Chapter 7

Energy-Related Carbon Dioxide Emissions

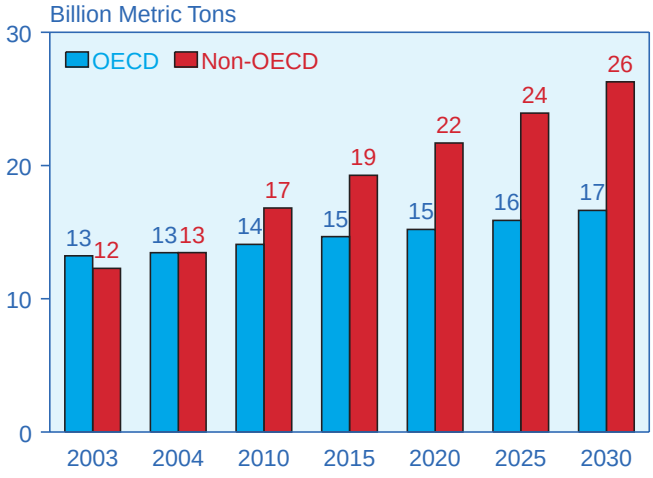
In 2004, non-OECD emissions of carbon dioxide were greater than OECD emissions for the first time. In 2030, carbon dioxide emissions from the non-OECD countries are projected to exceed those from the OECD countries by 57 percent.

Carbon dioxide is the most abundant anthropogenic (human-caused) greenhouse gas in the atmosphere. In recent years, atmospheric concentrations of carbon dioxide have been rising at a rate of about 0.5 percent per year, and because anthropogenic emissions of carbon dioxide result primarily from the combustion of fossil fuels for energy, world energy use has emerged at the center of the climate change debate. In the *IEO2007* reference case, world carbon dioxide emissions are projected to rise from 26.9 billion metric tons in 2004 to 33.9 billion metric tons in 2015 and 42.9 billion metric tons in 2030.[17]

From 2003 to 2004, carbon dioxide emissions from the non-OECD countries grew by almost 10 percent, largely because of a 17-percent increase in coal-related emissions in non-OECD Asia, while emissions from the OECD countries grew by less than 2 percent. The result of the large increase in non-OECD emissions was that 2004 marked the first time in history that energy-related carbon dioxide emissions from the non-OECD countries exceeded those from the OECD countries (Figure 77). Further, because the projected average annual increase in emissions from 2004 to 2030 in the non-OECD countries (2.6 percent) is more than three times the increase projected for the OECD countries (0.8 percent), carbon dioxide emissions from the non-OECD countries in 2030, at 26.2 billion metric tons, are projected to exceed those from the OECD countries by 57 percent.

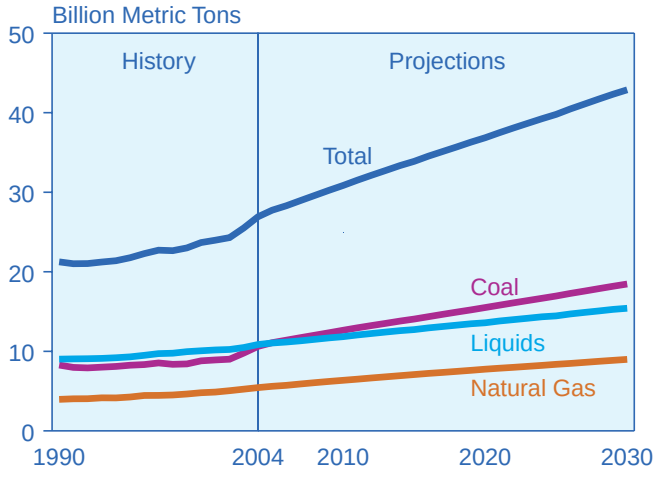
The relative contributions of different fossil fuels to total energy-related carbon dioxide emissions have changed over time. In 1990, emissions from petroleum and other liquids combustion made up an estimated 42 percent of the world total. In 2004, the petroleum share was 40 percent, and in 2030 its share is projected to be 36 percent, of the world total (Figure 78). Carbon dioxide emissions from natural gas combustion, which accounted for 19 percent of the total in 1990, increased to 20 percent of the 2004 total. That share is projected to rise to 21 percent in 2030. Coal's share in 2004 was the same as its share in 1990, at 39 percent; however, its share is projected to increase to 43 percent in 2030. Coal is the most carbon-intensive of the fossil fuels, and it is the fastest-growing energy source in the *IEO2007* reference case projection.

