Chapter 7

Energy-Related Carbon Dioxide Emissions

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

Carbon dioxide is one of the most prevalent greenhouse gases in the atmosphere. Anthropogenic (human-caused) emissions of carbon dioxide result primarily from the combustion of fossil fuels for energy, and as a result world energy use has emerged at the center of the climate change debate. In the *IEO2006* reference case, world carbon dioxide emissions increase from 25,028 million metric tons in 2003 to 33,663 million metric tons in 2015 and 43,676 million metric tons in 2030 (Figure 65).[14]

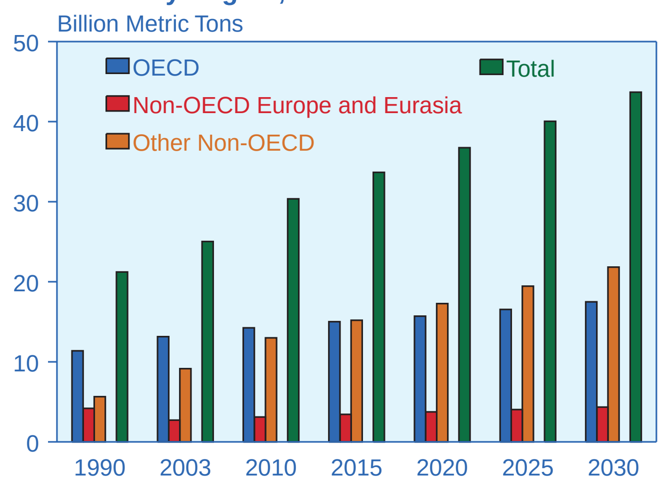
The Kyoto Protocol, which requires participating "Annex I" countries to reduce their greenhouse gas emissions collectively to an annual average of about 5 percent below their 1990 level over the 2008-2012 period, entered into force on February 16, 2005, 90 days after it was ratified by Russia. Russia's ratification satisfied the terms necessary to bring the treaty into force; that is, the total number of signatories had reached more than 55 countries, including Annex I signatories that accounted for more than 55 percent of Annex I carbon dioxide emissions in 1990. The Annex I countries include all the OECD countries except for Mexico and South Korea, along with the non-OECD countries Bulgaria, Estonia, Latvia, Lithuania, Monaco, Romania, Russia, Slovenia, and Ukraine.[15]

The *IEO2006* reference case projections are based on U.S. and foreign government laws in effect on January 1, 2006. The potential impacts of pending or proposed legislation, regulations, and standards are not reflected in the projections, nor are the impacts of legislation for which implementing mechanisms have not been announced. The *IEO2006* reference case does not include the potential impacts of the Kyoto Protocol, because the treaty does not indicate the methods by which ratifying parties will implement their obligations. Moreover, the Protocol does not address signatory obligations beyond 2012, making it impossible to assess its impacts on energy markets and carbon dioxide emissions through 2030 in the context of a reference case projection. In the year since the Kyoto Protocol entered into force, there has been little progress toward establishing goals for a second commitment period.

Another difficulty in projecting energy-related carbon dioxide emissions in the context of the Kyoto Protocol is that, in the 5-year increments of the SAGE model, upon which the *IEO2006* projections are based, 2010 is the only projection year that is part of the Protocol's first commitment period. While some participating countries have identified goals by energy-consuming sectors, not all have; and even for those that have done so, it is difficult to assess how the goals will be implemented with specific actions by the participants.

Despite the challenges, it is important to address the possible impacts of the Kyoto Protocol, because they could strongly influence future energy trends. Accordingly, this chapter begins with a presentation of the *IEO2006* reference case projections for regional carbon dioxide emissions, which can serve as an estimate against which future emissions reductions can be measured. The *IEO2006* Kyoto Protocol case assumes that the emissions goals of the Protocol will be met by the countries that have ratified the treaty and have

Figure 65. World Carbon Dioxide Emissions by Region, 1990-2030



Sources: **1990 and 2003:** Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **2010-2030:** EIA, System for the Analysis of Global Energy Markets (2006).

[14]In keeping with current international practice, *IEO2006* presents data on carbon dioxide emissions in million metric tons of carbon dioxide. The figures can be converted to carbon equivalent units by multiplying by 12/44.

[15]As of April 16, 2006, 162 countries and the European Community had ratified, accepted, acceded to, or approved the Kyoto Protocol. A list of the 162 countries is provided in Appendix J.

obligations to limit or reduce their greenhouse gas emissions, using a combination of domestic actions and purchases of international emissions permits. Further, although the current agreement extends only to 2012, the targets specified under the Protocol for the first commitment period are assumed to remain in place through 2030. Results from the Kyoto Protocol case are analyzed in the second part of the chapter.

