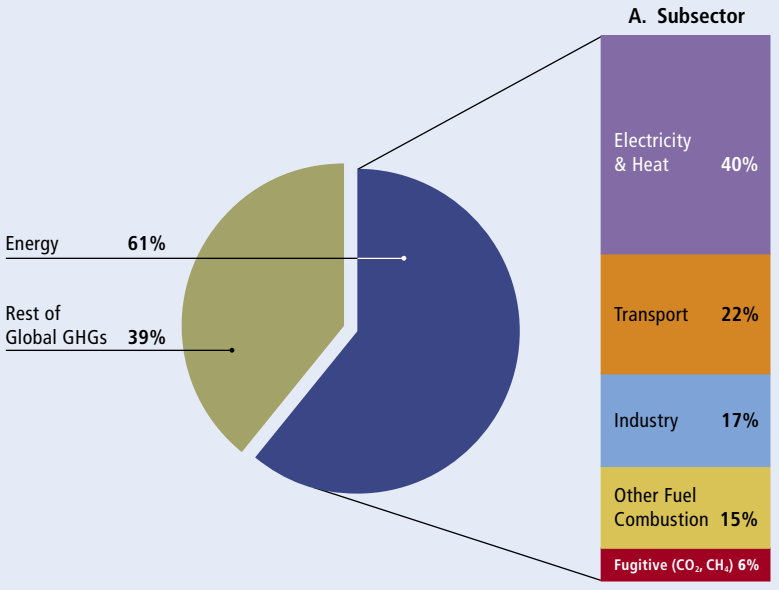
CHAPTER 8

Energy and Fuels

As discussed in Chapters 2 and 5, energy fuel mix and energy intensity (shaped by economic structure and energy efficiencies) play important roles as drivers of CO_2 emissions. Within a broader context, this chapter examines the energy sources that emit CO_2, focusing on production, consumption, and reserves of the main fossil fuels.

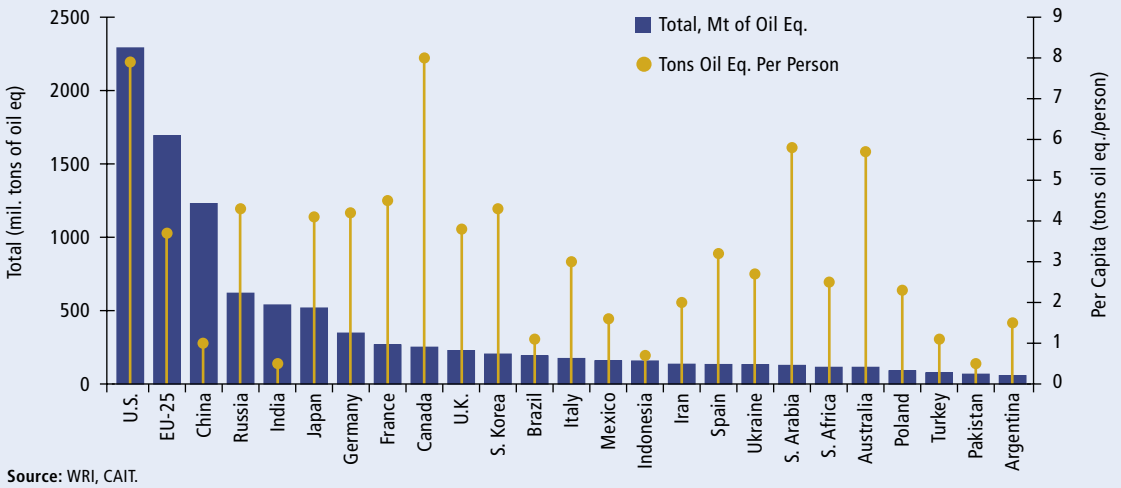
Levels of emissions are highly correlated with levels of energy use, in large part because 61 percent of total GHGs (and almost 75 percent of all CO_2) stem from energy-related activities, with the large majority coming from fossil fuel combustion (Figure 8.1). These emissions result from electricity and heat generation, transport, industry, other fuel combustion, and fugitive emissions (for example, from oil and gas extraction)—most of which are examined in detail in Part II of this report. Figure 8.2 shows energy consumption in the top 25 GHG emitting countries, in both absolute and per capita terms. These 25 countries are all within the top 30 energy-consuming countries. Together, this group accounts for 85 percent of global energy consumption, with the 10 largest users accounting for over 70 percent. The United States, EU-25, and China, are the largest consumers at 22, 17, and 11 percent, respectively.

