3 ENVIRONMENT

Energy and a changing climate

The world economy needs ever-increasing amounts of energy to sustain economic growth, raise living standards, and reduce poverty. But today's trends in energy use are not sustainable. As the world's population grows and economies become more industrialized, nonrenewable energy sources will become scarcer and more costly. And carbon dioxide emissions from the use of fossil fuels will continue to build in the atmosphere, accelerating global warming. Energy-related carbon dioxide now accounts for 61–65 percent of global greenhouse gas emissions (IEA 2008a; IPCC 2007a; WRI 2005). Global warming will have particularly pernicious effects for developing economies, with their high exposure and low adaptive capacity. Where energy comes from, how we produce it, and how much we use will profoundly affect development in the 21st century.

This introduction focuses on recent trends in energy use and carbon dioxide emissions—and projections through 2030. There is now a consensus that action is needed to curb the growth in human-made greenhouse-gas emissions (IPCC 2007b; IEA 2008a). A new post-2012 policy regime on global climate change—to be agreed in Copenhagen in late 2009—aims to set a quantified global goal for stabilizing greenhouse gases in the atmosphere and to establish robust policy mechanisms that ensure the goal is achieved.

Without government initiatives on energy or climate change, global temperatures may rise as much as 6°C by the end of the century. This outcome of the Intergovernmental Panel on Climate Change Trend Scenario can be compared with a 3°C rise under a Policy Scenario in which greenhouse gasses are stabilized at 550 parts per million (ppm) of carbon dioxide equivalent and a 2°C rise under a Policy Scenario in which concentrations are stabilized at 450 ppm. The consequences of the Trend Scenario go well beyond what the international community regards as acceptable.

The global financial and economic crisis, while reducing the demand for energy in the short run, may also slow efforts at energy saving by lowering the price of oil and other fossil energy sources. And by discouraging investments in fossil fuel substitutes and more energy-efficient production processes, the crisis may leave the world on a higher carbon dioxide emission path. The world's largest economy and biggest contributor to carbon dioxide emissions has new leadership that could make climate change a top priority and commit resources to finding alternative sources of cleaner energy.

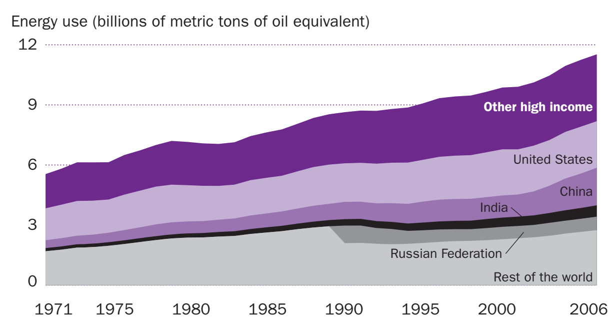
Energy use: unsustainable trend, unacceptable future

In 2006 global energy use from all sources reached 11.5 billion metric tons of oil equivalent—twice as high as its 1971 level (figure 3a). High-income economies, with just 15 percent of world population, use almost half of global energy (figure 3b). Energy use grew by 2.4 percent a year in low-income economies, 2.0 percent in middle-income economies, and 1.6 percent in high-income economies over 1990–2006. It rose 4.4 percent a year in China and 3.5 percent in India. The United States, Russian Federation, Germany, Japan, China, and India are the top energy consumers, accounting for 55 percent of global energy use (figure 3c and table 3.7). On average, high-income economies use more than 11 times the energy per capita of low-income economies, with huge differences across countries and within countries and regions (figure 3d).

The accelerating trend in energy use and the potential consequences have been matters of concern for the international community. The recent global financial crisis, economic downturn, and significant fluctuations in the price of energy, particularly oil, make projections of energy demand difficult. The International Energy Agency forecasts that energy demand in 2030 will be 45 percent higher than energy use in 2006, for an average annual growth of 1.6 percent, or just a little slower than the 1.9 percent from 1980 to 2006 (IEA 2008a, b). More than 80 percent of the energy used in 2006 was from nonrenewable fuels—carbon dioxide–emitting oil, coal, and gas. In the absence of new policies this share is projected to remain above 80 percent in 2030, with demand for coal—cheaper and more abundant—growing faster than that for oil and gas (figure 3e and table 3f).