Figure 77. World Energy-Related Carbon Dioxide Emissions by Region, 2003-2030



Sources: **2003 and 2004:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets (2007).

Figure 78. World Energy-Related Carbon Dioxide Emissions by Fuel Type, 1990-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets (2007).

[17] In keeping with current international practice, *IEO2007* presents data on greenhouse gas emissions in billion metric tons carbon dioxide equivalent. The figures can be converted to carbon equivalent units by multiplying by 12/44.

The increasing share of coal is reflective of its important role in the energy mix of non-OECD countries—especially China and India. In 1990, China and India combined for 13 percent of world emissions, but by 2004 that share had risen to 22 percent—largely because of a strong increase in coal use in these two countries. This trend is projected to continue; and by 2030, carbon dioxide emissions from China and India combined are projected to account for 31 percent of total world emissions, with China alone responsible for 26 percent of the world total. As both economies expand, coal will become a greater part of the world energy mix and play a correspondingly larger role in the composition of world carbon dioxide emissions.

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. Annex I countries include the 24 original OECD countries, the European Union, and 14 countries that are considered "economies in transition." Although the Protocol is technically "in force," it would have an effect on only one year of the *IEO2007* forecast—2010. The *IEO2007* projections do not explicitly include the impacts of the Kyoto Protocol, because the treaty does not indicate the methods by which ratifying parties will implement their obligations. Moreover, the participants have been unable to agree on a second commitment period, nor on any actions that might occur after 2012. Until those issues are resolved, it will be difficult to project the effects of the Kyoto Protocol through 2030.[18]

There are some signs that concerns about global climate change are beginning to affect the world fuel mix. In recent years, many countries have begun to express new interest in expanding their use of non-carbon-emitting nuclear power, in part to stem the growth of greenhouse gas emissions. The *IEO2007* reference case projection for electricity generation from nuclear power in 2030 is up by almost 10 percent from the *IEO2006* projection, reflecting a generally more favorable perception of nuclear power as an alternative to carbon-producing fossil fuels for electric power production. Many of the industrialized nations of OECD Europe have ratified the Kyoto Protocol, and in the *IEO2007* reference case the projected rate of decline in the region's nuclear electricity generation is considerably slower, at 0.4 percent per year, than the rate of 1.0 percent per year that was projected in the *IEO2006* reference case.

Reference Case

Carbon Dioxide Emissions

In the *IEO2007* reference case, world energy-related carbon dioxide emissions are projected to grow by an average of 1.8 percent per year from 2004 to 2030 (Table 11). For the OECD countries, total emissions are projected to average 0.8-percent annual growth, from 13.5 billion metric tons in 2004 to 14.7 billion metric tons in 2015 and 16.7 billion metric tons in 2030. The highest rate of increase among the OECD countries is projected for Mexico, at 2.3 percent per year (Figure 79). Mexico is less developed than most of the OECD countries, and it is projected to have the highest GDP growth rate in the OECD region. Much of that GDP growth is expected to

Table 11. World Carbon Dioxide Emissions by Region, 1990-2030
(Billion Metric Tons)

Region	History		Projections					Average Annual Percent Change	
	1990	2004	2010	2015	2020	2025	2030	1990-2004	2004-2030
OECD	**11.4**	**13.5**	**14.1**	**14.7**	**15.2**	**15.9**	**16.7**	**1.2%**	**0.8%**
North America	5.8	6.9	7.3	7.8	8.2	8.8	9.4	1.3%	1.2%
Europe	4.1	4.4	4.5	4.6	4.6	4.6	4.7	0.5%	0.3%
Asia	1.5	2.2	2.3	2.4	2.4	2.5	2.6	2.5%	0.6%
Non-OECD	**9.8**	**13.5**	**16.8**	**19.2**	**21.6**	**23.9**	**26.2**	**2.3%**	**2.6%**
Europe and Eurasia	4.2	2.8	3.1	3.3	3.5	3.7	3.9	-2.8%	1.2%
Asia	3.6	7.4	9.7	11.4	13.1	14.8	16.5	5.2%	3.1%
Middle East	0.7	1.3	1.6	1.8	2.0	2.1	2.3	4.4%	2.3%
Africa	0.6	0.9	1.1	1.3	1.4	1.5	1.7	2.5%	2.3%
Central and South America	0.7	1.0	1.2	1.4	1.6	1.7	1.9	3.1%	2.3%
Total World	**21.2**	**26.9**	**30.9**	**33.9**	**36.9**	**39.8**	**42.9**	**1.7%**	**1.8%**

Sources: **1990 and 2004:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **2010-2030:** EIA, System for the Analysis of Global Energy Markets (2007).