Figure 8.1. GHGs from Energy



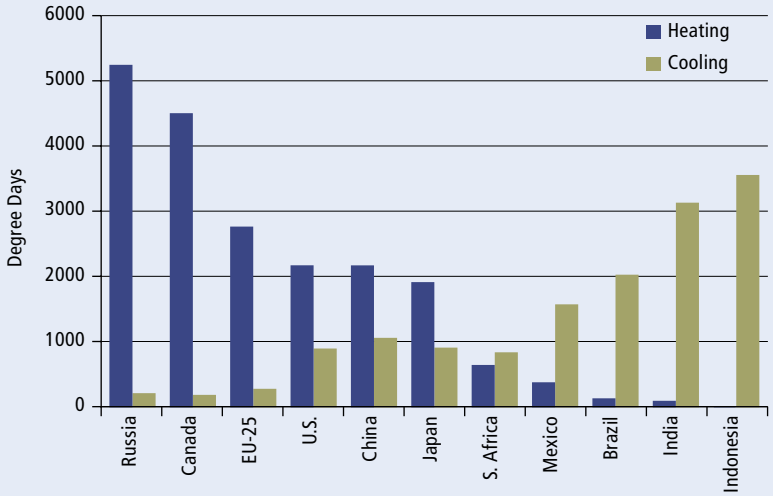
Sources & Notes: See Appendix 2.A for sources and sector definition. Absolute energy-related emissions, estimated here for 2000, are 25,611 $MtCO_2$.

Figure 8.2. Energy Consumption, Total and Per Capita, 2002
Top 25 GHG emitters



Source: WRI, CAIT.

Figure 8.3. Heating and Cooling Degree Days



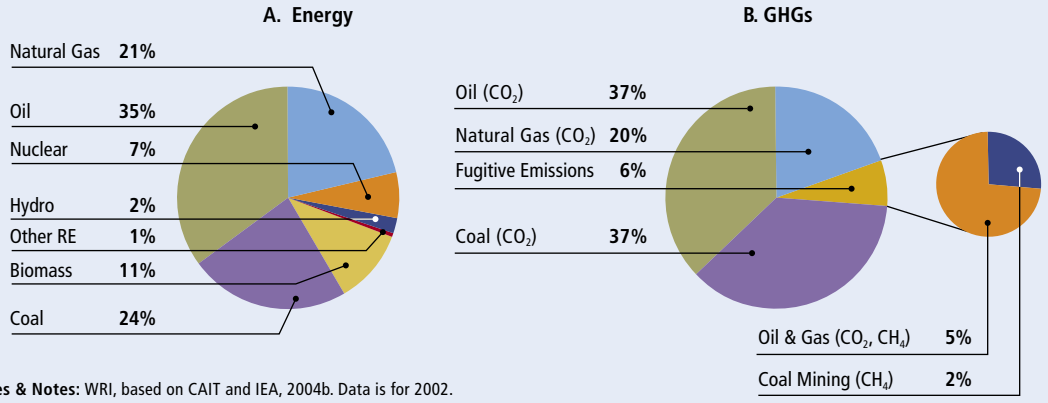
Sources & Notes: WRI, CAIT. The "degree-day" is a measure commonly used to evaluate demand for heating and cooling services. The measure is based on departures from an average temperature of 18°C (65°F), a base temperature considered to have neither heating nor cooling requirements. For underlying methodologies, see WRI (2003).

As with emissions, per capita energy disparities are large. The largest per capita energy consumers are Canada, the U.S., and Australia, while India, Brazil, and China use energy at only a fraction of the rate of the industrialized countries. There are also disparities among industrialized countries; for example, per capita consumption in Japan and the EU is about half the U.S. level.