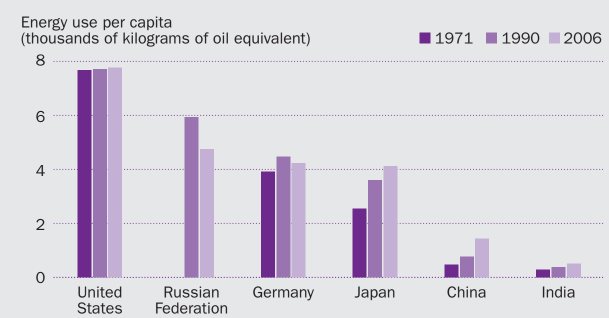
Growing 2 percent a year on average, world demand for coal is projected to be 60 percent higher in 2030 than in 2006. Most of the increase in demand comes from the power generation sector. China and India together account for 85 percent of this increase. Oil demand grows far more slowly than demand for other fossil fuels, mainly because of high final prices. Yet, oil remains the dominant fuel in the primary mix, even with the drop in its share from 34 percent in 2006 to 30 percent in 2030.

Energy use has doubled since 1971 **3a**



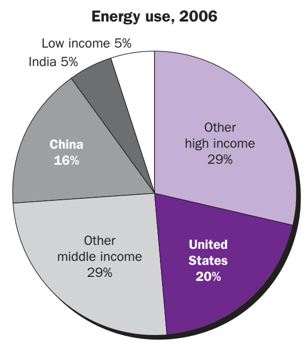
Source: World Development Indicators data files.

The top six energy consumers use 55 percent of global energy **3c**



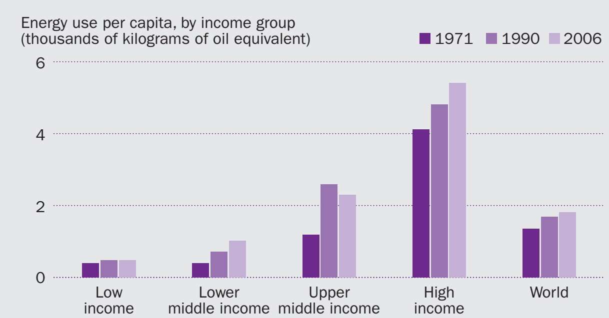
Source: Table 3.7.

High-income economies use almost half of all global energy **3b**



Source: Table 3.7.

High-income economies use more than 11 times the energy that low-income economies do **3d**



Source: Table 3.7.

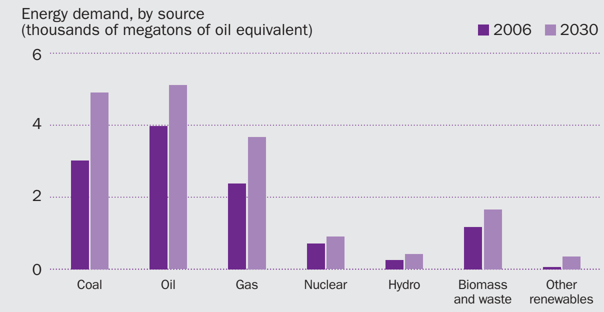
Uncertain supply

It is not going to be easy to meet the expected growth in energy demand, particularly for oil, despite seemingly large available reserves (table 3g). Based on a field by field analysis of production trends, the cost of investment, opportunities for expanding capacity, and possible constraints and risks—both above and below ground—the International Energy Agency has drawn attention to the possibility of an oil-supply crunch by the middle of the 2010s, if upstream investments fall short of requirements. A growing number of oil companies and analysts have suggested that oil production may peak within the next two decades, a result of rising costs, political and geological factors, and limits on the investment that can be mobilized (IEA 2008a). The rate of decline in production from existing fields—especially large, mature fields that have been the mainstay of global output for several decades—has been faster than anticipated (figure 3h). How output from these fields evolves—with or without the deployment of enhanced recovery techniques—will have major implications for the required investment in new fields, which are typically smaller, more complex, and more costly to develop.

Despite the improved environment for emerging, climate-friendly, renewable energy sources and technologies, many barriers remain. The costs of some technologies are high at their early stages, when economies of scale cannot be realized. Research and development were limited until the recent oil price rise. Concerns are growing about the impact on food supplies with more use of crops for energy. And there is skepticism about the net contribution of biofuels to lower greenhouse gas emissions (FAO 2008).

