

IMPLICATIONS OF CURRENT ENERGY POLICIES

Why is the Reference Scenario unsustainable?

H I G H L I G H T S

- The Reference Scenario projections have profound implications for each of the “three Es” of sound energy policy making: energy security, environmental protection and economic development.
- In the absence of new initiatives to tackle climate change, rising global fossil-fuel use continues to drive up energy-related CO₂ emissions, from 29 Gt in 2007 to 40 Gt in 2030 – an increase of 40%. Although the financial crisis has slowed the growth in emissions, current trends put us on a path to a global average temperature increase of up to 6 °C. The projected rise in energy demand also has implications for ambient air quality, with serious public health and environmental effects, particularly in developing countries.
- While the OECD will be importing less oil in 2030 than today, some non-OECD countries, notably China and India, will see big increases. Most gas-importing regions also see their net imports rise. China overtakes the United States, soon after 2025, to become the world’s biggest spender on oil and gas imports, while India’s spending surpasses that of Japan soon after 2020 to become the world’s third-largest importer.
- Cumulative OPEC revenues from oil and gas exports increase to \$30 trillion between 2008 and 2030, almost a five-fold increase on earnings over the past 23 years. Even in the event of a global commitment to curb greenhouse-gas emissions, as assumed in the 450 Scenario, OPEC countries would be called upon to produce 11.4 mb/d more oil in 2030 than they produce today. In both scenarios, the market power of OPEC increases.
- In some respects, energy supplies become more flexible, diverse and robust to interruptions in the years to come, for example as global LNG trade grows. Growing dependence on international trade, in some cases dependent on vulnerable transit routes, pulls in the other direction. Uncertainties about the adequacy of supply-side investment are an important component of long-term risk. The security of electricity supply is as much an issue for governments as the security of oil and gas supply.
- 1.3 billion people lack access to electricity in 2030, compared with 1.5 billion people today. Universal electricity access could be achieved with additional power-sector investment of \$35 billion per year in 2008-2030, or just 6% of the annual average investment in the power sector in the Reference Scenario. Furthermore, the resulting increase in primary energy demand and CO₂ emissions would be modest.

Introduction

The Reference Scenario provides a baseline vision of how global energy markets are likely to evolve if no new government policies are introduced during the projection period. This chapter draws out the implications of the results in this scenario for each of the “three Es” of balanced energy policy making: environmental protection, energy security and economic development.

The projected rate of growth in fossil-fuel consumption in the Reference Scenario would drive up energy-related carbon-dioxide (CO₂) emissions over the next two decades. Although the economic downturn, along with a range of government policies, including those intended to address climate change and enhance energy security, has slowed the rate of growth in emissions, in most countries, emissions are still rising fast. Moreover, the environmental consequences of the Reference Scenario go beyond climate change. Increasing reliance on fossil fuels would also intensify problems of local air pollution, particularly in countries that do not have advanced emissions-control systems in their power plants, industry and vehicles. Noxious and toxic emissions contribute directly to health problems, urban smog and acid rain.

Rising fossil-energy use also has energy security implications. The risks of disruptions to oil and natural gas supplies increase, as much of the incremental production is set to come from politically unstable parts of the world and to be shipped along vulnerable maritime and pipeline routes. In addition, because of the concentration of resources in a small group of countries, the market dominance of these countries increases.

The continuation of current trends in energy demand and supply would also have significant implications for economic and human development. The Reference Scenario projections, combined with our price assumptions, imply an increasing transfer of wealth from consuming countries to producing countries to pay for oil and gas imports. Energy poverty is already a major problem in the world’s least-developed regions, holding back much-needed improvements in productivity, employment, communication, health-care and education.¹

Implications for the environment

Global trends in energy-related CO₂ emissions²

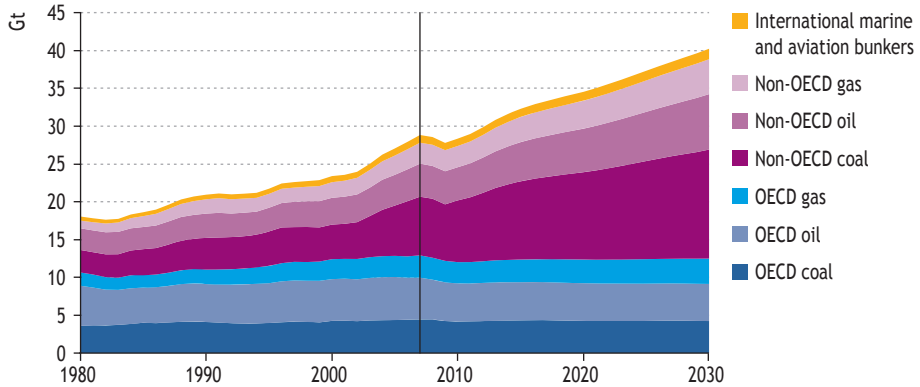
The Reference Scenario sees a continued rapid rise in energy-related CO₂ emissions through to 2030, resulting from increased global demand for fossil energy. Having already increased from 20.9 Gt in 1990 to 28.8 Gt in 2007, energy-related CO₂ emissions are projected to reach 34.5 Gt in 2020 and 40.2 Gt in 2030 – an average

1. *WEO-2010* will include detailed analysis of policy measures to improve rural electrification and to promote the sustainable use of biomass.

2. See Part B for a detailed analysis of trends in energy-related CO₂ emissions in both the Reference and 450 Scenarios.

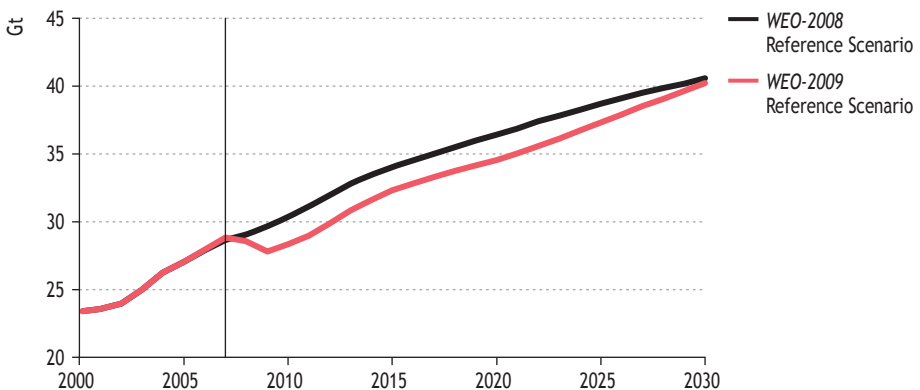
rate of growth of 1.5% per year over the full projection period (Figure 2.1). Non-OECD countries account for all of this emissions growth: OECD emissions are projected to dip slightly over the period, due to a slowdown in energy demand (resulting mainly from big improvements in energy efficiency) and the increased use of nuclear and renewables, in large part due to the policies already adopted to mitigate climate change and boost energy security.

Figure 2.1 • Energy-related CO₂ emissions by fuel and region in the Reference Scenario



The rate of increase in CO₂ emissions over the projection period in this year's Reference Scenario is less than that projected in *WEO-2008* (Figure 2.2). For the period to 2020, this is partly explained by the current global recession, which has dramatically slowed the growth in energy demand and CO₂ emissions in the short term.

Figure 2.2 • World energy-related CO₂ emissions in *WEO-2009* and *WEO-2008*



In 2009, global emissions of energy-related CO₂ are set to decline for the first time since 1992. Even so, emissions in 2020 in this year's Reference Scenario are 2 Gt below those in *WEO-2008*, largely on account of the persistent effects of the recent set-back to economic activity. But by 2030, despite lower assumptions for global gross domestic product (GDP), emissions are only 0.3 Gt lower than last year's Reference Scenario. This is due to upward revisions of GDP for several non-OECD countries that are heavily dependent on coal. In cumulative terms, between 2007 and 2030, world energy-related CO₂ emissions are 35.1 Gt lower than in *WEO-2008*.