Many of the cross-country differences can be explained by the same factors discussed in Chapters 2 and 5, namely economic structure and energy efficiency. More significantly, levels of economic development shape energy use. As discussed in Chapter 7, many developing countries lack access to electric power and modern transportation. Developing countries also have lower penetration rates for many energy-consuming appliances, such as refrigerators, televisions, computers, and air conditioners. Still other cross-country differences are explained by "natural factors" such as climatic conditions, land area, population densities, and natural resource endowments.[56] These factors influence energy use through differential heating and cooling needs, transportation requirements, and energy technology choices. The concept of heating and cooling "degree days," for instance, shows that heating and cooling demands are significantly higher in some countries (Figure 8.3).[57]

Across fuels, oil constitutes the most commonly used energy fuel, at 35 percent of global primary energy use, followed by coal (24 percent), natural gas (21 percent), and other non-fossil sources that do not emit GHGs directly.[58] These figures, along with the shares of GHG emissions from different fuels, are shown in Figure 8.4. Differences between energy use and GHG shares are explained by differences in efficiencies and the carbon content of the fuels. Coal, the highest carbon fuel, has a carbon content that is 34 percent higher than oil and 75 percent higher than gas (Figure 8.5). The remainder of this chapter examines the fuels that contribute to climate change in more detail. Figures 8.5 to 8.9 provide basic information about coal, oil, and gas, including carbon content, reserves, consumption levels, projected growth, and trade.

Figure 8.4. World Primary Energy Consumption and GHG Emissions *(by fuel)*



Sources & Notes: WRI, based on CAIT and IEA, 2004b. Data is for 2002.

Coal

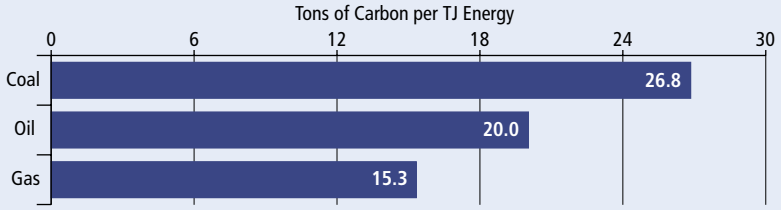
The top 25 GHG emitting countries collectively account for 93 to 94 percent of global coal consumption, production, and known reserves (Table 8). Coal mining and use is highly concentrated. Five countries account for more than three-quarters of worldwide consumption (Figure 8.10). Six countries—the United States, Russia, China, India, Australia, and South Africa—contain 81 percent of global coal reserves and account for an equal share of coal production. Globally, coal reserves are significantly larger than other fuels. At current prices and consumption rates, present reserves will not be depleted until the year 2168.[59]

Future growth in coal consumption is expected to be significant, though not as fast as growth in oil and gas (Figure 8.8). IEA projects that coal consumption will more than double by 2030, with China and India alone accounting for 68 percent of this increase.[60]

Unlike oil and to some extent natural gas, most coal is consumed domestically. Exceptions include Japan, Europe, South Korea, and Taiwan, which are significant importers. Conversely, Australia, South Africa, and Indonesia are leading exporters.[61] Despite being bulky and expensive to transport, higher grade coal (such as coking coal for steel making) is relatively amenable to transport.[62] Overall, only 17 percent of total world coal production is traded across national borders (Figure 8.9). Increased seaborne trade in coal is expected in the coming decades.[63]

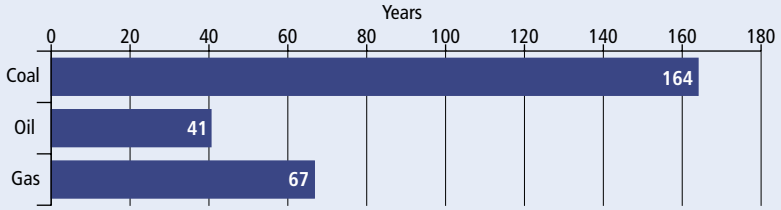
Electricity and heat account for 70 percent of coal consumption; industry accounts for the second largest share (16 percent) (Figure 8.11-A).