In many countries climate change has risen to the top of the political agenda—the result of a growing body of evidence on global warming and ever more startling predictions of the ecological consequences (IPCC 2007b). The commitment of the new U.S. administration to containing the impact of global climate change and the changing attitudes toward wind and solar energy offer promise of reducing the carbon footprint of energy use.

Nonrenewable fuels are projected to account for 80 percent of energy use in 2030—about the same as in 2006 **3e**



Source: Table 3.7.

Fossil fuels will remain the main sources of energy through 2030 **3f**

Fuel	1980	2006	2030	Annual growth, 2006–30 (%)
Total (million metric tons oil equivalent)	7,224	11,730	17,014	1.6
Share (% of total)				
Coal	24.8	26.0	28.8	2.0
Oil	43.0	34.3	30.0	1.0
Gas	17.1	20.5	21.6	1.8
Nuclear	2.6	6.2	5.3	0.9
Hydropower	2.0	2.2	2.4	1.9
Biomass and waste	10.4	10.1	9.8	1.4
Other renewables	0.2	0.6	2.1	7.2

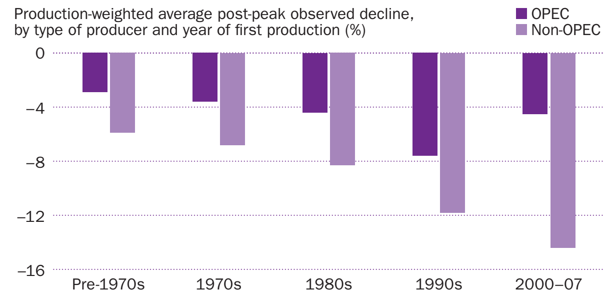
Source: IEA 2008a.

Known global oil reserves and countries with highest endowments in 2006 **3g**

Country	Oil reserves (billions of barrels)	Share of world total (%)
Saudi Arabia	264.3	20.4
Canada	178.9	13.8
Iran	132.5	10.3
Iraq	115.0	8.9
Kuwait	101.5	7.9
United Arab Emirates	97.8	7.6
Venezuela, RB	79.7	6.2
Russian Federation	60.0	4.6
Rest of the world	262.8	20.3
Total	1,292.5	

Source: Deutch, Lauvergeon, and Prawiraatmadja 2007.

Production declines from existing oil fields have been rapid **3h**



Source: IEA 2008a.

Energy and climate change

Economic activity, energy use, and carbon dioxide emissions move together (figure 3i). The world is already experiencing the impact of rising average global temperature on physical and biological systems, and the situation is worsening. The 13 warmest years since 1880 have occurred in the last 16 years (IPCC 2007a; Rosenzweig and others 2008). There is a risk of reaching unpredictable tipping points, such as a rise in Arctic temperatures precipitating a massive release of methane from permafrost zones. Thawing permafrost could also threaten oil and gas extraction infrastructure and pipeline stability.

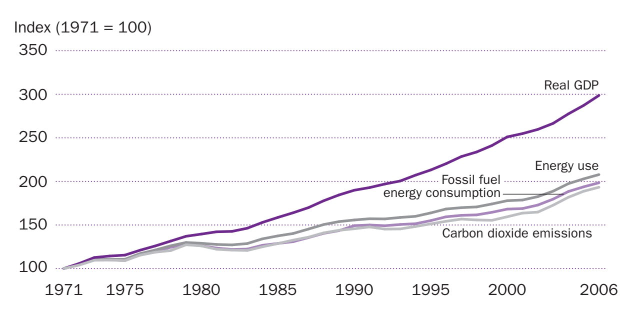
Current carbon dioxide levels

In the 1980s global energy-related carbon dioxide emissions (up 1.7 percent annually) rose more slowly than primary energy demand (up 1.9 percent annually), mainly because the shares of natural gas, nuclear power, and renewables in the power mix expanded. But this decarbonization of energy reversed at the beginning of the 21st century as the share of nuclear energy fell while that of coal rose. In the Trend Scenario recarbonization of the energy sector is projected to continue until after 2020, when changing supply patterns again cause emissions growth to fall below the rate of growth of primary energy use (figure 3j). But as the world becomes wealthier, energy-related carbon dioxide emissions continue to rise in absolute terms.