Reference Case

Carbon Dioxide Emissions

In the *IEO2006* reference case, world carbon dioxide emissions from the consumption of fossil fuels grow at an average rate of 2.1 percent per year from 2003 to 2030. Emissions in 2030 total 43,676 million metric tons. Combustion of petroleum products contributes 5,028 million metric tons to the increase from 2003, coal 8,801 million metric tons, and natural gas 4,804 million metric tons (Figure 66). In the absence of carbon constraints, coal use is projected to grow at about the same rate as natural gas use, from 2003 consumption levels (in Btu) that are nearly identical; however, coal is a more carbon-intensive fuel than natural gas, and thus the increment in carbon dioxide emissions from coal combustion is larger than the increment in emissions from natural gas.

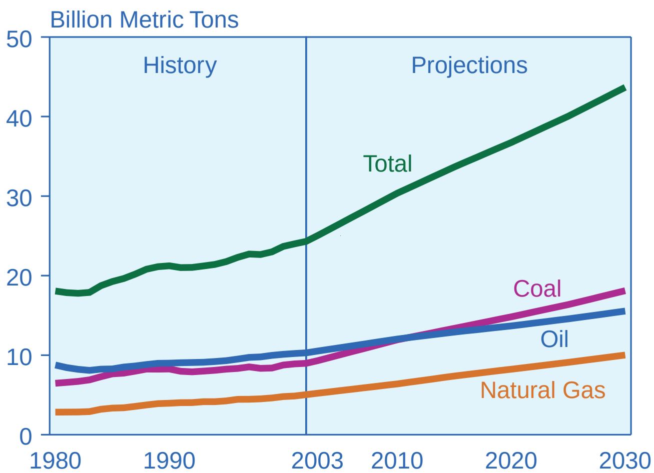
With oil prices in 2025 about 35 percent higher in the *IEO2006* reference case than projected in *IEO2005*, oil consumption and related emissions increase at a slower rate in the *IEO2006* projections (by an average of 1.5 percent per year, as compared with 1.9 percent per year in the *IEO2005* reference case), well below the growth rates for emissions related to natural gas and coal in this year's projections. As a result, coal combustion overtakes oil as the largest source of carbon dioxide emissions from 2015 to 2030 (Figure 66).

The OECD economies, for the most part, are growing more slowly than the non-OECD economies, and their growth tends to be in less energy-intensive sectors. As a result, carbon dioxide emissions from the OECD economies grow by 1.1 percent per year from 2003 to 2030 in the reference case, absent binding constraints (Figure 67 and Table 12). Emissions from North America grow the most rapidly among the OECD regions, by 1.3 percent per year. North America's average annual increase in GDP is 3.1 percent from 2003 to 2030, resulting from the combination of a 2.2-percent average increase in per capita income and population growth that averages 0.9 percent annually. That strong economic growth drives the demand for fossil fuels and thus the projected increase in the region's carbon dioxide emissions.

In contrast to North America, fairly modest growth in GDP is projected for OECD Europe and OECD Asia (2.2 and 1.9 percent per year, respectively), resulting from per capita income growth of 2.0 percent per year in OECD Europe and 1.9 percent per year in OECD Asia and population growth rates that average only 0.2 percent and 0.1 percent per year, respectively. Thus, only limited growth in demand for energy is projected for the two regions, leading to slower growth in emissions. Carbon dioxide emissions in OECD Europe grow by 0.7 percent per year on average from 2003 to 2030, and emissions in OECD Asia grow by an average of 0.9 percent per year.

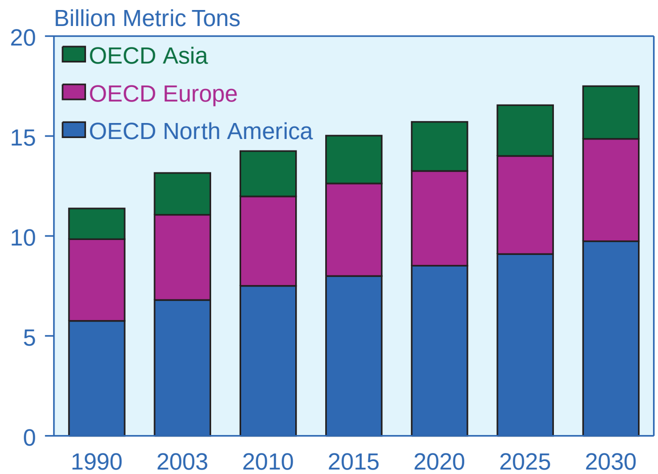
Carbon dioxide emissions in non-OECD Europe and Eurasia increase on average by 1.7 percent per year in

Figure 66. World Carbon Dioxide Emissions by Fuel Type, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2006).

