program continued throughout the 1990s but became less effective as people began to acquire two cars to avoid the regulation. In 1999 it was recast to allow cars equipped with emissions control systems equivalent to U.S. Tier 1 limits to drive on any day of the week, and stricter driving limits (No Driving for Two Days) were placed on cars without the updated technology [*31*].

In addition to transportation, electricity generation from the two power plants in the Mexico City metropolitan area is a major source of air pollution. In 1986 the two plants switched from high-sulfur fuel oil to natural gas, significantly reducing sulfur dioxide emissions in the region. The plant operators have also installed new pollution control technology, improved maintenance programs, and implemented continuous stack monitoring systems [*32*]. More recently, operators have begun switching generating units in one of the power plants to combined-cycle generation, which will further reduce nitrogen oxide emissions while meeting the growing demand for electricity. Despite the improvements made recently, both power plants near Mexico City are aging, and rising maintenance and administrative costs may limit the extent to which their emissions can be reduced [*33*].

European Union

In Europe, efforts to limit aggregate emissions of sulfur dioxide, nitrogen oxides, volatile organic compounds, and particulate matter were first coordinated under the 1979 United Nations/European Economic Commission's Convention on Long-Range Transboundary Air Pollution (CLRTAP), which was drafted after scientists demonstrated the link between sulfur dioxide emissions in continental Europe and the acidification of Scandinavian lakes. Since its entry into force, the Convention has been extended by eight protocols that set emissions limits for a variety of pollutants. The 1999 Gothenburg Protocol calls for national emissions ceilings for sulfur dioxide, nitrogen oxides, volatile organic compounds, and ammonia in 2010.

The establishment of national emission ceilings is a regulatory innovation in air pollution control in the EU, in that the different emissions ceilings are tailored to meet country-specific circumstances and allow member countries flexibility in implementing control measures. As with previous CLRTAP protocols, the Gothenburg Protocol specifies tight limit values for specific emissions sources and requires best available technologies to be used to achieve the emissions reductions. Once the Protocol is fully implemented, Europe's sulfur emissions should be cut by about 75 percent, nitrogen oxide emissions by almost 50 percent, emissions of volatile organic compounds by about 55 percent, and ammonia emissions by 15 percent from their 1990 levels. As of December 5, 2003, however, only Denmark, Luxembourg, Norway, Romania, the European Community, and Sweden had ratified the Gothenburg Protocol [*34*].

While CLRTAP addresses both stationary and mobile sources, another EU directive on the Limitation of Emissions of Certain Pollutants into the Air from Large Combustion Plants (Directive 2001/80/EC0) was passed in late 2001 targeting only stationary combustion. This directive amended the Large Combustion Plant Directive of 1988 (Directive 88/609/EEC), which imposed emissions limits for sulfur dioxide, nitrogen oxides, and dust on existing and new power plants with a rated thermal input capacity greater than 50 megawatts. For plants licensed before July 1, 1987, the 1988 directive placed a gradually declining ceiling (cap) on total annual emissions of each pollutant. The ceiling values differed by country. The directive did not stipulate how the emissions reductions were to be achieved, although the general approach used by several European countries has been to require the use of specific emissions control technologies and combustion fuels. All plants licensed after July 1, 1987, faced uniform emissions limit values, which were set according to plant capacity, size, and fuel type.

The new directive was seen as a package deal, along with CLRTAP, toward the development of a comprehensive EU strategy to deal with acidification. The directive takes into account advances in combustion and abatement technologies and reduces the nitrogen oxides limit values for large solid fuel plants from 650 milligrams per cubic meter to 200 milligrams per cubic meter. This limit, which applies to both new and existing plants from 2016 onward, will be a crucial benchmark in the forthcoming negotiations with Eastern European candidate countries hoping to enter the EU. However, existing plants may be exempt from obligations concerning new emissions standards if they are operated for less than 20,000 hours between January 2008 and December 2015. The directive does provide member countries with some flexibility in terms of specifying control technologies but, unlike the U.S. regulatory scheme, does not include provisions for market-based emission reductions, such as allowance trading.