[18]For a modeling analysis of the effects of the Kyoto Protocol, see Energy Information Administration, *International Energy Outlook 2006*, DOE/EIA-0484(2006) (Washington, DC, June 2006), "Kyoto Protocol Case," pp. 75-79, web site www.eia.doe.gov/oiaf/ieo.

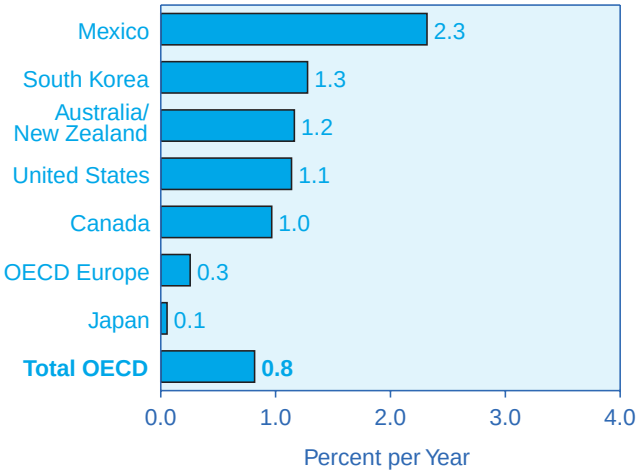
come from energy-intensive industries. For all the other OECD countries, annual increases in carbon dioxide emissions are projected to average less than 1.5 percent, reflecting the overall maturity of their energy infrastructures. In Japan, emissions are projected to increase by 0.1 percent per year from 2004 to 2030, and the average for OECD Europe is 0.3 percent per year.

For the non-OECD countries, total carbon dioxide emissions are projected to average 2.6-percent annual growth (Figure 80). The highest growth rate in the non-OECD regions is projected for China, at 3.4 percent annually from 2004 to 2030, reflecting the country's continued heavy reliance on fossil fuels, especially coal, over the projection period. China's energy-related emissions of carbon dioxide are projected to exceed U.S. emissions by about 5 percent in 2010 and by 41 percent in 2030. The lowest growth rate in the non-OECD region is projected for Russia, at 1.0 percent per year. Over the projection period, Russia is expected to expand its reliance on indigenous natural gas resources and nuclear power to fuel electricity generation, and a decline in its population growth rate is expected to slow the overall rate of increase in energy demand.

By fuel, world carbon dioxide emissions from the consumption of oil and other liquids are projected to grow at an average annual rate of 1.4 percent from 2004 to 2030. The average growth rates for the OECD and non-OECD regions are projected to be 0.6 percent and 2.3 percent per year, respectively (Figure 81). The highest rate of growth in petroleum-related carbon dioxide emissions is projected for China, at 3.5 percent per year, as its demand for liquid fuels increases to meet growing demand in the transportation and industrial sectors. The United States is expected to remain the largest source of petroleum-related carbon dioxide emissions throughout the period, with projected emissions of 3.3 billion metric tons in 2030—still 66 percent above the corresponding projection for China.

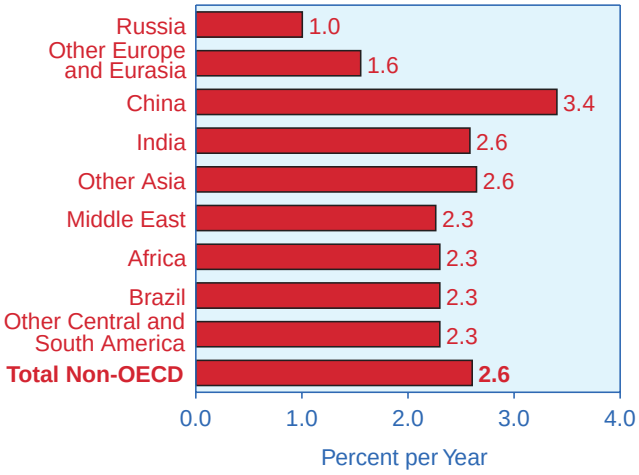
Carbon dioxide emissions from natural gas combustion worldwide are projected to increase on average by 1.9 percent per year, to 9.0 billion metric tons in 2030, with