Figure 67. Carbon Dioxide Emissions in the OECD Economies, 1990-2030

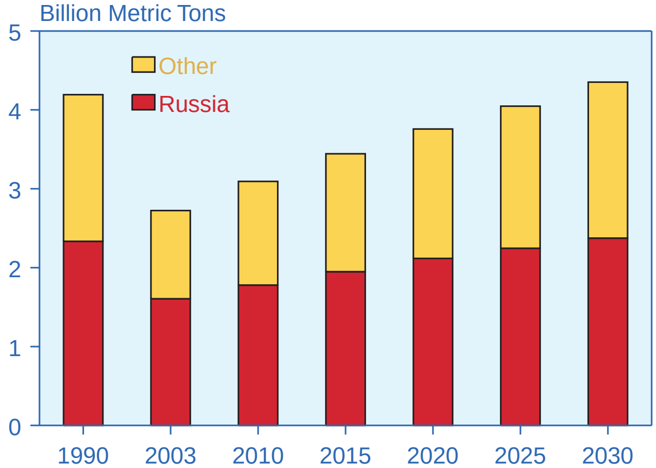


Sources: **1990 and 2003:** Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **2010-2030:** EIA, System for the Analysis of Global Energy Markets (2006).

the *IEO2006* reference case, from 2,725 million metric tons in 2003 to 3,444 million metric tons in 2015 and 4,352 million metric tons in 2030 (Figure 68 and Table 12). Russia, the region's largest economy, accounted for 60 percent of regional energy consumption and 59 percent of regional carbon dioxide emissions in 2003.

The economic collapse of the Soviet Union and the Eastern European countries in its sphere of influence—most of which are included in non-OECD Europe and Eurasia—slowed the growth of carbon dioxide emissions not only in the region but also on a worldwide basis for many years after the breakup of the Soviet Union in 1991. In 2003, total carbon dioxide emissions in the countries of non-OECD Europe and Eurasia were still 35 percent below their level in 1990, and in the reference case projection they do not return to 1990 levels until after 2025.

Figure 68. Carbon Dioxide Emissions in Non-OECD Europe and Eurasia, 1990-2030



Sources: **1990 and 2003:** Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **2010-2030:** EIA, System for the Analysis of Global Energy Markets (2006).

Although GDP growth in non-OECD Europe and Eurasia averages 4.4 percent per year from 2003 to 2030 in the reference case, improvements in energy infrastructure are expected to keep the growth in energy demand at an annual average of only 1.8 percent. In addition, an increase in the natural gas share of total energy consumption and a drop in coal's share are expected to lower the carbon intensity of energy supply in the region. Consequently, carbon dioxide emissions in non-OECD Europe and Eurasia in 2030 are only 159 million metric tons above the 1990 level.

For the other non-OECD economies, the reference case projects strong economic growth driven largely by the energy-intensive industrial and transportation sectors. Accordingly, their carbon dioxide emissions grow at twice the rate projected for non-OECD Europe and Eurasia (and three times the rate for the OECD economies), bringing the average annual increase in emissions for all non-OECD countries to 3.0 percent per year from 2003 to 2030. The most rapid increases are projected for the nations of non-OECD Asia (Figure 69).

Carbon Dioxide Intensity

World carbon dioxide intensity has improved (decreased) substantially over the past decade, falling from 629 metric tons per million 2000 U.S. dollars of GDP in 1990 to 493 metric tons per million dollars in 2003. Although the pace of improvement in emissions intensity is expected to be slower over the 2003-2030 period than it has been over the past decade, a continuing decline in intensity is projected in the reference case, to

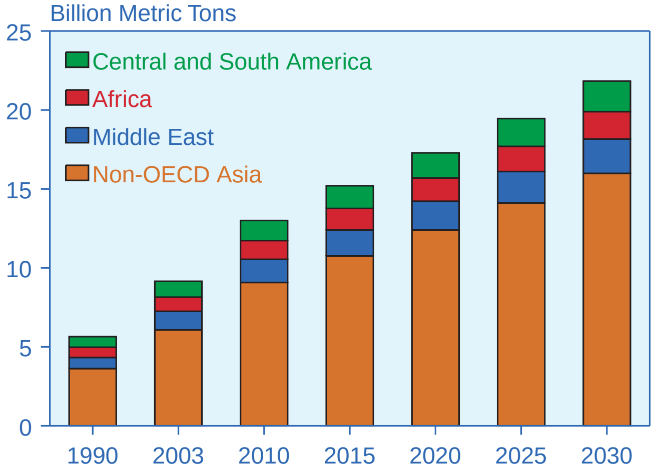
Table 12. World Carbon Dioxide Emissions by Region, 1990-2030
(Million Metric Tons)