Emissions from motor vehicles have been regulated in Europe since the 1970 Motor Vehicle Directive. The most stringent vehicle emission limits were passed in 1998 and 1999 by Directives 98/69/EC and 99/96/EC. As the law currently stands, all new vehicles must meet the "Euro 3" emissions standards for carbon monoxide, hydrocarbons, and nitrogen oxides by 2000 and 2001, depending on weight class. Between 2005 and 2008, the tighter Euro 4 and Euro 5 standards for new vehicles will take effect. Germany, the Netherlands, Belgium, and the United Kingdom have encouraged the switch to low-sulfur gasoline and diesel by offering tax incentives. Sweden already requires "city diesel" to meet the same sulfur standard (50 parts per million) required by the EU in 2005. The EU recently finalized regulations that include the mandatory introduction of sulfur-free gasoline and diesel fuels, with sulfur levels lower than 10 milligrams per kilogram, by January 1, 2005, and a complete ban on all non-sulfur-free fuels by January 1, 2009 [*35*]. The implementation of the measure would coincide with the introduction of Euro 4 vehicles in the European market.

Hungary

Hungary submitted its application for EU membership in 1994 and signed the EU Ascension Treaty in April 2003. It is expected to become a member of the EU in May 2004. Many of Hungary's energy and environmental policies have focused on bringing regulations in line with EU standards. For instance, an energy tax and an environmental tax (with air, water, and soil pollution provisions) were introduced in January 2004. The energy tax, which targets only nonresidential entities, is designed to encourage energy-saving practices. The air pollution provision of the environmental tax, beginning at 40 percent of the proposed final tax rate, will also target companies and will be levied on emissions of carbon dioxide, nitrogen oxides, sulfur dioxide, and particulate matter. The rate of the environmental tax will rise each year until it reaches the desired level in 2008. The energy and environment taxes are expected to generate about $50 million in revenue for the Hungarian government [*36*].

In 1973, Hungary generated more than 65 percent of its electricity from coal-fired power plants, many of which used lignite coal, a relatively low-grade coal with many impurities. As of 2000, however, only about 28 percent of the country's electric power came from coal-fired power plants, and more than 40 percent came from nuclear facilities. Much of the growth in electricity demand from 1973 to 2000 was met with nuclear and, to a smaller extent, natural-gas-fired generation. The diversity of its fuel mix has helped improve Hungary's environment, with total sulfur dioxide pollution falling from more than 800,000 tons in 1992 to less than 600,000 tons in 1998 [*37*]. Although sulfur dioxide emissions have been falling, they are greater, on a per capita basis, than the EU average, probably because of the continued use of lignite for power generation.

Developing Countries

While emissions of sulfur dioxide, nitrogen oxides, and particulate matter have either declined or slowed in most industrialized countries, many developing countries are seeing rapid growth in energy-related pollution. The most pressing problems are growing sulfur dioxide emissions and acid rain from coal-fired power plants and increasing levels of smog and particulate matter in urban areas from both transportation and power generation. To address these environmental problems, many developing countries have introduced regulations targeting motor vehicle use and coal-fired power generation; however, compliance with emissions regulations is often low in developing countries, where funding may be limited and enforcement inadequate [***38***]. Thus, in the face of strong population growth and economic development, emissions of air pollutants in urban centers of the developing world have increased steadily.

China

Many cities across China suffer from air pollution problems. In 2003, 63 percent of the 330 Chinese cities being monitored had poor air quality [***39***]. One of the main pollutants is sulfur dioxide, resulting in the formation of acid rain, which now falls on about 30 percent of China's total land area [***40***]. About 34 percent (6.6 million tons) of the country's total sulfur dioxide emissions in 2002 were released from power plants [***41***]. Because more than 70 percent of China's electricity comes from coal-fired plants, the country faces a challenge in providing adequate supplies of electricity while trying to reduce sulfur dioxide emissions, particularly near major cities [***42***]. Given that rolling blackouts were a feature of China's electricity markets in 2003, the difficulties are sure to mount in the future.

China has implemented a new coal policy, which is expected to reduce sulfur dioxide emissions in 2005 by 10 percent from 2000 levels nationwide and by 20 percent in "control zones" with high pollution, including Beijing, Shanghai, Tianjin, and 197 other cities [***43***]. The control zones account for only 11.4 percent of China's land area but for 66 percent of the 20 million tons of sulfur dioxide emitted each year. The new policy increases the pollution levy to 5 yuan (60.4 cents) per ton and requires power companies and large industrial facilities to install desulfurization equipment [***44***]. Smaller facilities must use low-sulfur coal or cleaner fuel alternatives.