Figure 79. Average Annual Growth in Energy-Related Carbon Dioxide Emissions in the OECD Economies, 2004-2030



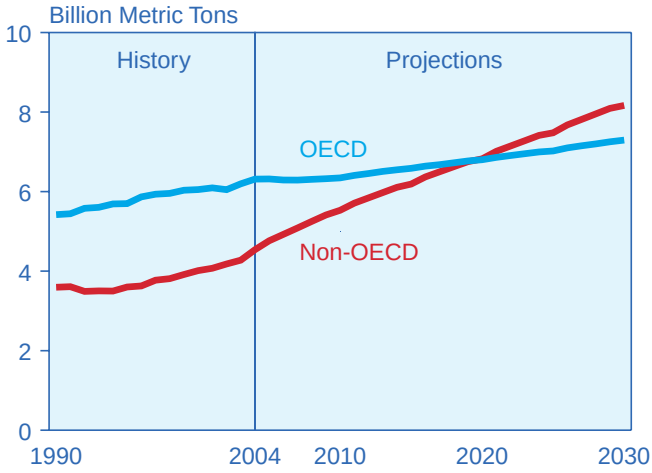
Sources: **2004:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **2030:** EIA, System for the Analysis of Global Energy Markets (2007).

Figure 80. Average Annual Growth in Energy-Related Carbon Dioxide Emissions in the Non-OECD Economies, 2004-2030



Sources: **2004:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **2030:** EIA, System for the Analysis of Global Energy Markets (2007).

Figure 81. World Carbon Dioxide Emissions from Liquids Combustion by Region, 1990-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets (2007).

the OECD countries averaging 1.2 percent and the non-OECD countries 2.6 percent (Figure 82). Again, China is projected to see the most rapid growth in emissions, averaging 6.5 percent annually; however, China's emissions from natural gas combustion amounted to only 0.1 billion metric tons in 2004, and in 2030 they are projected to total only 0.4 billion metric tons, or less than 5 percent of the world total. In contrast, the growth in U.S. emissions is projected to average 0.6 percent per year, but the projected level of 1.4 billion metric tons in 2030 is more than triple the projection for China.

Total carbon dioxide emissions from the combustion of coal throughout the world are projected to increase by 2.2 percent per year, from 10.6 billion metric tons in 2004 to 18.5 billion metric tons in 2030. Total coal-related emissions from the non-OECD countries have been greater than those from the OECD countries since 1987, and in 2030 they are projected to be more than double the OECD total (Figure 83), in large part because of the increase in coal use projected for China and India. Together, China and India account for 72 percent of the projected world increment in coal-related carbon dioxide emissions. For China alone, coal-related emissions are projected to grow by an average of 3.3 percent annually, from 3.8 billion metric tons in 2004 to 8.8 billion metric tons (48 percent of the world total) in 2030. India's carbon dioxide emissions from coal combustion are projected to total 1.4 billion metric tons in 2030, accounting for 8 percent of the world total.

Carbon Dioxide Intensity Measures

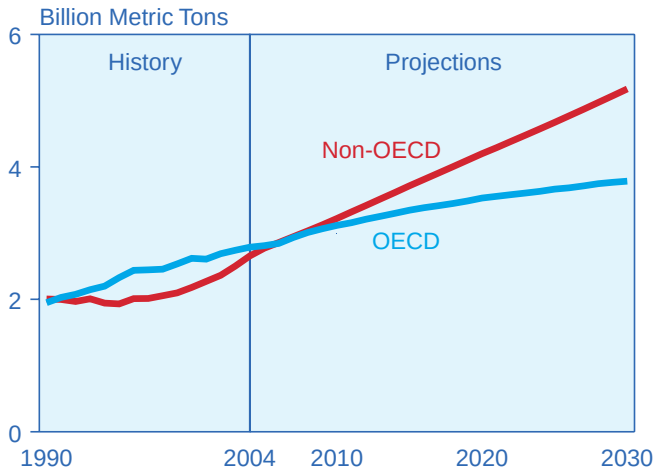
Emissions per Dollar of GDP

In all countries and regions, carbon dioxide intensity—expressed in emissions per unit of economic output—are projected to improve (decline) over the projection period as the world economy moves into a post-industrial phase. In 2004, estimated carbon dioxide intensity was 470 metric tons per million dollars of GDP in the OECD region and 516 metric tons per million dollars in the non-OECD region (Table 12).[19]

Because of the high rate of economic growth projected for the non-OECD countries, their carbon dioxide intensity in 2030 is projected to be about 263 metric tons per million dollars. In the OECD countries, carbon dioxide intensity in 2030 is projected to be 306 metric tons per million dollars. China, with a relatively high projected rate of growth in emissions (3.4 percent per year), has an even higher projected growth rate for GDP (6.5 percent).