Region	History		Projections					Average Annual Percent Change	
	1990	2003	2010	2015	2020	2025	2030	1990-2003	2003-2030
OECD	**11,378**	**13,150**	**14,249**	**15,020**	**15,709**	**16,545**	**17,496**	**1.1**	**1.1**
North America	5,753	6,797	7,505	7,997	8,513	9,096	9,735	1.3	1.3
Europe	4,089	4,264	4,474	4,632	4,741	4,909	5,123	0.3	0.7
Asia	1,536	2,090	2,269	2,390	2,455	2,540	2,638	2.4	0.9
Non-OECD	**9,846**	**11,878**	**16,113**	**18,643**	**21,039**	**23,500**	**26,180**	**1.5**	**3.0**
Europe and Eurasia	4,193	2,725	3,113	3,444	3,758	4,047	4,352	-3.3	1.7
Asia	3,626	6,072	9,079	10,753	12,407	14,113	15,984	4.0	3.6
Middle East	704	1,182	1,463	1,647	1,811	1,987	2,177	4.1	2.3
Africa	649	893	1,188	1,363	1,477	1,593	1,733	2.5	2.5
Central and South America	673	1,006	1,270	1,436	1,586	1,758	1,933	3.1	2.4
Total World	**21,223**	**25,028**	**30,362**	**33,663**	**36,748**	**40,045**	**43,676**	**1.3**	**2.1**

Sources: **1990 and 2003:** Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **2010-2030:** EIA, System for the Analysis of Global Energy Markets (2006).

408 metric tons per million dollars in 2015 and 311 metric tons per million dollars in 2030 (Table 13).

Figure 69. Carbon Dioxide Emissions in Other Non-OECD Economies, 1990-2030



Sources: **1990 and 2003:** Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **2010-2030:** EIA, System for the Analysis of Global Energy Markets (2006).

On a regional basis, the most rapid rates of improvement in carbon dioxide intensity are projected for the economies of non-OECD Europe and Eurasia and for the economies of India and other non-OECD Asia. In Eurasia, economic recovery from the upheaval of the 1990s following the breakup of the Soviet Union is expected to continue throughout the projections, and old, inefficient capital stock is expected to be replaced as the economic recovery progresses. Even with substantial improvement in efficiency, however, carbon dioxide intensity in non-OECD Europe and Eurasia is expected to be higher than in all other non-OECD countries except those of the Middle East.

Economic recovery has been slower in Russia than in the other nations of non-OECD Europe and Eurasia, where strong investment in improving the efficiency of energy use and a push to increase the use of natural gas have improved carbon dioxide intensity by an average of 3.5 percent annually from 1990 to 2003, as compared with an annual average of 1.1 percent for Russia. From 2003 to 2030, Russia's carbon dioxide intensity is projected to improve by 2.4 percent per year on average, while the rest of the region averages 2.8 percent per year.

Table 13. Carbon Dioxide Intensity by Region and Country, 1990-2030
(Metric Tons per Million 2000 U.S. Dollars of Gross Domestic Product)

Region	History		Projections					Average Annual Percent Change	
	1990	2003	2010	2015	2020	2025	2030	1990-2003	2003-2030
OECD	**565**	**473**	**421**	**391**	**361**	**338**	**318**	**-1.4**	**-1.5**
United States	701	562	488	445	406	377	351	-1.7	-1.7
Canada	693	611	574	561	538	520	498	-1.0	-0.8
Mexico	441	415	360	337	311	286	261	-0.5	-1.7
Europe	510	395	352	326	300	280	264	-1.9	-1.5
Japan	349	357	311	293	274	261	250	0.2	-1.3
South Korea	711	687	629	572	529	501	475	-0.3	-1.4
Australia/New Zealand	679	631	583	546	512	482	453	-0.6	-1.2
Non-OECD	**723**	**516**	**466**	**423**	**380**	**341**	**307**	**-2.6**	**-1.9**
Russia	1,042	903	711	637	579	522	474	-1.1	-2.4
Other Europe/Eurasia	1,622	1,018	737	654	578	521	473	-3.5	-2.8
Asia	627	449	430	390	350	314	282	-2.5	-1.7
China	1,240	591	579	517	463	414	372	-5.5	-1.7
India	343	299	265	238	208	182	156	-1.1	-2.4
Other	353	368	316	293	267	245	222	0.3	-1.9
Middle East	869	871	752	693	633	581	533	0.0	-1.8
Africa	444	411	386	357	315	279	249	-0.6	-1.8
Central and South America	310	327	307	290	269	251	232	0.4	-1.3
Brazil	215	252	235	220	203	189	176	1.2	-1.3
Other	393	388	362	342	317	295	272	-0.1	-1.3
Total World	**629**	**493**	**444**	**408**	**372**	**340**	**311**	**-1.9**	**-1.7**

Sources: **1990 and 2003:** Derived from Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **2010-2030:** EIA, System for the Analysis of Global Energy Markets (2006).