Figure 8.5. Carbon Content of Fossil Fuels



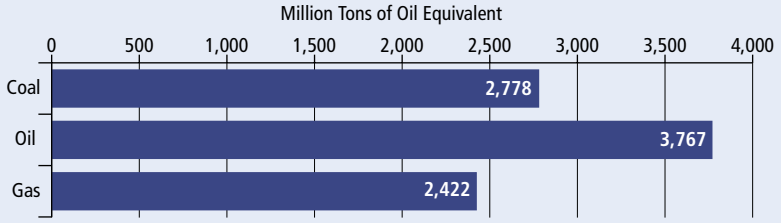
Sources & Notes: IPCC, 1997. The carbon emissions factor for coal is based on anthracite coal. There are slightly different carbon contents for other grades of coal, such as coking (25.8), bituminous (25.8), and lignite (27.6).

Figure 8.6. Reserves to Production (R/P) Ratios, 2004



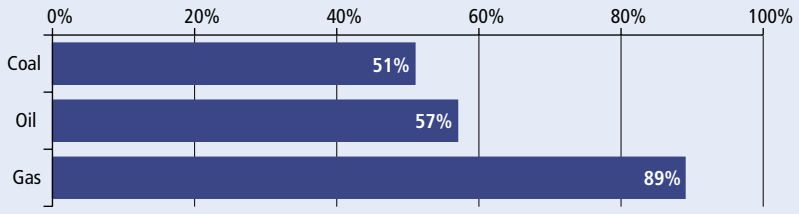
Sources & Notes: BP, 2005. An R/P ratio is the reserves remaining at the end of the year divided by the production in that year. The result is the length of time that those remaining reserves would last if production were to continue at that level.

Figure 8.7. Global Fossil Fuel Consumption, 2004



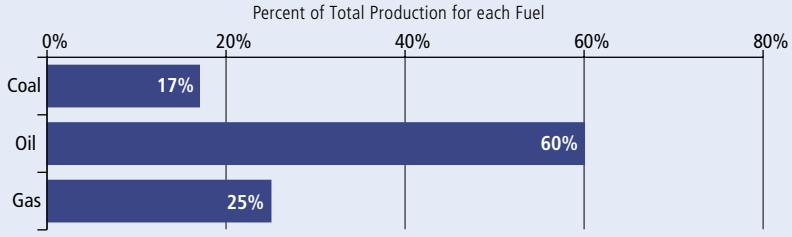
Source: BP, 2005.

Figure 8.8. Projected Growth in Energy Demand, 2002–2030



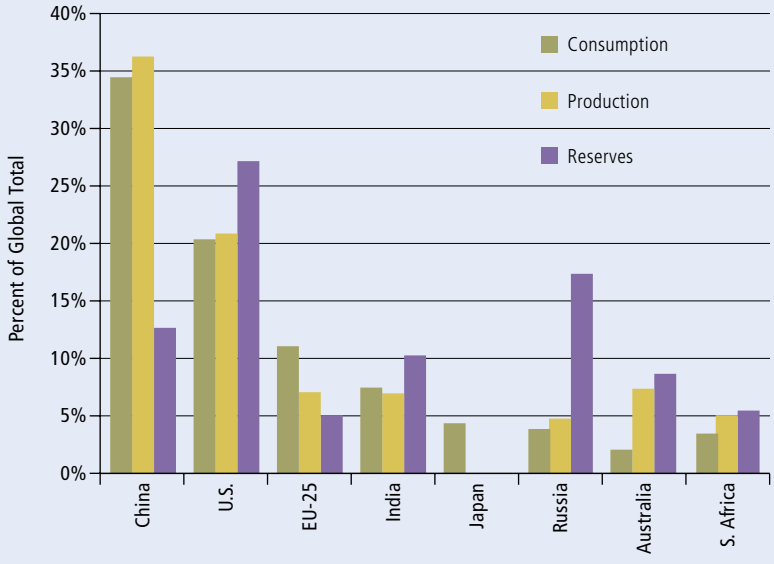
Source: IEA, 2004c.