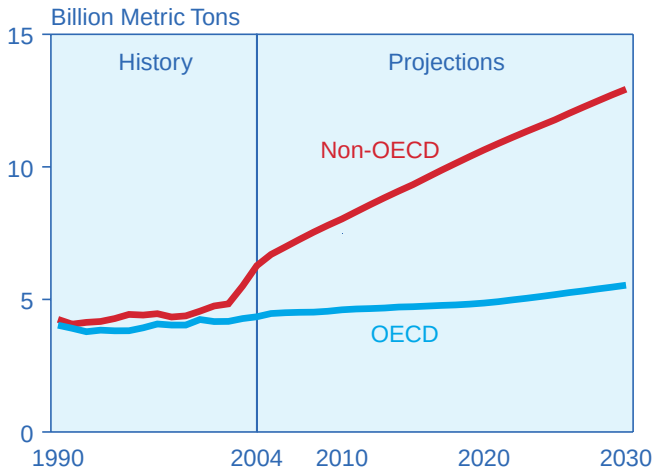
In 2030, OECD Europe is projected to have the lowest carbon dioxide intensity among the OECD regions, at 235 metric tons per million dollars, followed by Mexico at 273 metric tons per million dollars and Japan at 292 metric tons per million dollars. Without carbon dioxide constraints, Canada is projected to have the highest carbon dioxide intensity in the OECD region in 2030, at 410 metric tons per million dollars, followed by Australia/New Zealand at 400 metric tons per million dollars. U.S.

Figure 82. World Carbon Dioxide Emissions from Natural Gas Combustion by Region, 1990-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets (2007).

Figure 83. World Carbon Dioxide Emissions from Coal Combustion by Region, 1990-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets (2007).

[19]GDP is measured in chain-weighted 2000 dollars converted to the currency of the relevant country or region, based on purchasing power parity.

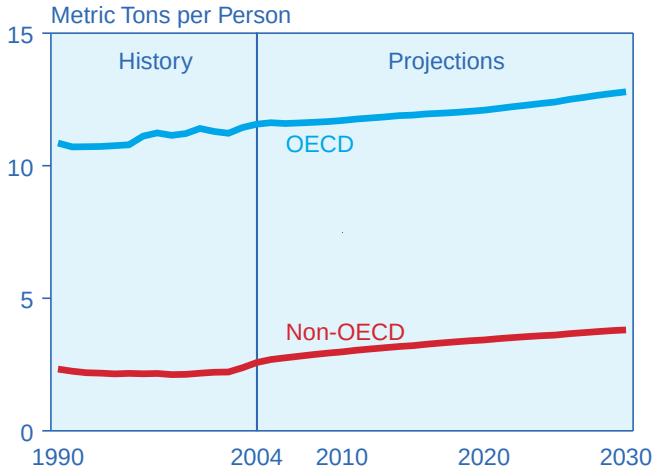
carbon dioxide intensity in 2030 is projected to be 353 metric tons per million dollars of GDP.

Emissions per Capita

Another measure of carbon dioxide intensity is emissions per person. Carbon dioxide emissions per capita in the OECD region are significantly higher than in the non-OECD region (Figure 84). If non-OECD countries consumed as much energy per capita as the OECD countries, the projection for world carbon dioxide emissions in 2030 would be much larger, because the non-OECD countries would consume about 3.5 times more energy than the current reference case estimate of 404 quadrillion Btu. And, given the expectation that non-OECD countries will rely heavily on fossil fuels to meet their energy needs, the increase in carbon dioxide emissions would be even greater.

Among the countries of the non-OECD region, Russia has the highest projected increase in carbon dioxide emissions per capita in the *IEO2007* reference case, from

Figure 84. World Carbon Dioxide Emissions per Capita by Region, 1990-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets (2007).