Fairly rapid improvement in carbon dioxide intensity in non-OECD Asia is expected to result primarily from rapid economic growth rather than a switch to less carbon-intensive fuels. Although China and India, in particular, are expected to remain heavily reliant on coal and other fossil fuels, their combined annual GDP growth averages 5.8 percent from 2003 to 2030, compared with a 4.0-percent annual increase in fossil fuel use. As a result, China's carbon dioxide intensity improves by 1.7 percent per year on average and India's by 2.4 percent per year from 2003 to 2030.

Overall, carbon intensity in the non-OECD countries in 2030 is projected to be slightly below that in the OECD countries. For the non-OECD region as a whole, GDP growth averages 5.0 percent per year while emissions grow by 3.0 percent per year, resulting in a 1.9-percent average annual improvement in carbon dioxide intensity. For the OECD region, GDP growth averages 2.6 percent per year while emissions grow by 1.1 percent per year, for an average annual improvement in carbon intensity of 1.5 percent per year.

Rates of improvement in carbon dioxide intensity could vary considerably in the future, based on technological advances, government policy initiatives, and economic growth rates. In the *IEO2006* reference case, world carbon dioxide intensity falls from 493 metric tons per million dollars of GDP in 2003 to 311 metric tons per million dollars in 2030. If world economic growth expanded to the levels projected in the *IEO2006* high economic growth case, carbon dioxide intensity could fall more quickly, to 298 metric tons per million dollars in 2030. In contrast, if the world economy expanded more slowly, as in the low economic growth case, carbon dioxide intensity could decline to 329 metric tons per million dollars in 2030.

Kyoto Protocol Case

Modeling Approach

Under the Kyoto Protocol, participating Annex I nations are required to reduce or limit emissions of carbon dioxide and other greenhouse gases over the first commitment period (January 2008 to December 2012) to a level that was determined as part of the negotiation process. The year 1990 was used as the base year for most countries, although some were allowed to use other years.[16] To fulfill their obligations under the treaty, the Annex I countries must limit their emissions over the 5-year commitment period to an annual average that is at or below their commitment goals. Because the SAGE model projections for *IEO2006* are in 5-year increments, 2010 is used as the basis year for achieving commitments in the first period.[17] The targets specified under the Protocol for the first commitment period are assumed to remain in place through 2030, although the current agreement extends only to 2012.

The SAGE model comprises 16 regions. In the Kyoto Protocol case, the model regions affected by the treaty are Canada, Japan, OECD Europe, and non-OECD Europe and Eurasia. Although New Zealand has ratified the Protocol and intends to honor the terms of the treaty, Australia has not. In SAGE, New Zealand and Australia are treated as a single entity; and Australia's energy use far exceeds New Zealand's. Therefore, projections for Australia/New Zealand are not included in the results of the Kyoto Protocol case. On the other hand, Turkey, which is included in OECD Europe, has not agreed to binding constraints. Because Turkey is not a participant in the Protocol, its emissions are allowed to grow in the Kyoto Protocol case, and the total goal for OECD Europe is adjusted accordingly.

For non-OECD Europe and Eurasia, countries other than Russia are split almost evenly between Kyoto participants and nonparticipants. The participants (such as Ukraine) have their emissions capped, whereas the nonparticipants have no emissions caps. Emissions in the participating countries of non-OECD Europe and Eurasia are expected to remain below the level of their emissions commitments through 2030; however, demand for credits by Kyoto participants in other regions are expected to absorb the difference between their projected emissions and commitments by the end of the projection period.

For the *IEO2006* Kyoto Protocol case, assumptions were made about how participating countries in the affected regions would achieve their reductions, based whenever possible on official government statements. For instance, the European Union (EU) has stated that "most" of its greenhouse gas emissions reductions must be achieved domestically. The Kyoto Protocol case therefore assumes that 50 percent of the aggregate emissions reduction for OECD Europe will be met by domestic reductions, as opposed to the use of international market mechanisms, such as permit trading. For Japan and Canada, which are expected to have higher domestic reduction costs than OECD Europe, both countries are assumed to achieve 25 percent of their total reductions domestically.