World carbon dioxide emissions per capita fell until around 2000, but have since risen rapidly. In the absence of new policies, this upward trend is projected to continue through 2030. Government policies, including those to address climate change, air pollution, and energy security, have slowed the growth in emissions in some countries. But in most, emissions are still rising fast. In 2005 per capita emissions were greatest in the United States, followed by the Russian Federation, Japan, and Germany (table 3.8 and figure 3k). China's per capita emissions were 4.3 tons—close to the global average and about one-third of the level of high-income economies (figure 3l)—while India's were 1.3 tons.

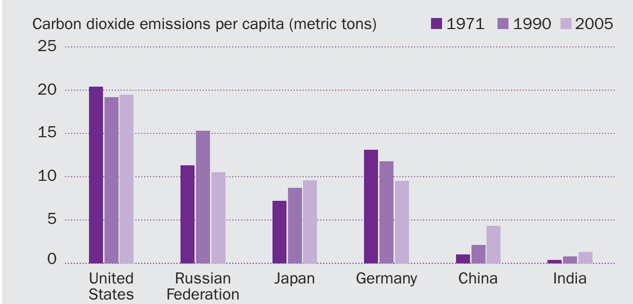
Carbon dioxide emissions are attributed to the country or region consuming the fossil fuel. Yet the consumption benefits from the goods and services produced using the fossil fuel are often realized in a country other than that in which the emissions arise. This concerns some emerging market economies, which tend to be more export-oriented,

Economic activity, energy use, and greenhouse gas emissions move together **3i**



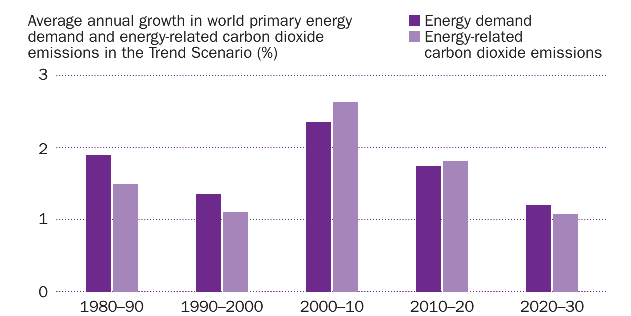
Source: World Development Indicators data files.

The top six carbon dioxide emitters in 2005 **3k**



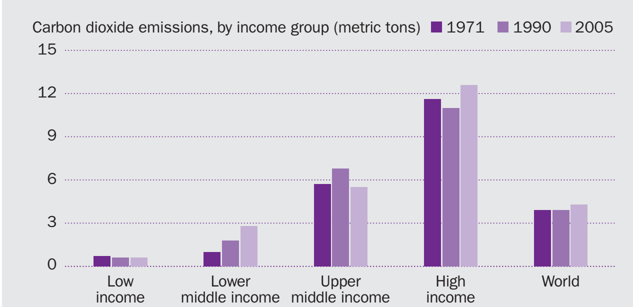
Source: Table 3.8.

Decarbonization of energy reversed at the beginning of the 21st century **3j**



Source: IEA 2008a.

High-income economies are by far the greatest emitters of carbon dioxide **3l**



Source: Table 3.8.

with energy-intensive manufactured exports. A detailed input-output analysis in China tracked the distribution of fuels, raw materials, and intermediate goods to and from industries throughout the economy. Taking carbon intensities and trade data into account, it estimated the energy-related carbon dioxide emissions embedded in domestic production for export at 34 percent of its 2004 emissions (IEA 2007). With China's production facilities expanding rapidly, the figures for later years could be higher (box 3m).

Trend and Policy Scenarios

Annual greenhouse gas emissions are projected to grow from 44 gigatons of carbon dioxide equivalent in 2005 to 60 gigatons in 2030, a 35 percent increase. The share of energy-related carbon dioxide emissions in total emissions is forecast to increase from 61 percent in 2005 to 68 percent in 2030 (IEA 2008a). With emissions of greenhouse gases building in the atmosphere faster than natural processes can remove them, concentrations rise. The Trend Scenario puts us on a path to doubling aggregate concentrations by the end of the century, increasing global average temperatures up to 6°C (IPCC 2007a; IEA 2008a).