Table 12. Carbon Dioxide Intensity by Region and Country, 1980-2030
(Metric Tons per Million 2000 U.S. Dollars of Gross Domestic Product)

Region	History			Projections					Average Annual Percent Change	
	1980	1990	2004	2010	2015	2020	2025	2030	1990-2004	2004-2030
OECD	**731**	**565**	**470**	**419**	**385**	**353**	**328**	**306**	**-1.3%**	**-1.6%**
United States	917	701	553	486	448	407	378	353	-1.7%	-1.7%
Canada	867	693	581	545	490	465	437	410	-1.3%	-1.3%
Mexico	395	441	379	380	353	329	300	273	-1.1%	-1.3%
Europe	672	507	394	349	316	284	258	235	-1.8%	-2.0%
Japan	483	355	375	336	319	307	299	292	0.4%	-1.0%
South Korea	883	719	694	543	488	451	418	392	-0.3%	-2.2%
Australia/New Zealand	693	678	621	590	529	480	443	400	-0.6%	-1.7%
Non-OECD	**687**	**701**	**516**	**434**	**383**	**338**	**298**	**263**	**-2.2%**	**-2.6%**
Europe/Eurasia	1,018	1,164	846	643	562	504	446	392	-2.3%	-2.9%
Russia	882	1,042	883	689	606	548	494	441	-1.2%	-2.6%
Other	1,242	1,366	796	587	511	454	396	344	-3.8%	-3.2%
Asia	738	605	468	393	346	305	269	238	-1.8%	-2.6%
China	1,766	1,120	610	500	425	367	321	284	-4.2%	-2.9%
India	305	340	298	227	202	178	158	138	-0.9%	-2.9%
Other	400	352	363	319	302	276	248	220	0.2%	-1.9%
Middle East	454	860	887	821	743	677	609	545	0.2%	-1.9%
Africa	398	448	425	388	344	301	261	223	-0.4%	-2.4%
Central and South America	314	307	311	288	273	252	230	209	0.1%	-1.5%
Brazil	214	215	231	227	216	201	186	174	0.5%	-1.1%
Other	393	388	374	332	313	285	259	230	-0.3%	-1.8%
Total World	**713**	**621**	**492**	**427**	**384**	**344**	**309**	**278**	**-1.6%**	**-2.1%**

Note: GDP is expressed in terms of purchasing power parity.
Sources: **1980-2004:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **2010-2030:** EIA, System for the Analysis of Global Energy Markets (2007).

12 metric tons per person in 2004 to 17 metric tons per person in 2030. Russia continues to be a fairly inefficient energy consumer. With Soviet-era capital equipment that has not yet been replaced and a wealth of relatively inexpensive fossil fuel resources, there has been little incentive for Russia to introduce energy conservation or efficiency measures. The lowest levels of per capita emissions in the non-OECD region, and in the world, are in India and Africa, where they are projected to remain at about 1 metric ton per person through 2030.

The OECD countries have higher levels of carbon dioxide emissions per capita, in proportion to their higher per capita incomes. In the United States, emissions per capita are projected to rise from 20 metric tons in 2004 to 22 metric tons in 2030. In both Canada and Australia/New Zealand, emissions per capita are projected to rise from 18 metric tons in 2004 to 19 metric tons in 2030. In Mexico, with the lowest level of per capita emissions among the OECD countries, an increase from 4 metric tons in 2004 to 5 metric tons in 2030 is projected.

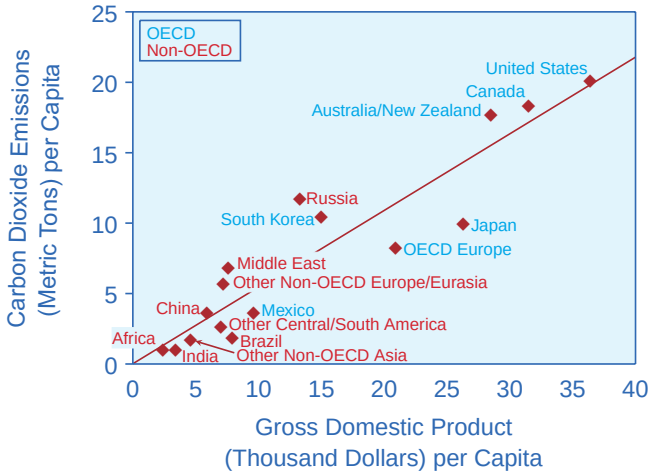
As shown in Figures 85 and 86, there is a strong correlation between income and emissions per capita. In the figures, countries and regions that are plotted on the trend line produce roughly the average amount of carbon dioxide emissions per capita relative to income per capita. Countries and regions that appear above the trend line are more carbon-intensive than average, and those below the trend line are less carbon-intensive than average.