In the Kyoto Protocol case, a country or region is first required to achieve its domestic reduction goal. After the domestic requirement has been met, the country or region is free to seek other means of meeting its overall reduction goal—for example, by trading carbon permits

[16]The countries using a base year other than 1990 are Bulgaria (1988), Hungary (1985-1987), Poland (1988), and Romania (1989).
[17]For key assumptions in the Kyoto Protocol case, see Appendix G.

internationally. In SAGE, the marginal cost (also known as the "shadow price") of reducing carbon dioxide emissions by 1 metric ton in a given country or region is used to determine the price that the country or region will be willing to pay for the next additional reduction of 1 metric ton. If the price of a carbon permit traded internationally exceeds the shadow price of the domestic reduction, then the country or region will be better off achieving that reduction domestically. If the price of a purchased permit is less than the shadow price, then the country or region is expected to choose the trading option.

In order to find a "clearing price" for internationally traded emissions permits, various price levels were tested. It was determined that, at approximately $42 per metric ton, the supply of credits (2.1 billion metric tons) equaled the demand over the projection period. At a price higher than $42, countries could find additional domestic actions to reduce emissions, and some of the credits would not be purchased. At prices lower than $42, the demand for credits would be greater than the supply, and the available credits would be exhausted before the end of the projection period.

SAGE does not explicitly model Clean Development Mechanisms (credits purchased by Annex I countries of reductions made by non-Annex I countries), because they can involve factors such as carbon storage in trees that are outside the current model structure. Also, the generation of additional permits from non-OECD Europe and Eurasia or elsewhere was not allowed in determining the market clearing price for permits. Therefore, the $42 price probably represents an upper bound, assuming that the Kyoto Protocol goals remain in place until 2030. If the goals were relaxed, the permit price would be likely to fall; if they were made more stringent, the price would be likely to rise.

Summary

The Kyoto Protocol case assumes that energy use will not vary from the reference case projections for Annex I countries that are not expected to participate in the treaty (the United States and Australia, for example) or for countries that are not required to make reductions according to the terms of the treaty (China and India, for example). As a result, only the projections for energy use in the Annex I nations committed to participating are affected in the Kyoto Protocol case. For the participating Annex I group, total energy demand in the Kyoto Protocol case is about 3 quadrillion Btu lower than in the reference case in 2010 and 2 quadrillion Btu lower in 2030, assuming that the Kyoto targets remain constant over the entire projection period (Table 14). Energy-related carbon dioxide emissions in the participating nations are 422 million metric tons lower than in the reference case in 2010 and 675 million metric tons lower in 2030. Total coal use among the participating Annex I nations in 2030 is about 27 percent lower than in the reference case in 2030.

Total petroleum consumption in the participating nations is just under 1 quadrillion Btu lower in the Kyoto Protocol case than in the reference case in 2030, and the associated emissions are 58 million metric tons lower. In the short term, natural gas is expected to displace coal use among the participating Annex I nations, because natural gas is cleaner than coal and has an economic advantage over nuclear and renewable energy sources, which produce no net carbon dioxide emissions. In the longer term, as the marginal costs of carbon dioxide reductions increase, natural gas becomes less attractive than the non-fossil fuels (especially nuclear power), which begin to displace natural gas by 2030.

The projection for natural gas consumption in the Kyoto Protocol case is 1 quadrillion Btu higher than the reference case projection in 2010 but 2 quadrillion Btu lower in 2030, when non-fossil fuel use is almost 6 quadrillion Btu higher in the Kyoto Protocol case than in the reference case. Renewables account for about 1.6 quadrillion Btu of the increase and nuclear power 4.3 quadrillion Btu.

Table 14. Energy Consumption and Carbon Dioxide Emissions by Fuel in Participating Annex I Countries in Two Cases, 2010 and 2030

	Energy Consumption (Quadrillion Btu)				Carbon Dioxide Emissions (Million Metric Tons)			
	2010		2030		2010		2030	
Fuel	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case
Oil	48.4	47.6	49.7	48.8	3,090	3,039	3,174	3,116
Natural Gas	29.3	30.5	41.0	38.9	1,548	1,610	2,167	2,054
Coal	18.5	14.2	20.2	15.5	1,719	1,285	1,874	1,370
Nuclear	13.4	13.7	12.5	16.8	—	—	—	—
Renewables	13.1	13.4	14.6	16.2	—	—	—	—
Total	**122.7**	**119.4**	**138.0**	**136.2**	**6,357**	**5,935**	**7,216**	**6,541**

Source: Energy Information Administration, System for the Analysis of Global Energy Markets (2006).