Figure 8.9. Shares of Fossil Fuel Traded



Sources & Notes: WRI, based on BP, 2005 (oil and gas); IEA, 2004b (coal). Shares are total production for a fuel divided by the amount of that fuel traded internationally. Figures are based on data from 2004 (oil and gas) and 2002 (coal).

Figure 8.10. Coal Consumption, Production, and Reserves, 2004



Sources & Notes: BP, 2005. Countries shown are the top five consumers, plus selected others with large reserves. Countries are ordered according to consumption. See also Table 8. Total global coal consumption, production, and reserves in 2004 are 2,778, 2,732, and 448,464 million tons of oil equivalent, respectively.

Oil

Together, the top GHG emitting countries account for 84 percent of oil consumption, 58 percent of production, and 48 percent of known oil reserves (Table 9). Oil reserves are highly concentrated; OPEC countries account for 74 percent of global reserves.[64] Almost an equal amount of known reserves (72 percent) are concentrated in just seven countries—Saudi Arabia, Iran, Iraq, United Arab Emirates, Kuwait, Venezuela, and Russia. Of these, only Russia is among the top 15 GHG emitting countries (Figure 8.12). Although global reserves of oil are widely disputed, the most recent estimates from BP suggest that, at current prices and consumption rates, just over 40 years of reserves remain.[65] Improved extraction technologies and new discoveries may extend reserve estimates. On the other hand, if expected increases in consumption—57 percent by 2030—are realized, demand may put continued upward pressure on oil prices (Figure 8.8).

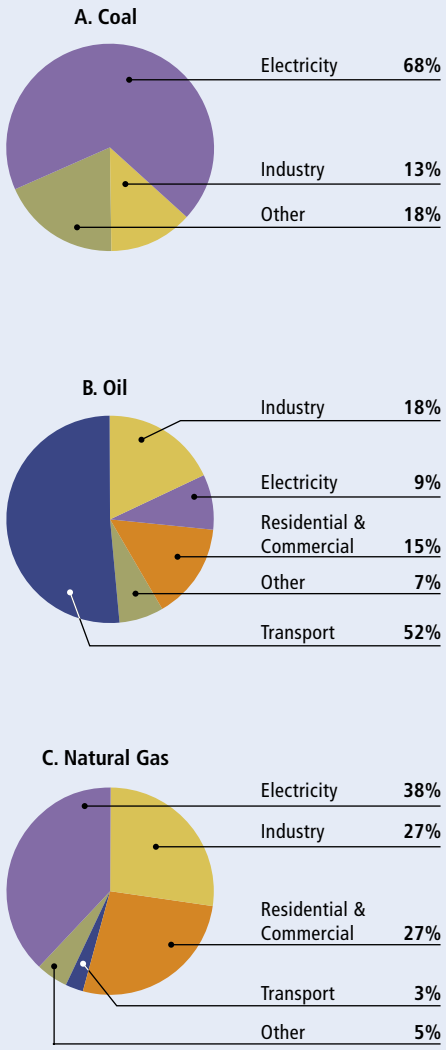
Oil consumption is less geographically concentrated than other fuels. This is primarily due to two factors: (1) oil's dominance in the transport sector, and (2) its tradability. First, in the transport sector, oil maintains nearly complete dominance, accounting for 96 percent of global energy consumption in the sector.[66] Overall, transport represents about 52 percent of the total world oil consumption (Figure 8.11-B). Industry accounts for an additional 18 percent, and residential and commercial activities (such as heating) collectively account for about 15 percent. In developing countries, however, oil is used in greater proportions for electricity generation and industry, with transport accounting for only 40 percent of the total.[67]

Second, oil is the most heavily traded fossil fuel, with about 60 percent[68] of global production being moved across borders through a well-developed global transit network of tanker fleets (Figure 8.9). The hub of world trade is the Middle East, accounting for 46 percent of world crude exports in 2004.[69] Total volume of world trade in oil is expected to double by 2030, with exports increasing most from the Middle East.[70]