Of the OECD countries and regions shown in Figure 85, two (Canada and the United States) are situated slightly above the trend line for 2004. Two (South Korea and Australia/New Zealand) are above the trend line, and three (Mexico, OECD Europe, and Japan) are below the trend line. Factors that can influence the position of a country or region relative to the trend line include level of industrialization, climate, population density, energy efficiency, and fuel mix. For example, South Korea, which is above the trend line, is still in the process of industrialization. Australia has a low population density and relies heavily on coal for its electricity generation, having no nuclear power capacity. Both Europe and Japan have relatively dense populations, and both have nuclear power generation capacity. Also, the economies of both Europe and Japan have entered the post-industrial phase. The United States benefits from post-industrialization and nuclear power but has relatively low population density in comparison with Europe and Japan.

Of the non-OECD countries shown in Figure 85, Brazil is the farthest below the trend line. Factors contributing to Brazil's position include a relatively warm climate, a high rate of ethanol use for transportation, and ample hydropower capacity for electricity generation. Africa, India, other non-OECD Asia, and Central and South America (excluding Brazil) are slightly below the trend line. China is slightly above the trend line. Russia is well above the trend line. The other countries of non-OECD Europe and Eurasia are above the trend line, as is the Middle East.

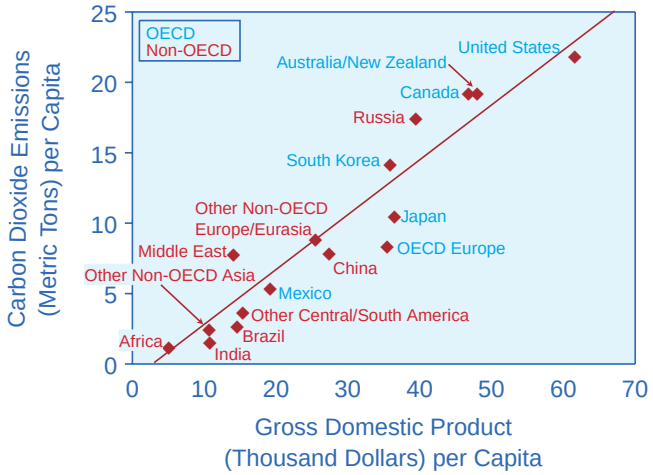
In the 2030 projections, most countries and regions have roughly the same positions relative to the trend line (Figure 86) that they did in 2004; however, there are

Figure 85. Carbon Dioxide Emissions and Gross Domestic Product per Capita by Region, 2004



Source: Derived from Energy Information Administration, *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea.

Figure 86. Carbon Dioxide Emissions and Gross Domestic Product per Capita by Region, 2030



Source: Energy Information Administration, System for the Analysis of Global Energy Markets (2007).

some exceptions. China moves from slightly above the trend for 2004 to slightly below the trend for 2030, mainly as a result of its projected rapid economic growth and movement toward a post-industrial economy. China's GDP is projected to increase by 6.5 percent per year from 2004 to 2030, while its carbon dioxide emissions increase by 3.4 percent per year. In addition, China's projected population growth rate is lower than the rates projected for most of the other non-OECD nations (excluding non-OECD Europe and Eurasia). Among the other non-OECD countries, India is projected to be the farthest below the trend line for 2030—surpassing Brazil—indicating that its projected economic growth is less carbon-intensive than in other countries, as it moves more toward service industries rather than energy-intensive manufacturing. Per capita GDP in India is projected to grow by 4.5 percent per year from 2004 to 2030, while its carbon dioxide emissions per capita are projected to increase by only 1.5 percent per year.

Alternative Macroeconomic Growth Cases

Economic growth is the most significant factor underlying the projections for growth in carbon dioxide emissions in the mid-term, as the world continues to rely on fossil fuels for most of its energy use. Accordingly, projections of world carbon dioxide emissions are lower in the *IEO2007* low economic growth case and higher in the high economic growth case.