In the Trend Scenario rising global use of fossil energy continues to drive up energy-related carbon dioxide emissions over at least the next two decades. Emissions grew by 2.5 gigatons from 1990 to 2000, when their growth accelerated, and increased a further 4.5 gigatons to 28 gigatons by 2006. They are projected to increase a further 45 percent by 2030, approaching 41 gigatons in the Trend Scenario. This acceleration in carbon dioxide emissions calls for urgent stabilization measures.

There is not yet an international consensus on long-term stabilization targets. Most discussions center on stabilization levels between 450 ppm and 550 ppm of carbon dioxide equivalent and their consequences (table 3n and figure 3o; IPCC 2007). The required reduction in energy-related emissions varies with level of international participation by economies sorted by income groups. In both the 450 ppm and 550 ppm Policy Scenarios, even after allowing for international emissions trading and active engagement by non–Organisation for Economic Co-operation and Development (OECD) countries, International Energy Agency projections show that OECD countries would have to substantially reduce emissions domestically (IEA 2008a).

Carbon dioxide emissions embedded in international trade **3m**

Energy and energy-related carbon dioxide emissions are embedded in imports as well as exports, and some goods and services are more emissions-intensive than others. There are ways of calculating the emissions embedded in international trade, none of them fully accurate because of the lack of complete, reliable, and up-to-date data. A detailed input-output analysis for China reveals the complexity, involving calculating carbon intensity all along the production chain and across the economy, including outsourcing (IEA 2007; Houser and others 2008).

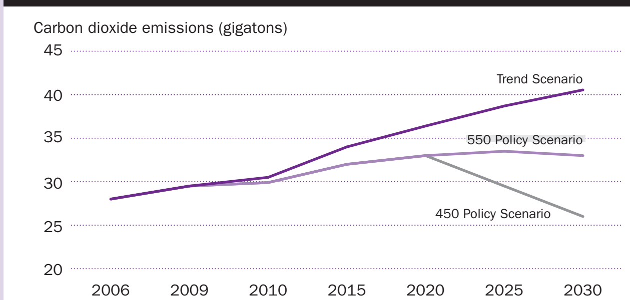
At the global level the percentage of exports in GDP can be used as a simple proxy for the share of energy-related carbon dioxide emissions embedded in domestic production for export. The countries for which up-to-date trade data are available represent 83 percent of total world energy-related carbon dioxide emissions (IEA 2008a). The International Energy Agency estimate of the share of emissions embedded in exports in 2006 ranges from 15 percent for North America to 48 percent for the Middle East. The difference reflects variations in the amount and type of exports and the carbon intensity of energy use. The shares for China (44 percent) and Asian countries other than China and India (41 percent) are next highest. Of the 23 gigatons of energy-related carbon dioxide emissions in the International Energy Agency sample, one-third were embedded in production for export. China alone accounted for 2.3 gigatons (31 percent) of this, and Europe and the Russian Federation combined for another 1.7 gigatons (23 percent). Africa and Latin America each accounted for just 2 percent of embedded emissions (IEA 2008a).

Impact of Policy Scenarios: carbon dioxide concentration, temperature increase, emissions, and energy demand **3n**

Carbon dioxide concentration (parts per million)	Temperature increase	Global emissions by 2030 (gigatons): Energy-related carbon dioxide	Global emissions by 2030 (gigatons): Total greenhouse gases	Global energy demand (metric tons oil equivalent): 2020	Global energy demand (metric tons oil equivalent): 2030
550	3°C	33	48	14,360	15,480
450	2°C	26[a]	36	14,280	14,360

a. Emissions peak in 2020 at 32.5 gigatons and then decline to 25.7 gigatons in 2030.
Source: IPCC 2007b; IEA 2008a.

Reductions in energy-related carbon dioxide emissions by region in the 550 and 450 parts per million Policy Scenarios relative to the Trend Scenario **3o**



Source: IEA 2008a.