Natural Gas

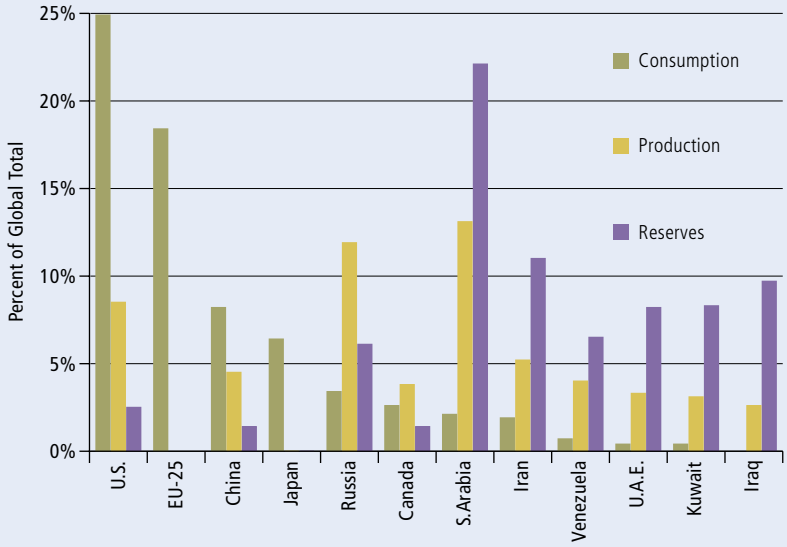
With respect to natural gas, the top 25 GHG emitters account for 84 percent of global consumption, 76 percent of production, and 59 percent of gas reserves (Table 10). As with oil, natural gas reserves are highly concentrated; 69 percent of known gas reserves are in just seven countries—Russia, Iran, Qatar, Saudi Arabia, the United Arab Emirates, the United States, and

Figure 8.11. Fossil Fuel Consumption by Sector and Fuel, 2002



Sources & Notes: WRI, based on IEA, 2004b. Residential and commercial includes agriculture. Other includes energy transformation and energy industries (e.g., oil and gas extraction).

Figure 8.12. Oil Consumption, Production, and Reserves, 2004



Sources & Notes: BP, 2005. Countries shown are the top five consumers, plus selected others with large reserves. Countries are ordered according to consumption. See also Table 9. Total global oil consumption, production, and reserves in 2004 are 3,767, 3,868, and 161,900 million tons, respectively.

Nigeria. Russia, Iran, and Qatar alone account for 56 percent (Figure 8.13). More than half of all production and consumption takes place in the U.S., Russia, and EU-25, with the remainder widely dispersed geographically. If gas production continued at the current pace, about 67 years of known reserves are extractable at current prices and technologies. However, among the fossil fuels, growth in natural gas use is expected to increase the fastest, with the IEA projecting 89 percent growth by 2030 (Figure 8.8).

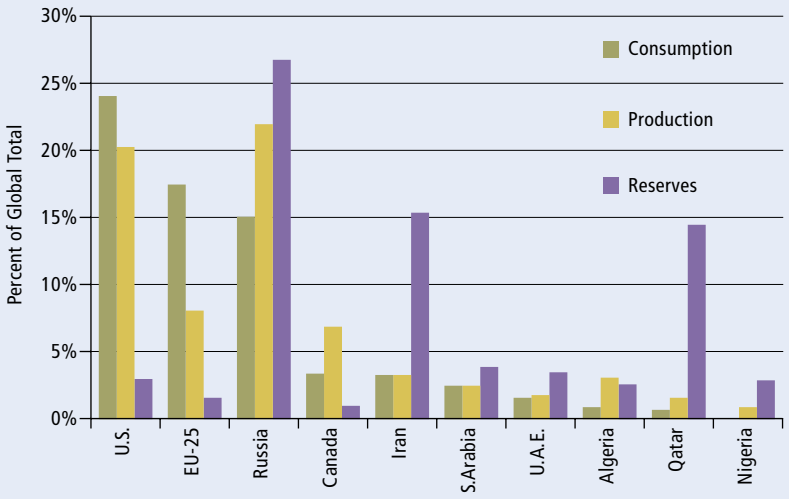
Unlike oil, most gas is consumed domestically, although exports and imports are significant and growing. In 2004, 25 percent of global gas production was traded across borders (Figure 8.9).[71] Trade in gas is primarily regional—mainly in North America and Europe—with about three-fourths of the total trade moving via pipeline.[72] The remainder of trade is via tanker transport of liquefied natural gas (LNG), predominantly in the Asia-Pacific and Middle East regions, where LNG infrastructure is more developed.[73] Global trade in gas is expected to triple by 2030, with most of the increase coming from growing LNG trade.[74]