In addition, pilot sulfur dioxide emissions trading programs are underway in Benxi (Liaoning Province) and Nantong (Jiangsu Province), and in early 2002 the State Environmental Protection Administration (SEPA) announced that the provinces of Shandong, Shanxi, Henan, and Jiangsu, the special administrative regions of Macau and Hong Kong, and three cities (Shanghai, Tianjin, and Liuzhou) would pioneer China's first emissions trading scheme across provincial borders near the end of the decade. Officials hope to establish rules for emissions trading by 2006.

Although point sources are a major source of both sulfur dioxide and particulate matter in China, mobile sources in major cities account for an increasing percentage of the country's air pollution. For instance, city planners in Shanghai estimate that about 90 percent of the city's air pollution is from vehicle traffic [***45***]. The number of vehicles in China has increased considerably in recent years. In Beijing, vehicle ownership has risen from 1 million in 1997 to 2 million in 2003, and during 2003 new vehicles were coming onto Beijing's roads at a rate of 27,000 per month [***46***]. The crowd of vehicles on the road has exacerbated traffic to the extent that average rush hour speeds in certain parts of Beijing are less than 7 miles per hour [***47***].

Shanghai has developed programs to limit the number of drivers in the city, including charging registration fees for new vehicles valued at more than $4,000 [***48***]; however, Beijing is not prepared to take such measures to limit cars on the roads and instead is building more roads and expanding the public transportation system in the city. In a measure that will help reduce pollution from existing vehicles, cars in Beijing will have to meet European emissions standards as of summer 2004. In an additional effort to reduce air pollution, the Beijing municipal government has converted more than 1,900 municipal buses to liquefied petroleum gas and plans to increase the number to 18,000 by 2008 [***49***].

Beijing and Shanghai have a strong incentive to improve air quality over the next 5 to 6 years: Beijing will host the 2008 Olympics, and Shanghai will host the 2010 World Expo. Some progress has already been made. In 2003, Beijing had 219 days of "satisfactory" air quality, compared with only 100 in 1998 [***50***]. Still, the concentration of small particulate matter in Beijing's air is 65 micrograms per cubic meter higher than China's national standard of 100 micrograms per cubic meter. In the United States, a value of 165 micrograms per cubic meter would be "code red," and the EPA would recommend that people reduce heavy or prolonged exertion [***51***].

India

Urban air quality in India ranks among the world's poorest [***52***]. Efforts to improve urban air quality have focused on vehicles, which account for the majority of the country's air pollution. Emissions limits for gasoline- and diesel-powered vehicles came into force in 1991 and 1992, respectively. Emissions standards for passenger cars and commercial vehicles were tightened in 2000 at levels equivalent to the Euro 1 standards. For the metro areas of Delhi, Mumbai, Chennai, and Kolkata, tighter Euro 2 standards have been required since 2001. In October 2003, the Indian government introduced new standards for automotive fuel and vehicle emissions, including a ban on sales of vehicles that do not meet Euro 3 emissions standards by 2010, a similar but earlier (April 2005) ban in 11 major cities, and a 2010 requirement that new vehicles in those 11 cities (including New

Delhi) meet the stringent Euro 4 emissions standards [*53*].

The measures taken to reduce vehicle emissions in New Delhi have been more controversial. In 1998, India's Supreme Court mandated a number of measures to improve the city's air quality. One such measure stipulated that all the city's buses be run on CNG by March 31, 2001. Compliance was to be achieved either by converting existing diesel engines or by replacing the buses themselves. The conversion of the fleet had not been achieved as the deadline approached, and rather than paralyze the transportation system with a shutdown of bus service, the courts extended the deadline to September 2001 and then to January 2002 [*54*]. During the additional period, diesel buses could remain on the road if their owners demonstrated that they had placed an order for a replacement or conversion to CNG. Although difficult for many bus owners during the conversion period, the program increased the number of CNG buses in New Delhi from 900 in May 2001 to about 6,800 in mid-2002, an increase of more than 650 percent. One challenge with the swift conversion of the fleet has been a number of safety issues with CNG buses, which the government continues to address.