Need for cleaner, more efficient energy

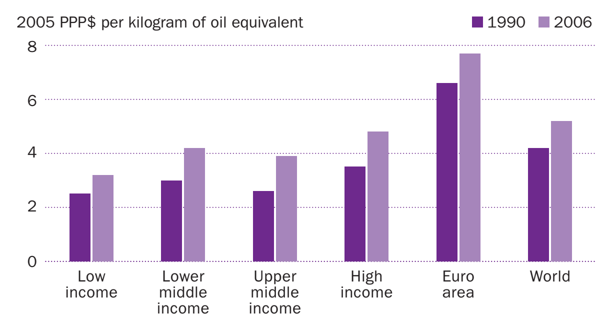
Adequate energy supplies are required for economies to grow and poverty to be reduced, but the current reliance on fossil fuels is not sustainable. Transitioning to new energy sources poses a significant challenge to all economies. Humanity's future on this planet may depend on finding ways to supply the world's growing energy needs without irreparably harming the environment. This could be achieved through new energy technologies, greater energy efficiency, and alternative renewable sources that provide a low-carbon path to growth.

For the low-carbon growth needed to stabilize carbon dioxide emissions, technological innovations are crucial. Because much of today's energy-using capital stock will be replaced only gradually, it will take time before most of the impact of recent and future technological developments that improve energy efficiency are felt. Rates of capital-stock turnover differ greatly by industry and sector. Most of today's cars, trucks, heating and cooling systems, and industrial boilers will be replaced by 2030. But most buildings, roads, railways, and airports and many power stations and refineries will still be in use unless governments encourage or force early retirement. Despite the slow turnover, refurbishment in some cases could significantly improve energy efficiency at an acceptable net economic cost.

On the supply side technological advances can improve the technical and economic efficiency of producing and supplying energy. In some cases they are expected to reduce unit costs and to lead to new and cleaner ways of producing and delivering energy services. Some major new supply-side technologies that are approaching commercialization are expected to become available to some degree before 2030 (IEA 2008a).

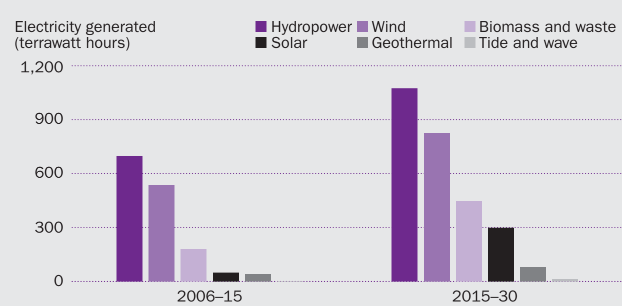
- *Carbon capture and storage.* This technology mitigates emissions of carbon dioxide from power plants and other industrial facilities, but it has not yet been deployed on a significant scale (IEA 2008a). The basic technology already exists to capture carbon dioxide gas and transport and store it permanently in geological formations. Four large-scale carbon capture and storage projects are operating around the world, each separating around 1 megaton of carbon dioxide per year from produced natural gas: Sleipner and Snohvit in Norway, Weyburn in Canada (with the carbon dioxide sourced in the United States), and In Salah in Algeria. Yet there are technical, economic, and legal barriers to more widespread deployment, particularly high energy intensity and the cost.
- *Second-generation biofuels.* New biofuel technologies —notably hydrolysis and gasification of woody lignocellulosic feedstock to produce ethanol—are expected to reach commercialization by around 2020. Although the technology already exists, experts believe that more research is needed to improve process efficiencies. There is virtually no commercial production of ethanol yet from cellulosic biomass, but several OECD countries are researching it. A recent Food and Agriculture Organization report is skeptical about the net contribution of biofuels to reduction of greenhouse gasses and blames biofuels production for last year's large food price increases (FAO 2008).
- *Coal-to-liquids.* The conversion of coal to oil products through gasification and synthesis—much like gas to liquid production—has been done commercially for many decades. Yet global production remains limited because it has been uneconomical, mainly because of the large amounts of energy and water used in the process, the high cost of building plants, and the volatility of oil and coal prices.

Energy efficiency has been improving **3p**



Source: Table 3.8.

Electricity generated from renewables is projected to more than double by 2030 **3q**



Source: IEA 2008a.