Consequences for global climate

While greenhouse-gas emissions in this year's Reference Scenario are lower than in *WEO-2008*, current policies are insufficient to prevent a rapid increase in the concentration of greenhouse gases in the atmosphere, with very serious consequences for climate change. As a general rule, higher greenhouse-gas emissions lead to higher greenhouse-gas concentrations, leading to higher global temperatures and more severe climatic consequences.³ However, the links between emissions of greenhouse gases and climate change are complex and factors such as carbon sinks, solar heat reflection, cloud cover, land-use change and aerosols might partially neutralise – or compound – these effects (IPCC, 2007). Nonetheless, it is clear that the rapid growth of greenhouse-gas emissions projected in the Reference Scenario would lead to a substantial long-term increase in the concentration of greenhouse gases in the atmosphere, as well as a large increase in global temperatures.

The atmosphere currently contains long-lived greenhouse gases at a concentration of around 455 parts per million of carbon-dioxide equivalent (ppm CO₂-eq)⁴, which is roughly 60% above pre-industrial levels (see Chapter 4). This level far exceeds the natural range over the last 650 000 years. Average global temperatures are currently around 0.76 °C higher than pre-industrial levels and are rising at an increasing rate. The world is already experiencing the adverse effects of rising levels of greenhouse gases in the atmosphere. For example, the Greenland ice sheet has been losing mass at a rate of 179 billion tonnes per year since 2003 (Wouters *et al.*, 2008), while global sea levels are on course to rise by around one metre over the remainder of the century. Developing countries and island states are particularly vulnerable to the impacts of global warming.

3. 1 ppm of atmospheric CO₂ concentration today equates to around 7.7 Gt CO₂. In the past 50 years, around 58% of all the CO₂ emitted has stayed in the atmosphere – the rest has been removed over different timescales by various processes, including absorption by oceans and the biosphere, or has been broken down (Hansen, 2006). Consequently, at the present levels of atmospheric concentration, each additional 13.3 Gt of CO₂-eq gases released corresponds to an approximate increase in concentration of around 1 ppm. This may change in the future as some of the removal processes reach saturation.

4. The concentrations of greenhouse gases other than CO₂ in the atmosphere can be measured in terms of the equivalent CO₂ concentration that would result in the same level of radiative forcing. Today, their additional warming effect is partly offset by the cooling effect of anthropogenic aerosols and tropospheric ozone – but this is unlikely to remain the case in future (IPCC, 2007).

We estimate that the trajectory of energy-related CO₂ emissions in the Reference Scenario, when projected out to 2050 and beyond and taking into account emissions of all greenhouse gases from all sources, would result in a concentration of greenhouse gases in the atmosphere of around 1 000 ppm of CO₂-eq over the long term.⁵ Our projected increase in energy-related CO₂ emissions to 2030 lies in the middle of the range of emissions and concentration scenarios that have been assessed by the Intergovernmental Panel on Climate Change (IPCC) in its *Fourth Assessment Report*, assuming an absence of new climate policies (IPCC, 2007).⁶

According to our analysis, the greenhouse-gas concentration implied by the Reference Scenario would result in an eventual global mean temperature rise of up to 6 °C. According to the studies summarised by the IPCC, this could lead to hundreds of millions of people being displaced from their homes, massive water and food shortages, widespread mortality of ecosystems and species, and substantial human health risks. Even long before this stage is reached, there is a risk that the world would reach significant tipping points that could propel the climate into a vicious cycle of deterioration. For example, melting ice caps could reduce the earth's reflection of solar energy, leading to higher temperatures. In turn, rising Arctic temperatures could precipitate the melting of permafrost across northern regions, leading to a massive release of methane and further temperature increases. Studies published since the IPCC report suggest that the risks associated with global warming are even more severe than previously thought.

Although opinion is mixed on what might be considered a sustainable long-term level of annual emissions for the energy sector (and total emissions depend on emissions in other sectors), a consensus on the need to limit the global temperature increase to 2 °C is emerging. This increase is consistent with a greenhouse-gas concentration of around 450 ppm CO₂-eq (as in the 450 Scenario). To achieve this would entail a complete and rapid transformation of the energy sector, relative to the Reference Scenario. None of the scenarios assessed by the IPCC with a concentration of greenhouse gases in the 445 ppm to 490 ppm CO₂-eq range (corresponding to a temperature increase of around 2 °C) had annual energy CO₂ emissions above 5 Gt over the long term – whereas the Reference Scenario has emissions of 40.2 Gt in 2030.

Local and regional air pollution⁷

The negative environmental consequences of the Reference Scenario extend beyond climate change. Rising energy consumption and increasing reliance on fossil fuels have already led to a deterioration in ambient air quality in many parts of the world, particularly in the least-developed countries. Emissions of sulphur dioxide (SO₂),

5. These projected emissions are consistent with model outputs of concentrations from the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) (Version 5.3).

6. The atmospheric CO₂ concentration by around the end of the next century implied by the Reference Scenario is in line with the range of 855 ppm to 1 130 ppm CO₂-eq (660 ppm to 790 ppm CO₂) in five scenarios assessed by the IPCC.

7. This section discusses emissions of sulphur dioxide (SO₂), nitrogen oxides (NO_x) and particulate matter with an aerodynamic diameter of less than 2.5 µm (PM_{2.5}).

nitrogen oxides (NO_x) and particulate matter (PM), in particular, are directly harmful to human health and are also in part responsible for other environmental problems, such as acid rain and urban haze.

In 2007, world emissions of SO₂ were about 90 million tonnes (Mt). OECD countries contributed just over a quarter to this total (Table 2.1). The main sources are power plants and industry. In the Reference Scenario, the implementation of current policies on air-pollution control result in a 4% decline in world emissions of SO₂ between 2007 and 2030. This leads to a 48% decline in emissions in the OECD and a 11% increase in the rest of the world.

Table 2.1 • Emissions of major air pollutants by region in the Reference Scenario (Mt)

	2007	2015	2030	2007-2030*
Sulphur dioxide (SO₂)				
OECD	23.7	14.3	12.2	-2.8%
Non-OECD	66.6	69.2	74.2	0.5%
E. Europe/Eurasia	11.3	9.9	10.2	-0.5%
Asia	42.5	48.2	52.6	0.9%
<i>China</i>	31.5	34.6	29.0	-0.4%
<i>India</i>	6.3	8.5	14.8	3.8%
<i>ASEAN</i>	2.6	2.3	3.0	0.5%
Middle East	4.6	4.1	4.0	-0.6%
Africa	4.7	3.7	3.7	-1.0%
Latin America	3.4	3.4	3.6	0.3%
World	90.3	83.6	86.4	-0.2%
Nitrogen oxides (NO_x)				
OECD	32.7	22.1	16.6	-2.9%
Non-OECD	49.1	53.6	67.1	1.4%
E. Europe/Eurasia	7.8	7.0	6.9	-0.6%
Asia	27.3	32.5	42.7	2.0%
<i>China</i>	16.9	21.3	24.3	1.6%
<i>India</i>	4.1	5.0	9.5	3.7%
<i>ASEAN</i>	4.5	4.3	5.9	1.2%
Middle East	4.0	4.2	5.6	1.4%
Africa	4.4	4.5	5.8	1.2%
Latin America	5.5	5.5	6.2	0.5%
World	81.8	75.7	83.7	0.1%
Particulate matter (PM_{2.5})				
OECD	3.7	3.2	3.1	-0.8%
Non-OECD	35.4	36.9	36.8	0.2%
E. Europe/Eurasia	2.0	1.3	2.2	0.4%
Asia	23.4	24.0	23.1	-0.1%
<i>China</i>	13.1	13.2	10.9	-0.8%
<i>India</i>	5.1	5.4	6.3	0.9%
<i>ASEAN</i>	3.5	3.7	3.8	0.3%
Middle East	0.7	0.7	0.6	-0.2%
Africa	7.3	8.1	9.0	0.9%
Latin America	2.0	2.0	2.0	-0.2%
World	39.1	40.1	40.0	0.1%

* Compound average annual growth rate.

Note: The base year of these projections 2005; 2007 is estimated by IIASA.

Source: IIASA (2009).