Buses were not the only vehicles converted to run on CNG. More than 27,000 automobiles and 14,000 other vehicles were also running on CNG by mid-2002 [*55*]. Many reporters have anecdotally described the improvements in air quality over the 2000-2002 period, during which many diesel vehicles were removed from circulation.

In other cities in India, emissions from diesel buses are eclipsed by those from "auto rickshaws" with 2-stroke and 4-stroke engines. Many rickshaw drivers concoct their own fuel, a mix of kerosene and engine lubricant that releases pollution as the fuel burns. Some cities in India (for instance, Ahmedabad) are looking into the possibility of converting existing auto rickshaws to run on LPG, a much cleaner fuel. The overhead of converting the rickshaws would be difficult for individual owners to finance, even though the lower cost of LPG can save money over the long term. Currently, proponents of the plan are looking for funding to help with the conversion of the 65,000 rickshaws on the streets of Ahmedabad [*56*].

Although India is a large coal consumer, its Central Pollution Control Board has not set any sulfur dioxide emissions limits for coal-fired power plants, because most of the coal mined in India is low in sulfur content. Coal-fired power plants do not face any nitrogen oxide emissions limits either, although thermal plants fueled by natural gas and naphtha face standards between 50 and 100 parts per million, depending on their capacity. Enforcement of the standards has been recognized as a major problem in India [*57*].

Chile

Chile's capital city, Santiago, is among the most polluted in the Western Hemisphere. Santiago, a city of 5.5 million people, is situated between two mountain ranges. In winter (June-August), when prevailing winds off the Southern Pacific Ocean lessen, cool air from the mountains traps polluted air in the city. For at least the past 5 years, Santiago has undergone a number of "environmental pre-emergencies," in which the concentration of particulate matter in the air exceeded 240 micrograms per cubic meter. (An "environmental emergency" is declared when the concentration of particulate matter reaches 330 micrograms per cubic meter [*58*].) For example, a pre-emergency was declared in May 2003, when the concentration of particulate matter in the air increased to more than 300 micrograms per cubic meter [*59*].

When the government declares an environmental pre-emergency, measures to reduce pollution immediately are put into effect. The volume of traffic in the city is limited by banning 60 percent of vehicles without catalytic converter technology from the roads as well as 20 percent of the cars that do have catalytic converters. Additionally, nearly a thousand high-pollution manufacturing plants may also be shut down, a move that could strain the city's economy if there are a large number of shutdowns each winter [*60*]. In the United States, a level of 240 micrograms per cubic meter would be considered extremely hazardous, and the EPA would recommend that older adults, children, and persons with chronic illness stay inside, and that all others avoid activity outside [*61*].

Santiago is pursuing a number of environmental policies designed to reduce the level of particulate matter in the air. One approach seeks to reduce the concentration of pollutants in the air through direct regulation, another program to introduce CNG as a fuel for buses in Santiago, and another to reduce air pollution by changing traffic patterns and increasing the average speed of vehicles in the city during peak hours.

Santiago is reducing direct emissions from both point sources and mobile sources. Fixed emitters were subject to more stringent regulations as of 1998, when the maximum allowable concentration of particle emissions was lowered from 112 micrograms per cubic meter to 56 micrograms per cubic meter [*62*]. The city is also trying to reduce pollution from mobile sources, especially heavier vehicles that use diesel, by changing the fuel types available in the city. The Santiago region switched to a low-sulfur diesel fuel (300 parts per million sulfur) at the beginning of 2001 and will be reducing the sulfur limit for diesel to 50 parts per million in July 2004.

Over the past 10 years, Santiago has been working on modernizing its bus fleet. In the mid-1990s, Chile's government bought a number of high-emissions diesel buses from private bus operators in Santiago—a measure that succeeded in removing the most polluting buses from the city's streets but at considerable expense [***63***]. More recently, Santiago has worked with the U.S. Department of Energy's Clean Cities program to switch a number of buses and taxis to CNG [***64***]. If the process of removing polluting diesel buses from the streets continues, it can make a major contribution toward reducing particulate matter pollution in Santiago.

Santiago has also instituted a number of policies designed to keep more traffic moving freely during peak travel times, which would also reduce emissions of particulate matter. By making some streets one-way during peak times, the city can handle its regular volume of traffic more easily. Although it may serve as a short-term solution, over time the excess road capacity may prove counterproductive, in that will provide an incentive for more people to drive to work [***65***].

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