Electricity and heat production account for about 38 percent of natural gas consumption, while the industrial and other sectors (primarily residential and commercial) account for about 27 and 35 percent respectively (Figure 8.11-C).

Implications for International Climate Cooperation

To date, international cooperation on climate change has not been focused directly on energy or specific energy fuels. In the future, international cooperation may likewise be fuel-neutral, although initiatives might be oriented around particular fuel-specific activities that are especially emissions-intensive, or

Figure 8.13. Natural Gas Consumption, Production, and Reserves, 2004



Sources & Notes: BP, 2005. Countries shown are the top five consumers (excluding individual EU members), plus selected others with large reserves. Countries are ordered according to consumption. See also Table 10. Total global gas consumption, production, and reserves in 2004 are 2,420, 2,422, and 161,574 million tons of oil equivalent, respectively.

that offer unique abatement opportunities. These could include initiatives to address coal-bed methane, sequester CO_2 in association with enhanced oil recovery, and phase-out certain gas flaring practices.[75] In addition, the interplay between the different fuels is likely to have significant implications for cooperative efforts.

Coal is used primarily for power generation, and there are immense reserves remaining in the largest emitting countries, including the U.S., China, Russia, and India. If emissions from coal use continue unabated from power generation, then the objective of the UNFCCC is unlikely to be met. International cooperation on climate change may need to pursue one or both of the following options: switch away from coal toward lower-carbon natural gas or renewables, or capture and sequester CO_2 emitted from coal plants. Both will require significant technology transfer and high capital investment costs. Some advanced coal technologies, it should be noted, are not conducive to climate protection. Emerging coal-to-liquids technologies, in particular, would enable coal to be consumed as a transport fuel (after liquification), which would increase the carbon intensity of transport.

Concerning oil, present consumption patterns, largely driven by transport, are weakly correlated with reserves, and those global reserves are heavily concentrated in the politically volatile Middle East. These two factors suggest a possible constellation of interests on the part of oil-importing countries to reduce dependence on oil. In other words, concerns about security of supply and rising future costs—along with associated issues related to external debt and balance of payments—are compelling reasons to pursue measures promoting energy efficiency and alternative fuels (for example, biofuels). For instance, the Biofuels Initiative launched by UNCTAD aims to assist developing countries in boosting their renewable energy potential through fuels—such as bioethanol, biodiesel and biogas—derived from agricultural crops. Such initiatives, especially if bolstered by significant financial and technical resources, could yield large energy security and poverty-reduction benefits while limiting GHG emissions.

Natural gas, the least carbon-intensive fossil fuel, is conducive to a wide variety of uses, ranging from power generation to industry to residential use. To the extent that natural gas consumption rises in step with the other fuels, gas is unlikely to be an important part of climate protection strategies. On the other hand, if gas can be used more strategically to substitute for coal use, it can provide identical energy services with 40 percent fewer CO_2 emissions, making it a key potential variable in climate protection. Natural gas has other advantages over coal as well. It can be used more efficiently than coal in many end-use applications, such as power generation (increasing the CO_2 savings), and can substitute for oil in transport, either compressed or through conversion to liquids. Furthermore, it may offer a promising pathway to hydrogen technologies. The potential for gas to play a role in climate change mitigation suggests global gas strategies may warrant further attention.