World emissions of NO_x were 82 Mt in 2007, of which 40% originated from OECD countries. Road transport was responsible for about one-third of NO_x emissions. In the Reference Scenario, NO_x emissions increase by 2% by 2030, the combined effect of a near-50% fall in emissions in the OECD and a 37% increase in the rest of the world. The majority of non-OECD countries are currently implementing emission standards for vehicles, which slows down the pace of increase of NO_x emissions.

Some 90% of global emissions of fine particulate matter (PM_{2.5}), which amounted to 35 Mt in 2007, come from non-OECD countries. The biggest sectoral contributors are the residential and commercial sector, and industry. In 2030, emissions are 2% above 2007 levels. This relatively small increase in emissions is due to changes in fuel use patterns by households (replacement of solid fuels with other energy forms) and better controls on sources in power plants, industry and road transport.

Implications for energy security

Concerns about energy security – defined as access to adequate, affordable and reliable supplies of energy – have evolved over time, with changes in the global energy system, and new perceptions about the risks and potential costs of supply disruptions. In the 1970s and 1980s, the focus was on oil and the risks associated with over-dependence on oil imports. Today, worries about energy security extend to natural gas, which is increasingly traded internationally, and to the reliability of electricity supply. While the focus of energy security is generally on the near-term threat to supply, there are also concerns about the adequacy of investment and of supply in the longer term. Furthermore, energy security is increasingly being discussed as an aspect of climate change and of national security.

The perceived risk of a serious disruption to energy supplies for any given country or at any given time depends on a large array of different factors, some of which are inherently difficult to measure. The most important indicators of energy security are the extent of imports (especially from politically unstable regions), the distance from production to consumption, the vulnerability of physical supply chains to disruption, the degree of fuel substitutability, the diversity of the fuel mix and the degree of concentration of market power.

Oil security

Rising trade and import dependence

Net inter-regional trade in oil is set to increase sharply through the *Outlook* period in the Reference Scenario, from 38 million barrels per day (mb/d) in 2008 to over 51 mb/d in 2030 – almost half of global oil production at that time (Table 2.2). Total non-OPEC (Organization of the Petroleum Exporting Countries) output is set to remain broadly flat over the projection period, while production in OPEC countries, especially in the Middle East, increases, reflecting their much larger resource base and their generally lower production costs. OPEC's market share consequently rises from 44% in 2008 to 52% in 2030, above its historical peak in 1973. Increased international trade in oil will bring

economic benefits to exporting countries and will underpin economic development in importing countries, but it will also heighten concerns about OPEC pricing and production policies, as OPEC market power increases.

In the Reference Scenario, net exports from the Middle East, already the biggest exporting region, rise from 20.2 mb/d in 2008 to 29.3 mb/d in 2030. The region's exports represent more than 57% of global oil trade in 2030, up from 54% today. Net exports from Africa and Eastern Europe/Eurasia also continue to expand steadily. Brazil contributes most to the increase in net exports from Latin America in the early part of the *Outlook* period and Venezuela thereafter.

Table 2.2 • Net inter-regional oil trade in the Reference Scenario (mb/d)

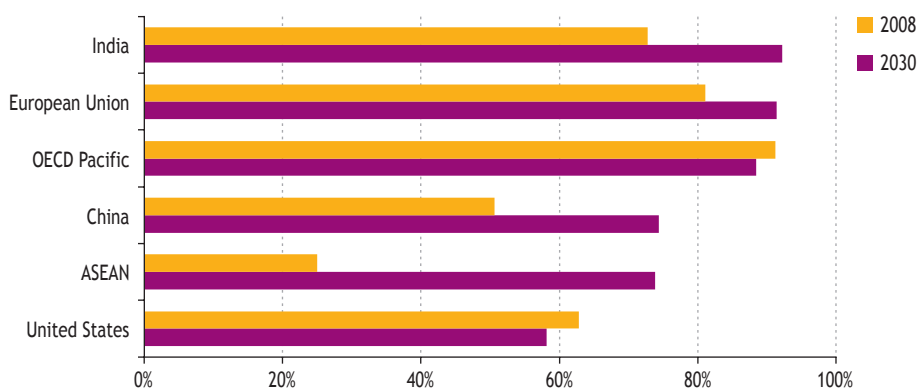
	1980	2000	2008	2015	2030
Net importers					
OECD	-24.0	-22.9	-24.6	-24.4	-20.5
<i>North America</i>	-6.6	-8.8	-9.5	-9.1	-5.2
<i>United States</i>	-7.1	-11.0	-11.6	-11.1	-10.0
<i>Europe</i>	-11.8	-6.8	-8.3	-9.0	-9.8
<i>Pacific</i>	-5.6	-7.3	-6.8	-6.3	-5.5
<i>Japan</i>	-4.8	-5.3	-4.5	-3.8	-3.1
Non-OECD Asia	0.1	-4.3	-8.4	-13.0	-24.5
<i>China</i>	0.2	-1.4	-3.9	-7.0	-12.1
<i>India</i>	-0.4	-1.5	-2.2	-3.0	-6.3
Net exporters					
Middle East	17.8	19.0	20.2	23.0	29.3
Africa	5.0	5.7	7.9	8.4	9.2
Latin America	0.3	2.3	1.5	2.3	1.9
<i>Brazil</i>	-1.1	-0.7	-0.1	1.2	0.7
E. Europe/Eurasia	3.0	4.1	8.3	8.8	11.5
<i>Russia</i>	<i>n.a.</i>	3.9	7.2	6.9	6.6
Total trade	27.3	33.5	37.8	41.6	51.5
<i>European Union (imports)</i>	<i>n.a.</i>	-9.4	-10.1	-10.3	-10.3

Note: Trade between *WEO* regions only. Positive figures denote exports; negative figures imports.

Trends in import dependence vary across regions. In the OECD as a whole, net imports as a share of total oil demand fall from 57% in 2008 to 51% in 2030, largely as a result of a sharp drop in imports into North America. Canadian output from oil sands displaces oil that would otherwise have been imported from outside the region, primarily from the Middle East. The import dependence of the United States alone declines from 63%

to 58%, mainly because of a decline in demand (Figure 2.3). The OECD Pacific's oil-import dependence remains high, at 88% in 2030, compared with 91% currently. The European Union sees a sharp rise in net import dependence, from 81% to 91%, as North Sea oilfields continue their rapid decline, having already passed their peak.

Figure 2.3 • Dependence on net imports of oil by major country/region in the Reference Scenario



Developing Asia becomes much more reliant on imports, both in absolute terms and as a share of demand. In 2008, China passed a milestone with its oil imports exceeding domestic production for the first time. By 2030, China's net imports are projected to reach 12 mb/d, comparable in volume to the current imports of the United States, and accounting for 74% of China's demand. The increase in dependence is also dramatic in India, where imports are projected to rise from today's level of around three-quarters of the total oil consumed domestically to 92% by 2030.

Fuel substitutability

In the Reference Scenario, the transport sector is responsible for 97% of the growth in oil demand to 2030. By that time, oil-based fuels account for 92% of all transport fuel consumption, a modest fall from the level of 94% in 2007, resulting from the wider deployment of biofuels and, to a lesser extent, the uptake of plug-in hybrids and electric vehicles. The growing concentration of oil demand in the transport sector is set to magnify the vulnerability of importing countries to price spikes. Opportunities for substituting oil-based fuels in existing vehicles are limited and fuel demand tends to change very little in the near term in response to price increases. For a given supply reduction, the price adjustment needed to bring global demand back into equilibrium is expected to increase. In other words, oil-price volatility will tend to rise with the increased rigidity of oil demand.

Vulnerability to oil supply disruptions

The prevalence and seriousness of major oil-supply disruptions could grow as the world becomes increasingly dependent on supply sourced from a small group of countries

and transported along vulnerable supply routes. In the Reference Scenario, a growing share of oil supplies is transported by pipeline or along maritime routes, some of which have narrow sections that are susceptible to piracy, terrorist attacks or accidents (Table 2.3). These choke points are typically in places that cannot easily be bypassed.