Energy efficiency

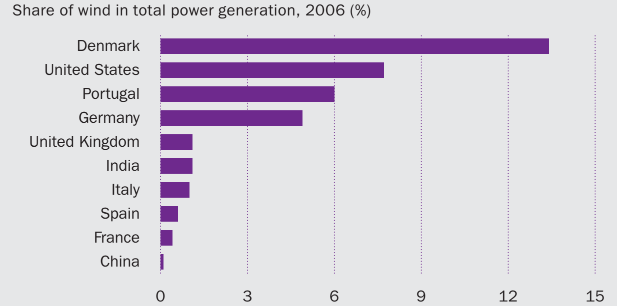
In recent years there has been an encouraging trend in producing more from each unit of energy (figure 3p), a powerful and cost-effective way to get on the path to a sustainable energy future. Greater energy efficiency can reduce the need for investing in energy infrastructure, cut fuel costs, increase competitiveness, and improve consumer welfare. And by reducing greenhouse gas emissions and air pollution, it can be good for the environment. The International Energy Agency estimates that implementing a host of 25 policy recommendations for promoting energy efficiency could reduce annual carbon dioxide emissions 8.2 gigatons by 2030—equivalent to one-fifth of global energy-related carbon dioxide emissions in the Trend Scenario (IEA 2008b). The recommendations cover policies and technologies for buildings, appliances, transport, and industry as well as end-use applications such as lighting.

Renewable energy

The share of renewables in global primary energy demand, excluding traditional biomass, is projected to climb from 7 percent in 2006 to 10 percent by 2030 in the Trend Scenario (IEA 2008a). This assumes that costs come down as renewable technologies mature, that higher fossil fuel prices make renewables more competitive, and that policy support is strong. The renewables industry could eliminate its reliance on subsidies and bring emerging technologies into the mainstream.

- World renewables-based electricity generation—mostly hydro and wind power—is projected to more than double by 2030 (figure 3q).
- Many countries have already begun exploiting wind to generate electricity (figure 3r). Global wind power is projected to increase 11-fold, becoming the second largest source renewable after hydropower by 2030.

Top 10 users of wind to generate electricity **3r**



Source: IEA 2008a.

- Biomass, geothermal, and solar thermal met around 6 percent of global heating demand in 2006, a share projected to rise to 7 percent by 2030. Where resources are abundant and conventional energy sources expensive, renewables-based heating can be cost competitive with conventional heating systems.
- The share of biofuels in road transport fuels worldwide is projected to rise from 1.5 percent in 2006 to 5 percent in 2030, spurred by subsidies and high oil prices. Most of the growth comes from the United States, European Union, China, and Brazil.

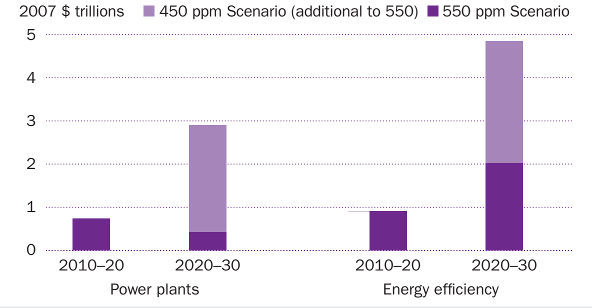
The cost of power generation from renewables is expected to fall. Greater deployment spurs technological progress and increases economies of scale, lowering investment costs. The costs of the more mature technologies, including geothermal and onshore wind, are assumed to fall least. Renewables account for just under half of the total projected investment in electricity generation. The cost of stabilizing carbon dioxide is significant, but there are also significant savings (box 3s). And the cost of inaction would be far higher.

Cost and savings under the Policy Scenarios **3s**

The 550 parts per million (ppm) Policy Scenario requires spending $4.1 trillion more on energy efficiency and power plants and reducing consumption of fossil fuels by 22 gigatons of oil equivalent over 2010–30 through more efficient energy use. The International Energy Agency estimates that the net undiscounted savings in the 550 ppm Policy Scenario, compared with the Trend Scenario, amount to more than $4 trillion.

The 450 ppm Policy Scenario requires additional investment of $3.6 trillion in power plants and $5.7 trillion in energy efficiency over 2010–30 relative to the Trend Scenario. This additional investment is much higher in 2021–30 than in 2010–20 (see figure). In the 450 ppm Policy Scenario substantially higher investment is needed in power plants. Also, investment in energy efficiency rises considerably, particularly beyond 2020. During that period improving energy efficiency in buildings will require the highest investment. In the 450 ppm Policy Scenario the additional investment in power plants and demand-side efficiency corresponds to 0.55 percent of cumulative world GDP over 2010–30, compared with 0.24 percent in the 550 ppm Policy Scenario.

Change in power plant and energy efficiency investments in the Policy Scenarios relative to the Trend Scenario



Source: IEA 2008a.