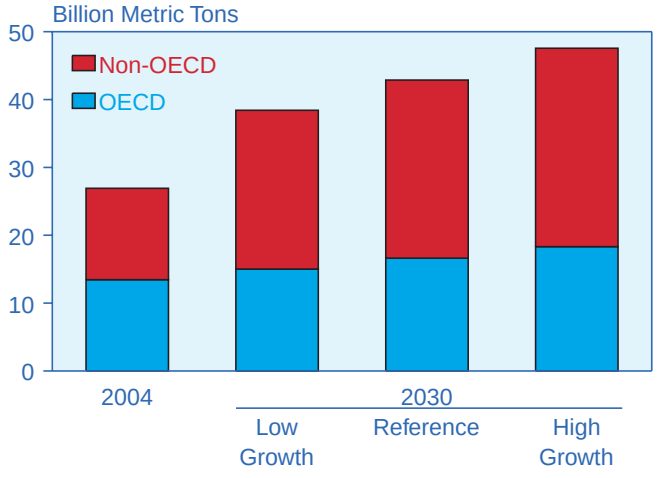
In the high growth case, world carbon dioxide emissions are projected to increase at an average rate of 2.2 percent annually from 2004 to 2030, as compared with 1.8 percent in the reference case. For the OECD countries, the projected average increase is 1.2 percent per year; for the non-OECD countries, the projected average increase is 3.0 percent per year. In the low growth case, world carbon dioxide emissions are projected to increase by 1.4 percent per year, with averages of 0.4 percent per year in the OECD countries and 2.1 percent per year in the non-OECD countries (compared with 0.8 percent and 2.6 percent, respectively, in the reference case). Total emissions worldwide are projected to be 38.4 billion metric tons in 2030 in the low growth case and 47.6 billion metric tons in the high growth case—24 percent higher than projected in the low growth case (Figure 87). The projections for emissions by fuel show similar variations across the cases.

Alternative World Oil Price Cases

The projections for carbon dioxide emissions in the *IEO2007* low and high world oil price cases (Figure 88) show smaller variations from the reference case than do those in the macroeconomic growth cases. In 2030, as compared with the reference case projection (42.9 billion metric tons), total carbon dioxide emissions are projected to be higher in the low price case (43.9 billion metric tons) and lower in the high price case (41.8 billion metric tons). Thus, there is a 5-percent difference between the projections in the two alternative world oil price cases, as compared with a 24-percent difference between the alternative macroeconomic growth cases.

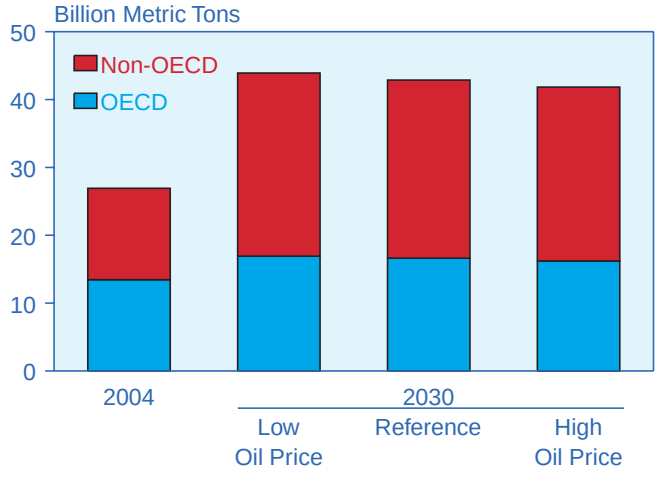
In the world oil price cases, natural gas prices are affected more strongly than coal prices. Because natural

Figure 87. Carbon Dioxide Emissions by Region in Three Economic Growth Cases, 2004 and 2030



Sources: **2004:** Energy Information Administration, *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **2030:** Energy Information Administration, System for the Analysis of Global Energy Markets (2007).

Figure 88. Carbon Dioxide Emissions by Region in Three World Oil Price Cases, 2004 and 2030



Sources: **2004:** Energy Information Administration, *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **2030:** Energy Information Administration, System for the Analysis of Global Energy Markets (2007).

gas prices are projected to rise with oil prices in the high price case, both oil and natural gas lose market share to coal. In the *IEO2007* reference case, coal's share of total energy use is projected to increase to 28 percent; in the high price case, its share increases to 31 percent. As a result, in the high price case, carbon dioxide emissions from natural gas combustion in 2030 are projected to total 8.7 billion metric tons worldwide, down from 9.0 billion metric tons in the reference case. In the low oil price case, coal's share of total energy use drops to 26 percent in 2030.