Table 2.3 • Key global oil transit choke points

Choke point	Main destination	Description
Straits of Hormuz	Europe, Japan, United States	Most important oil-shipping route. Tankers divide into two lanes just 3 km wide. Few alternative export routes for Persian Gulf oil.
Malacca Strait	Japan, China, ASEAN	Principal oil route in Asia. Only 2.7 km wide at narrowest. Rising demand in Asia will increase traffic.
Suez Canal	Europe, United States	Connects Red Sea with Mediterranean. Closure would force tankers to transit around the southern tip of Africa.
Bab el-Mandab passage	Europe, United States	Links Red Sea with the Gulf of Aden.
Sumed pipeline	Europe, United States	Links Red Sea with the Mediterranean.
Bosphorus/Turkish Straits	Europe	30-km waterway linking the Black Sea with the Mediterranean, less than 1 km wide at the narrowest point.
Druzhba pipeline	Europe	Transits Russian crude oil to Europe.
Baltic Pipeline System	Europe	Carries Russian crude to Baltic Sea ports.

Worries about the threat of disruptions to energy supplies are based on the experience of the last few decades. Since 1970, there have been 17 serious disruptions in the supply of crude oil that have involved an initial loss of 0.5 mb/d or more. Thirteen of these have involved countries in the Middle East. Oil supply disruptions can happen at any point from where the crude oil is extracted from the ground to where it is sold as refined product to end users – and the repercussions are sometimes global. The most recent major disruptions both occurred in the Gulf of Mexico: firstly in the summer of 2005, when Hurricanes Katrina and Rita removed some 1.5 mb/d of oil supply from the market; and then in August/September 2008, when Hurricanes Gustav and Ike caused comparable damage. Historically, there have been a number of interruptions stemming from incidents at key choke points. The most serious remains the Suez Canal crisis in 1956/1957, which blocked the passage of approximately half the oil reliant on transit through the canal. The estimated gross peak supply loss was around 2 mb/d.

Investment risks

High rates of investment in oil production, refining and transportation infrastructure are essential to maintaining security of supply over the longer term. The oil sector, like all other economic sectors, has been affected by the recent financial and economic crisis (see Chapter 3). Planned global investment in oil and gas production in 2009 has been reduced by about one-fifth. Unless quickly reversed, such investment cut-backs could have severely negative consequences for energy security by leading to a shortage of capacity and another spike in prices when the economy is back on the road to recovery.

Box 2.1 • The future of the IEA oil emergency response mechanisms

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The IEA's emergency response mechanisms were created pursuant to the 1974 Agreement on an International Energy Program (IEP). The Agreement requires IEA countries to hold strategic oil stocks and, in the event of a major oil supply disruption, to release stocks, restrain demand, switch to other fuels or increase domestic production. Experience has demonstrated that the most effective of these measures is the holding of emergency stocks and releasing them in a co-ordinated manner. IEA member countries currently hold 4.2 billion barrels of oil stocks, of which 1.5 billion are held by public organisations. Based solely on those public stocks, the IEA could replace a supply disruption of 4 mb/d - about the size of the current production of Iran – for one year. This is a relatively comfortable situation, especially as it is backed by other tools available under the IEP and elsewhere. The spare oil production capacity that some key producers, most notably Saudi Arabia, have historically maintained represents a valuable element of preparedness for many forms of emergencies (e.g. accidental loss of supply) and illustrates the importance attached by suppliers to the reputation of oil as a fuel on which customers can rely. This spare capacity has enabled important volumes of additional supplies to be made available in times of shortage, thereby stabilising the market.

Experience has demonstrated that the IEA's emergency response system works and that its member countries are ready to use it. Most recently, when Hurricane Katrina hit the Gulf of Mexico in 2005, the region's oil production and refining infrastructure was devastated and world energy markets were disrupted. The IEA member countries decided in a matter of days to bring 60 million barrels of additional oil to the market and acted promptly to implement their commitments. The market quickly stabilised.

To maintain a similar level of emergency preparedness the IEA will continue to adapt its policies and procedures to changing market conditions. Most important of these changes is the falling share of IEA member countries in global oil consumption. This is set to fall to just 36% by 2030 – from 68% when the Agency was established in 1974. International oil markets are closely inter-connected and no country can stand immune to an oil shock elsewhere. For example, despite a projected fall in the United States in dependence on oil imports, increasing import dependency in another major consuming region – notably Asia – means that a severe oil supply shock there would have rapid knock-on effects for the United States.

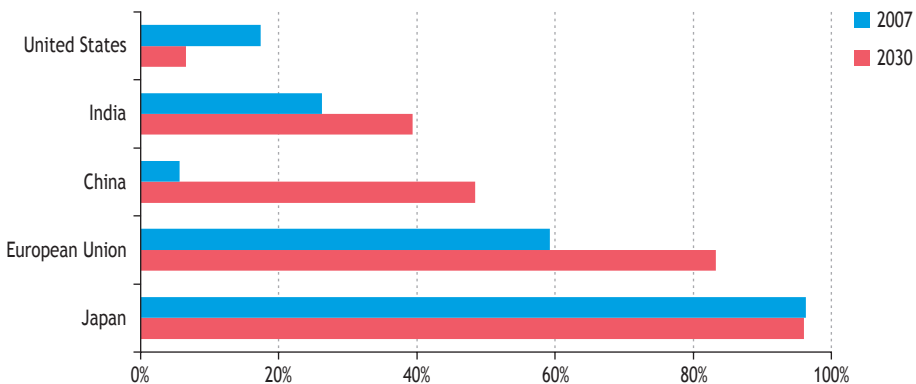
In view of these changing dynamics, the IEA is increasing its engagement on energy security issues with non-member countries. China, India, Thailand and other countries in Southeast Asia are building emergency oil stocks and the IEA is actively seeking to deepen its dialogue and exchanges with these countries, with the goal of improving co-ordination among all market players during an emergency. IEA non-member countries have started to participate in regular Emergency Response Exercises at IEA headquarters in Paris. In addition, the IEA has held Emergency Response Exercises in countries that are not IEA members. The first such exercise was held in Thailand in May 2009 and similar exercises are planned elsewhere in the region.

In the Reference Scenario, \$6 trillion (in 2008 dollars) of investment is needed in the oil sector through to 2030. The share of the Middle East in total upstream oil spending, at around 15%, is small relative to the region's contribution to the increase in global supply, because exploration and development costs are low. Nonetheless, there is considerable uncertainty about the pace at which investment in the region's upstream industry will occur, how quickly production capacity will expand and, given rising domestic energy needs, how much of the expected increase in supply will be available for export. Reductions in investment may reflect government decisions to limit budget allocations to the industry or constraints on the industry's ability or willingness to invest in upstream projects.

Natural gas security

A number of market developments are currently affecting natural gas security, including rising import dependence in some of the key consuming and emerging markets, and the globalisation of the gas market. In the Reference Scenario, gas trade between *WEO* regions is projected to increase by 58% over the projection period, from 677 billion cubic metres (bcm) in 2007 to around 1 070 bcm in 2030. The European Union is expected to require the biggest increase in import volumes through the *Outlook* period, due to declining indigenous production, particularly in the Netherlands and the United Kingdom, coupled with a modest increase in demand. By 2030, imports into the European Union meet 83% of its gas needs, compared with 59% at present (Figure 2.4). Developing Asia also becomes much more reliant on imports of gas. Both China and India have modest proven reserves of gas and limited potential for raising production. In the absence of large new discoveries, they will become increasingly reliant on imports. Imports as a share of total gas consumption reach 48% in 2030 in China and 39% in India, in the Reference Scenario.

Figure 2.4 • Dependence on net imports of natural gas by country/region in the Reference Scenario



In the Reference Scenario, the bulk of the increase in natural gas exports comes from Russia, Iran and Qatar, with lesser volumes provided by other Middle Eastern producers, Africa and the Caspian/Central Asian region. As with oil, increasing reliance on natural gas imports from a limited number of countries will increase the market dominance of producers and increase vulnerability to supply disruptions at major choke points.