Regional Projections

Canada

In April 2005, Canada unveiled its plan for compliance with the Kyoto Protocol, based on multiple approaches. The plan includes binding constraints on the country's electric power sector and large-scale industrial emitters, subsidies for wind power, a "partnership fund" between government and industry, soil management goals, and programs in consumer awareness and voluntary reductions by automakers. The Canadian government also has budgeted $3.2 billion to $4.0 billion for purchases of carbon credits, depending on the permit price [*1*].

In January 2006, Canada elected Conservatives to 124 of 308 Parliament seats, versus 103 for the Liberal party, resulting in a change to a Conservative government. Although the new government may reevaluate and reinterpret Canada's Kyoto commitment, the Kyoto Protocol case nevertheless assumes that Canada will remain a participant in the Protocol, and that it will achieve its goals through a combination of domestic actions and purchases of emissions credits.

At the permit price of $42 per metric ton, Canada achieves some reductions domestically below that price in all years of the projection period. Canada's energy demand in 2010 is 0.4 quadrillion Btu (2.6 percent) lower in the Kyoto Protocol case than in the reference case, and its energy-related carbon dioxide emissions in 2010 are 63 million metric tons (9.2 percent) lower (Table 15).

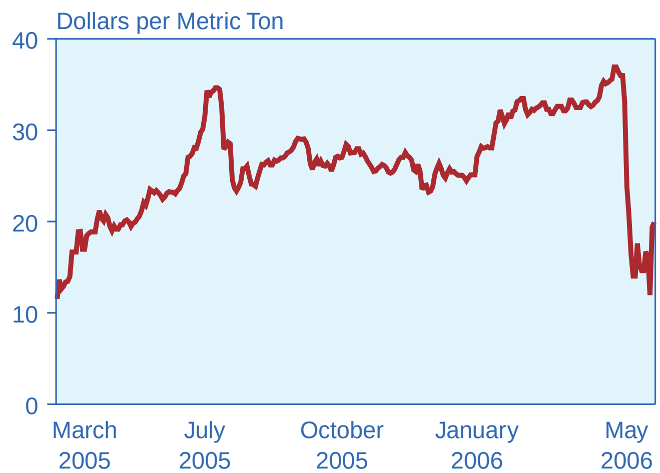
In 2010, Canada's coal consumption and associated carbon dioxide emissions both are about 43 percent lower in the Kyoto Protocol case than in the reference case. In 2030, its coal consumption is 32 percent lower than in the reference case, but emissions from coal are about 44 percent lower. The difference results from the introduction of technology that allows for the consumption of coal with 90 percent of the carbon dioxide sequestered. Emissions associated with oil consumption are about the same in the two cases in 2010 and 2030. Emissions from natural gas use are about the same in 2010 and 6 percent lower in the Kyoto Protocol case in 2030. Canada's consumption of non-fossil energy (nuclear and renewables) in 2030 is about 24 percent higher in the Kyoto Protocol case than in the reference case.

OECD Europe

The EU has developed its own plan for emissions trading in the 2005 to 2007 period, in preparation for the first Kyoto commitment period in 2008 [**2**]. The EU Greenhouse Gas Emission Trading Scheme (EU ETS) allocates emissions to more than 12,000 specific installations across 25 member countries and requires reductions or European Union Allowances (EUAs) to meet the allocated goals.

As of publication of this report, more than a year's worth of data has been accumulated since the EU ETS began trading in January 2005 (Figure 70). When trading began, the market price of an EUA for 1 metric ton of

Figure 70. Carbon Dioxide Allowance Price in the European Union, March 2005–May 2006



Sources: Deutsche Bank Commodities Research, e-mail dated May 17, 2006.

Table 15. Energy Consumption and Carbon Dioxide Emissions by Fuel in Canada in Two Cases, 2010 and 2030

Fuel	Energy Consumption (Quadrillion Btu)				Carbon Dioxide Emissions (Million Metric Tons)			
	2010		2030		2010		2030	
	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case
Oil	4.8	4.8	5.1	5.1	305	306	327	325
Natural Gas	4.2	4.2	5.4	5.1	224	222	286	269
Coal	1.7	1.0	2.8	1.9	154	92	260	146
Nuclear	1.2	1.2	1.2	1.6	—	—	—	—
Renewables	3.8	4.0	4.6	5.6	—	—	—	—
Total	**15.6**	**15.2**	**19.2**	**19.3**	**683**	**620**	**873**	**741**

Source: Energy Information Administration, System for the Analysis of Global Energy Markets (2006).

carbon dioxide was around $12,[18] with prices fluctuating between $25 and $35 for most of 2005 and into the early part of 2006. The market did, however, experience marked volatility with the release of official estimates of industry emissions by country—which initially indicated that in 2005 Europe's major industries emitted 44 million metric tons less carbon dioxide than permitted. As a result, in late April 2006 the EUA price dropped precipitously, from about $36 per metric ton to record low of $11 per ton on May 12, 2006, but then recovered to nearly $20 per metric ton on May 16, one day after the United Kingdom and Spain were among the countries that reported exceeding their emissions limits [*3*].