Although gas supply disruptions caused by external events typically receive much publicity, the vast majority of gas supply disruptions are domestic in nature. The list of actual and potential causes of disruptions is long and includes weather-related catastrophes (e.g. hurricanes), accidents (e.g. fires, explosions), contractual disputes, transit disputes and political decisions. The risks associated with political control of strategic pipeline routes were highlighted in early 2009 with the most severe supply disruption in history, as Russia and Ukraine disputed the continuation of their supply and transit contracts (Box 2.2). This followed numerous other high-impact disruptions in recent years, in the United States (2005 and 2008), the United Kingdom, Italy and Ukraine (2006), Turkey (2008), Australia (2000 and 2008) and elsewhere.

Box 2.2 • The 2009 Russia-Ukraine gas dispute

Interruption of Russian gas flows through Ukraine in January 2009, at a time of very high demand, triggered Europe's worst-ever gas-supply crisis. A dispute between Russia and Ukraine over the price of gas sold to Ukraine, payment of outstanding debt and transit fees resulted in the interruption of some 110 million cubic metres per day (mcm/d) of supply to Ukraine from 1 January, along with smaller volumes of supply to countries further west. On 5 January, supplies were further reduced and, on 7 January, all transit through the Ukrainian network was halted, causing the loss of 300 mcm/d to 350 mcm/d of supply to the rest of Europe. This came at a time of very high peak gas demand in Western and Central Europe, with the coldest weather in two decades.

European gas companies responded by drawing down gas from commercial storage, implementing demand-side measures and securing alternative supplies via other pipeline routes from Russia, other producers and as liquefied natural gas (LNG). Except for flows from the United Kingdom, cross-border flows within Europe were severely reduced and deliveries were slow to arrive, so that countries poorly equipped with storage and other emergency arrangements (notably in Eastern Europe) were heavily affected. When flows were restored on 20 January, following new deals on gas sales and transit, some 5 bcm of transit gas supplies had not been delivered over a two-week period, in addition to around 2 bcm of Ukrainian supplies.

The new agreements on gas sales and transit should put the gas relationship between Russia and Ukraine on a more solid commercial basis, but the risk of a renewed interruption to supply has not disappeared in the short term. As of September 2009, Ukraine has made its monthly payments for gas imports promptly, but it will take time for Ukrainian domestic prices and industry to adjust to the new European pricing mechanism for gas import. In the meantime, state-owned Naftogaz remains heavily in debt. Pricing reform, greater efficiency and broader energy-market restructuring in Ukraine will be vital to the medium-term health of the gas relationship with Russia.

A growing share of world trade is expected to take the form of liquefied natural gas (LNG). On the one hand, the growing LNG market offers greater supply flexibility, as cargoes can be diverted at short notice to offset a sudden loss of supply from another source. Nonetheless, recent events have also demonstrated that long-term LNG contracts do not guarantee security of supply. For the last several years, Japan has struggled with the inability of Indonesia to produce the quantities of LNG stipulated under long-term contracts, due to declining output and rising domestic demand.

Gas-importing countries have some concerns that the Gas Exporting Countries Forum (GECF) – which was established in 2001 and has a Secretariat based in Qatar – could one day evolve into a cartel intent on influencing world prices in the same manner as OPEC, which itself had existed for over a decade before exerting its collective influence during the first oil shock in 1973.⁸ The global economic crisis, which has sent spot prices plummeting and is expected to result in the first global contraction in natural gas demand in more than half a century, may well add impetus to such a development. But several market factors also stand in the way, including the prevalence of long-term contracts, the regionalised nature of gas markets, the scope to substitute other fuels for gas and the growing number of competing suppliers, such as those responsible for the recent surge in gas production from non-conventional sources in the United States. Nonetheless, the possibility of eventual formal co-ordination of investment, production and pricing policies by gas importers will be a risk taken into account by the purchasers of gas (see Chapter 10).

Electricity security

The reliability of electricity supply is a growing concern in both OECD and non-OECD countries. Most power systems in most OECD countries were conceived and constructed some 40 to 50 years ago. Many generation units are well in excess of 25 years old, especially nuclear and coal-fired plants. The demands on electricity-supply infrastructure are growing, with increasingly distributed and variable sources of generation, including wind and solar power. Furthermore, electricity demand still does not respond quickly to price changes when supply conditions change. Yet, in certain regions there appears to be a lack of timely, diverse electricity-generation investment, or investment in expanded and enhanced transmission interconnections. Public opposition to siting of new generation and transmission infrastructure sometimes causes delays and increases risks and costs for investors, and may totally prevent new investment. Regulatory complexity and uncertainty, especially as markets integrate over larger geographic areas, is a further inhibition. Greater reliance on natural gas for power generation in many markets has contributed to supply diversification, but gas-supply interruptions have been demonstrated to be a real threat.

8. See Chapter 14 Spotlight: Is the Gas Exporting Countries Forum the new “Gas-OPEC”?

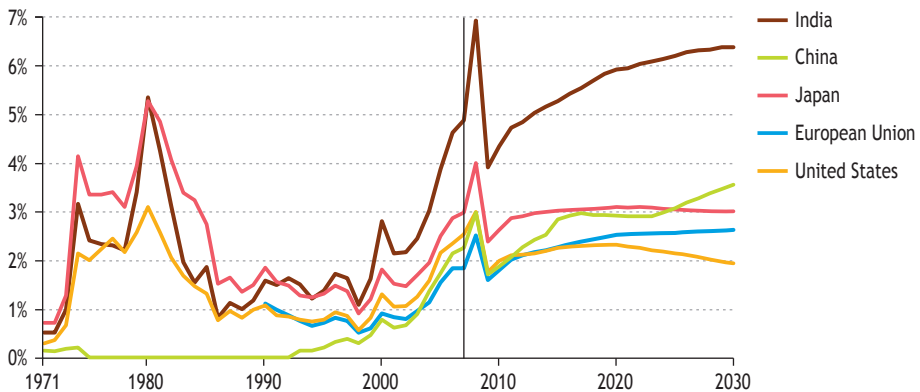
Selected economic implications

Spending on imports

2

The Reference Scenario projections imply a persistently high level of spending on oil and gas imports by almost all importing countries (Figure 2.5). As a share of GDP at market exchange rates, spending on oil and gas imports spiked in 2008, in line with the run-up in prices. For the OECD as a whole, the level reached 2.3%, which approached the peaks seen during the second oil shock in 1979. For many emerging economies, a new record level of spending was reached, as they have typically become more dependent on energy imports over the last several decades due to a sharp increase in demand and/or shrinking domestic production. Two examples illustrate the case: in 2008 spending on oil and gas imports reached 6.9% of GDP in India and 3.0% in China.

Figure 2.5 • Expenditure on net imports of oil and gas as a share of GDP at market exchange rates in the Reference Scenario



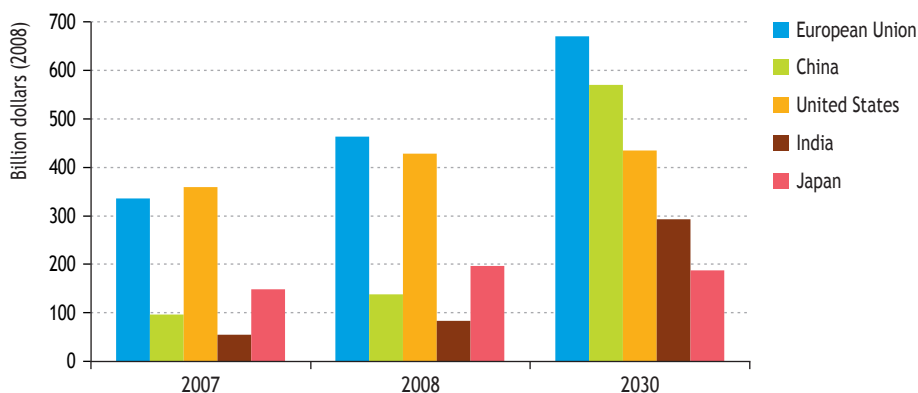
Note: Calculated as the value of net imports at prevailing average international prices. The split between crude/refined products and LNG/piped gas is not taken into account.

Based on current trends, spending on oil and gas imports in the OECD, as a share of GDP, is set to stabilise at around 1.8% over much of the *Outlook* period. Japan and Korea are expected to be slightly worse off, due to their near-total dependence on imports. In most cases, in developing countries the share of imports in GDP is significantly higher than in the OECD, as they tend to be more dependent on imports and consume more energy to generate one unit of economic output. In India, for example, although spending on oil and gas imports as a share of GDP has fallen back from the peak in 2008, it is projected to rise progressively through the *Outlook* period, reaching 6.4% in 2030.

These projections are based on the price assumptions that underpin the Reference Scenario. However, market tightness or significant geopolitical tensions could lead to price spikes or even sustained higher prices over the *Outlook* period, increasing the financial burden on countries dependent on oil and gas imports. Recent experience suggests that any such development could have important implications for the global economy: it is generally considered that the run-up in oil prices in the period 2003 to mid-2008 played a significant, albeit secondary, role in the current global economic downturn. On the other hand, short-lived bouts of over-supply could alleviate the burden on importing countries.

In the Reference Scenario, in real-dollar terms, annual expenditure on oil and gas imports continues to increase in most importing countries, even compared to the record levels experienced in 2008 (Figure 2.6). For example, the spending on oil and gas imports in the European Union is expected to reach \$671 billion (in year-2008 dollars) in 2030, up from \$463 billion in 2008 (and \$336 billion in 2007). On a country basis, China overtakes the United States soon after 2025 to become the world's biggest spender on oil and gas imports, in monetary terms, while India's spending on oil and gas imports surpasses that of Japan soon after 2020 to become the world's third-largest importer.

Figure 2.6 • Annual expenditure on net imports of oil and gas in the Reference Scenario



Note: Calculated as the value of net imports at prevailing average international prices. The split between crude/refined products and LNG/piped gas is not taken into account.

Reducing imports of oil and gas would lower the economic burden on oil importers, as well as bringing environmental and energy-security benefits. Such a reduction can be achieved through efforts to stimulate indigenous production of hydrocarbons and alternative sources of energy, such as biofuels, other renewable energy technologies and nuclear power, as well as through measures to improve energy efficiency. More importantly still, subsidies on oil and gas consumption can be removed (Box 2.3). Most countries are considering stronger policies and measures to reduce oil-import intensity for economic, security and/or climate change reasons (see Chapter 4).

Box 2.3 • The implications of phasing out energy subsidies

2

Large subsidies to the consumption of fossil fuels still exist in many non-OECD countries. As inferred from the gap between domestic and international fossil-fuel prices, they are currently highest in percentage terms in the Middle East, Russia, other non-EU Eastern European countries and India. In many cases, price controls prevent the full cost of higher imported energy from being passed through to end users, thereby dampening the responsiveness of consumption to increases in prices. Subsidies can also place a heavy direct burden on government finances and thereby weaken the potential for economic growth. In addition, by encouraging higher consumption and waste, subsidies exacerbate the harmful effects of energy use on the environment, while also impeding the development of more environmentally benign energy technologies. Although usually meant to help the poor, subsidies often benefit better-off households.

Energy subsidies take many different forms, some of which are not transparent. Some subsidies aim at making fossil fuels more affordable, while others aim to support domestic production. Closing the gap between domestic and international fossil-fuel prices is an important, albeit politically difficult, step towards improving all three central objectives of energy policy. Subsidy removal also frees up budgetary resources that can be used to target social objectives more directly.

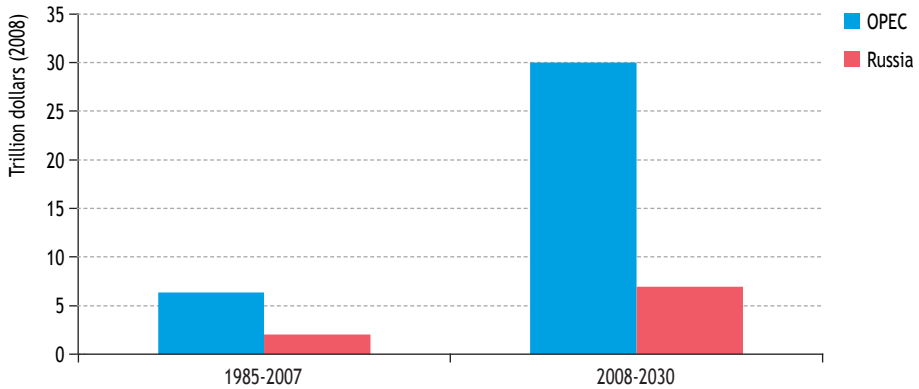
The *WEO-2008* found that subsidies on fossil fuel in 20 non-OECD countries (accounting for over 80% of total non-OECD primary energy demand) amounted to about \$310 billion in 2007 (IEA, 2008).⁹ A further study by the OECD in collaboration with the IEA, using IEA estimates of the gap between actual prices and the estimated true market prices of a range of fuels, found that if energy subsidies were phased out gradually between 2013 and 2020, total primary energy demand at the global level would be cut by slightly more than 5% by 2030, compared to a baseline in which subsidy levels remain unchanged. It was found that removing subsidies would also raise per-capita GDP in most countries concerned.

Export revenues

In the Reference Scenario, OPEC countries and Russia continue to earn substantial revenues from oil and gas exports, even after taking into account that more of their production is needed to satisfy rising domestic demand. On an undiscounted basis, cumulative OPEC country revenues from oil and gas exports between 2008 and 2030 amount to almost \$30 trillion – a near five-fold increase on earnings over the past 23 years (Figure 2.7). Russia's cumulative earnings to 2030 amount to \$7 trillion, some 3.5 times larger than over the previous 23 years.

9. *WEO-2010* will include an in-depth analysis of the impact subsidy removal would have on global energy trends, economic efficiency, CO₂ emissions and local pollution.

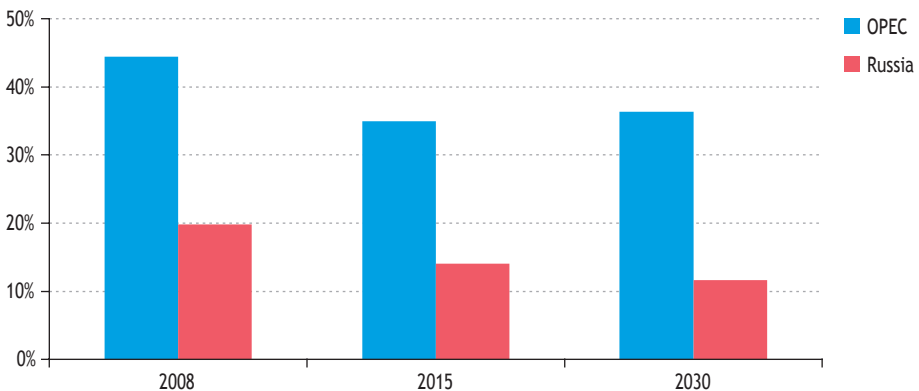
Figure 2.7 • Cumulative oil and gas export revenues in the Reference Scenario for selected key exporters



Note: Calculated as the value of net exports at prevailing average international prices. The split between crude/refined products and LNG/piped gas is not taken into account.

Existing and planned efforts in OPEC countries to implement structural economic reforms aimed at accelerating economic diversification are set to reduce gradually reliance on hydrocarbon export revenues. Nonetheless, revenues from oil and gas exports are still projected to represent 36% of the combined GDP of the OPEC countries in 2030, down from 44% in 2008 (Figure 2.8). On a per-capita basis, in real-dollar terms, in 2030 OPEC countries are set to earn around \$3 600 from exports of oil and gas compared to just under \$2 800 in 2008.

Figure 2.8 • Oil and gas export revenues as a share of GDP at market exchange rates for selected producers in the Reference Scenario



Note: Calculated as the value of net exports at prevailing average international prices. The split between crude/refined products and LNG/piped gas is not taken into account.

Do energy producers need greater security of demand?

With the economic weakness of 2008/2009 prompting the sharpest decline in oil demand in a quarter of a century, and with the prospect that an agreement may be brokered at the UN Climate Change Conference (COP 15) that could kick-start a transition to a low-carbon economy, it is important and timely to consider the other side of the energy security coin – security of demand. After all, in the same way that energy-importing countries seek security of supply, energy-exporting countries seek security of energy demand as they invest billions of dollars in production infrastructure.