The next trading period will begin in 2008, coinciding with the Kyoto Protocol's first commitment period. In the 2008-2012 commitment period, the price of EUAs will depend on the availability of credits from Russia and elsewhere, on the rules that ultimately apply to European domestic reductions by country, and on the rules governing European actions in total. As the SAGE model is currently configured, OECD Europe includes the Czech Republic, Hungary, Poland, and Slovakia—countries that in last year's report were part of the separate "Eastern Europe" region. This inclusion helps to mitigate the cost of achieving Kyoto goals for the OECD Europe region. To the extent that sharing of emissions reduction obligations across OECD Europe is restricted by provisions included in the Kyoto Protocol, the results of the Kyoto Protocol case may understate the challenges faced by countries of OECD Europe that were not included in the old "Eastern Europe" region.

OECD Europe's total projected energy demand is 2.2 quadrillion Btu lower in the Kyoto Protocol case than in the reference case in 2010 and 1.7 quadrillion Btu lower in 2030, and its energy-related carbon dioxide emissions are 284 million metric tons lower in 2010 and 446 million metric tons lower in 2030 (Table 16). Its coal consumption and associated emissions are 27 percent lower in 2010 in the Kyoto Protocol case than in the reference case and 25 percent lower in 2030. Oil consumption and related emissions are about 2.4 percent lower in the Kyoto Protocol case in 2030, natural gas consumption and associated emissions are 4.4 percent lower, and consumption of non-fossil fuels is 24 percent higher than in the reference case in 2030.

Japan

Japan's plan for compliance relies heavily on carbon sinks and Clean Development Mechanisms for most of the required emissions reductions to meet its Kyoto goal [*4*]. In 2010, Japan's energy demand is 0.7 quadrillion Btu lower in the Kyoto Protocol case than in the reference case, and emissions are 72 million metric tons lower (Table 17). Assuming that the country's goals for the first commitment period remain in place at the same level through 2030, its total energy demand in 2030 is 0.2 quadrillion Btu lower than in the reference case, and its energy-related carbon dioxide emissions are 94 million metric tons lower in 2030.

Japan's coal consumption in 2030 is 10 percent lower in the Kyoto Protocol case than in the reference case, and its oil consumption is 1 percent lower. Electricity generation from its nuclear power plants in 2030 is almost 0.7 quadrillion Btu higher than in the reference case, and with lower total energy demand, its natural gas consumption is 10 percent lower in the Kyoto Protocol case than in the reference case.

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Table 16. Energy Consumption and Carbon Dioxide Emissions by Fuel in OECD Europe in Two Cases, 2010 and 2030

Fuel	Energy Consumption (Quadrillion Btu)				Carbon Dioxide Emissions (Million Metric Tons)			
	2010		2030		2010		2030	
	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case
Oil	32.6	32.0	33.5	32.7	2,135	2,096	2,194	2,142
Natural Gas	21.7	23.1	31.6	30.2	1,146	1,220	1,668	1,595
Coal	12.7	9.3	13.4	10.0	1,191	872	1,257	938
Nuclear	9.5	9.7	7.5	10.7	—	—	—	—
Renewables	7.9	8.1	8.5	9.2	—	—	—	—
Total	**84.4**	**82.2**	**94.5**	**92.8**	**4,472**	**4,188**	**5,120**	**4,674**

Source: Energy Information Administration, System for the Analysis of Global Energy Markets (2006).

[18]Credits are traded in Euros. The conversion rate used here is 1.19 U.S. dollars per Euro.

Table 17. Energy Consumption and Carbon Dioxide Emissions by Fuel in Japan in Two Cases, 2010 and 2030

Fuel	Energy Consumption (Quadrillion Btu)				Carbon Dioxide Emissions (Million Metric Tons)			
	2010		2030		2010		2030	
	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case	Reference Case	Kyoto Protocol Case
Oil	11.0	10.8	11.1	11.0	648	637	652	649
Natural Gas . . .	3.4	3.2	4.0	3.6	179	169	211	190
Coal	4.1	3.9	4.0	3.6	373	321	356	286
Nuclear	2.8	2.8	3.8	4.5	—	—	—	—
Renewables . . .	1.4	1.3	1.6	1.4	—	—	—	—
Total	**22.7**	**22.0**	**24.3**	**24.1**	**1,200**	**1,128**	**1,219**	**1,125**

Source: Energy Information Administration, System for the Analysis of Global Energy Markets (2006).

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