The fall in global oil demand in 2009, which could exceed 2%, will almost certainly be the steepest since the early-1980s. It is understandable that resource holders may hesitate to commit new capital to increase upstream production capacity or to maintain spare capacity when they are unsure how long it will take before they see a return on their investment. Yet, even taking into account the current uncertainty, there is still widespread agreement that sustained investment will be needed to meet rising demand in the medium and longer term. In the Reference Scenario of this *Outlook*, global oil demand is projected to reach 105 mb/d in 2030, while in OPEC's *World Oil Outlook 2009* (OPEC, 2009), released in July 2009, it is slightly higher at 106 mb/d.

Naturally, these projections would not hold true if the UN Framework Convention on Climate Change (UNFCCC) process leads to a successful climate deal, as they are predicated on the assumption that there will be no major shift in government policies. But even in the 450 Scenario of this *Outlook* – in which the concentration of greenhouse gases is stabilised at 450 ppm CO₂-eq – oil demand in 2030 is projected to be slightly higher in 2030 than today, at 88.5 mb/d. Given that OPEC countries possess the world's largest and least-cost reserves, even in this scenario they would be called upon to produce 11.4 mb/d more oil in 2030 than they do today. In fact, the growth in OPEC production in this scenario over 2008-2030 is faster than the increase in output over the period 1980-2008 (see Chapter 5).

Our analysis suggests that investment by low-cost producers in new supplies will pay off, even if highly ambitious efficiency measures and alternative fuel and vehicle technology programmes are put in place in consuming countries. It therefore bodes well for economic prospects in the major producing countries, particularly when coupled with the ongoing efforts in countries such as the United Arab Emirates and Saudi Arabia to diversify their economies.

Russia's economy has become heavily dependent on earnings from oil and natural gas exports. For a brief period in mid-2008, earnings approached \$1 billion per day but by July 2009 they had halved, in line with the decline in energy prices and the fall

in demand for exports. In the Reference Scenario, Russia's earnings from oil and gas exports, predominately to European customers, amount to 12% of the country's GDP in 2030, down from 19% in 2008. Russian earnings on a per-capita basis increase steadily through the *Outlook* period, from around \$2 300 in 2008 to \$3 100 in 2030.

Oil and gas export revenues continue to make up an important part of the national budgets of producing countries. This is true even if stringent steps are taken by the international community to cut greenhouse-gas emissions (see Spotlight). This underscores the persistence of genuine interdependence between producers and consumers. But attempts by producers to actively manage the market to protect their revenue base can damage trust. Fears that producers may constrain investment in order to safeguard against possible future over-supply or exploit their growing market domination (by actively limiting short-term production in order to manipulate prices) can drive importers to adopt more stringent measures to reduce dependence on oil and gas.

Implications for energy poverty¹⁰

Current status of electricity access by region

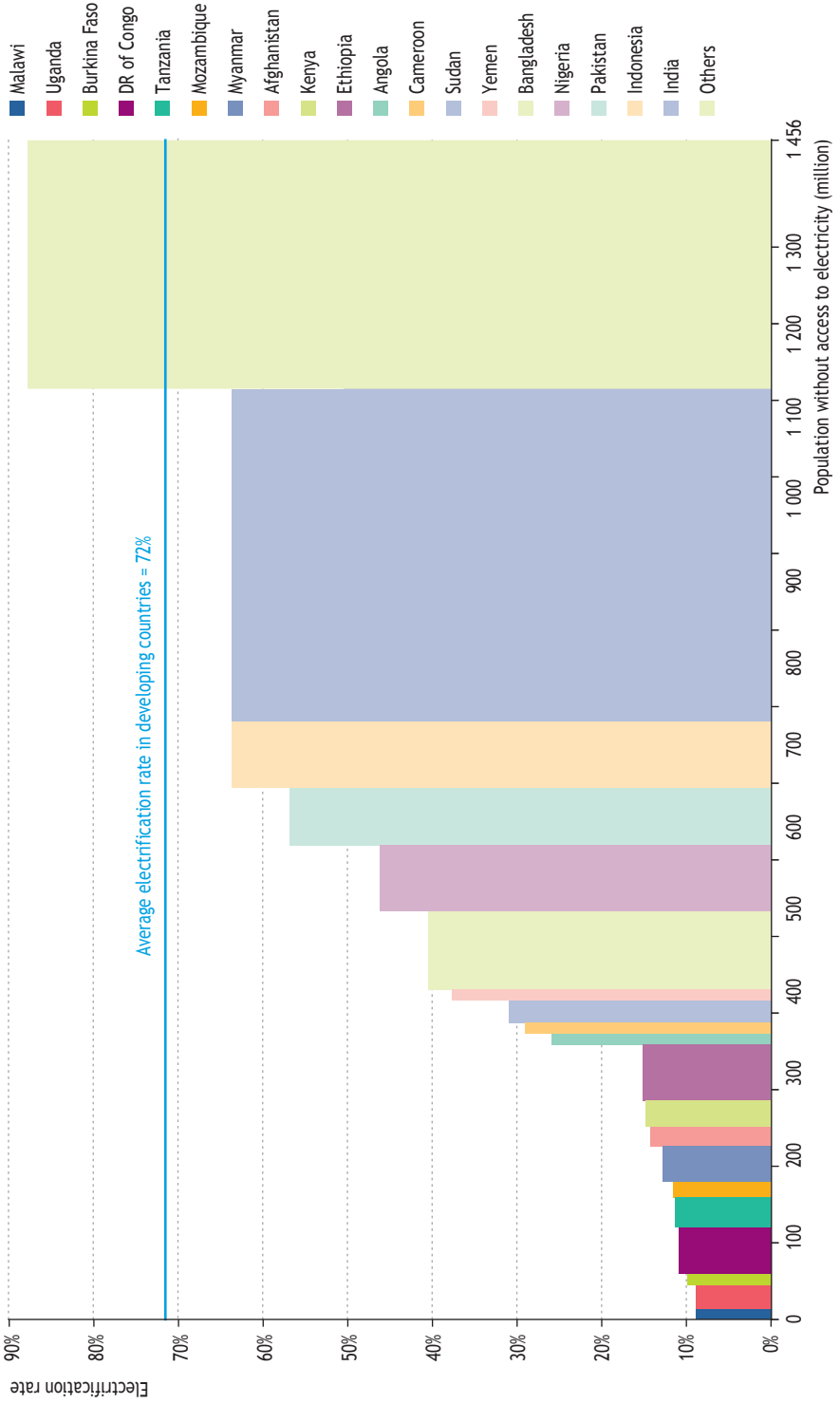
Based on a detailed country-by-country database updated for this *Outlook*, we estimate that in 2008 the number of people without access to electricity was 1.5 billion – or 22% of the world's population. Some 85% of those people live in rural areas. Expanding access to modern energy is a necessary condition for each of the economic, social and environmental dimensions of human development. The UN Millennium Project has emphasised the close links between energy use and the eight Millennium Development Goals (UN, 2009). Modern energy services help to reduce poverty, improve educational opportunities for children and promote gender equality.

Since the issue of energy poverty was first analysed in the *World Energy Outlook 2002*, the number of people without access to electricity has decreased by an estimated 188 million, despite the growth in world population of more than 500 million. Increased urbanisation and the successful implementation of electrification programmes have contributed to the improvement in these figures, but it is also partly due to revisions as data quality has improved.

South Asia currently accounts for 42% of the total number of people in the world without access to electricity, even though the percentage of the population with access to electricity in South Asia increased by around 8% over the last three years (Figure 2.9). Bangladesh, India and Pakistan in total have 570 million people without electricity, 92% of whom live in rural areas. The Indian government has declared reducing poverty and enhancing social and economic development a key priority, and has introduced a new

10. See www.worldenergyoutlook.org for the definitions and methodology utilised in the energy poverty analysis as well as disaggregated results.

Figure 2.9 • Electrification rates and population without access to electricity, 2008



remote village electrification programme. In Pakistan, nearly 133 000 villages have been electrified by the Water Resources and Power Development Authority and its rural electrification programme.

In *Sub-Saharan Africa* only 29% of the population has access to electricity today. Despite slightly increasing electrification rates, the total number of people in the region without access to electricity has grown by 78 million since 2001 – mainly due to rapid population growth, which has outpaced electrification.

The overall number of people without access to electricity in *East Asia* and *China* has fallen to 195 million, from 241 million in 2001. Myanmar has the lowest electrification rate in the region, at 13%, followed by East Timor (22%) and Cambodia (24%). China has achieved impressive results in electrification, providing electricity access to more than 1.3 billion people. The National Development and Reform Commission has introduced national renewable energy programmes, including the Riding the Wind Plan and the Brightness Project to provide electricity to people in remote areas through renewable technologies such as wind and solar (Zhang *et al.*, 2009).

Although the average electrification rate in *Latin America* was 93% in 2008, some countries in the region with large populations have much lower rates, including Peru, Nicaragua and Bolivia. While almost the entire urban population in Latin America has access to electricity, the rate in rural areas is just 70%.

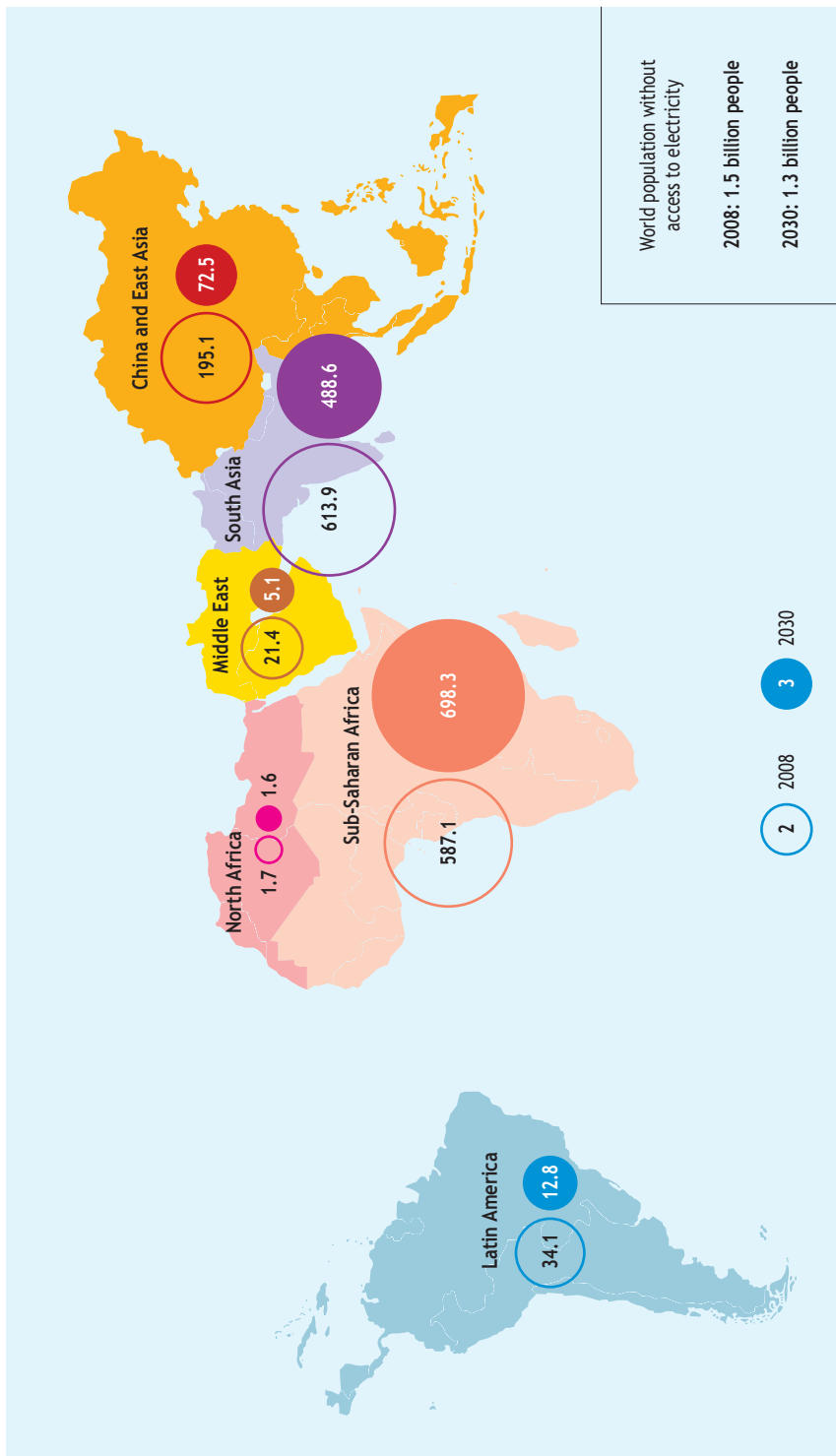
Prospects for electricity access

In the Reference Scenario, 1.3 billion people, or 16% of the world's population, still lack access to electricity in 2030, despite more widespread prosperity and more advanced technology (Figure 2.10). Though the Reference Scenario takes into account the effects of the current economic crisis, there is a risk that its consequences for the ongoing electrification process in developing countries could be understated: financing programmes to connect new customers, whether carried out by public-private partnerships or by local electric utilities, could be particularly severely affected.

On the Reference Scenario figures, the electrification rate at the global level reaches 84% in 2030, from 78% in 2008. This represents a reduction in the number of people without access to electricity of 176 million compared to today, despite the substantial projected rise in global population.

Most of the people without access to electricity in 2030 are in Sub-Saharan Africa (698 million) and South Asia (489 million). Four out of five of them live in rural areas (Table 2.4). In Sub-Saharan Africa, despite a projected increase in the electrification rate from 29% in 2008 to 47% in 2030, the number of people without access to electricity increases by 111 million by 2030. These projections are highly dependent on assumptions about incomes and electricity pricing; higher electrification rates could be achieved in 2030 if new policies to alleviate energy poverty were introduced.

Figure 2.10 • Number of people without access to electricity in the Reference Scenario (millions)



The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Table 2.4 • Electricity access in the Reference Scenario

	2008				Projections			
	Population without access (millions)	Electrification rate (%)			Population without access (millions)		Electrification rate (%)	
		Overall	Urban	Rural	2015	2030	2015	2030
Africa	589	40	67	23	627	700	45	54
<i>North Africa</i>	2	99	100	98	2	2	99	99
<i>Sub-Saharan Africa</i>	587	29	57	12	625	698	36	47
Non-OECD Asia	809	77	94	67	765	561	80	87
<i>China</i>	8	99	100	99	5	0	100	100
<i>India</i>	405	65	93	53	385	294	69	79
<i>Other</i>	396	63	85	48	374	267	68	81
Latin America	34	93	99	70	18	13	96	98
Middle East	21	89	98	71	11	5	95	98
Sub-total	1 453	72	90	58	1 420	1 279	75	81
E. Europe/Eurasia and OECD	3	100	100	100	2	2	100	100
Sub-total	3	100	100	100	2	2	100	100
World	1 456	78	93	63	1 422	1 281	80	84

Box 2.4 • The Universal Electricity Access Case

Achieving universal access to electricity by 2030 would result in higher global energy demand than projected in the Reference Scenario. It would also have implications for energy investment and for emissions of energy-related CO₂ emissions. The Universal Electricity Access Case (UEAC) seeks to quantify these increments. It is based on the assumption that new policies are introduced that result in a progressive increase in electrification rates to 100% of the world's population by 2030.

It is assumed that each person gaining access is at first going to use electricity only as a substitute for the traditional fuels used to cover basic needs (e.g. candles, liquefied petroleum gas [LPG], kerosene). Basic electricity consumption in rural areas is assumed to be 50 kWh per person per year, while the minimum urban consumption is set at 100 kWh per person per year. It is assumed that the consumption levels of the newly connected areas increase over time to reach the regional (rural and urban specific) average after 10 years, reflecting the income-generating effects of

modern energy services. It is also assumed that the electricity is generated using the fuel mix set out in the Reference Scenario for the country or region in question.

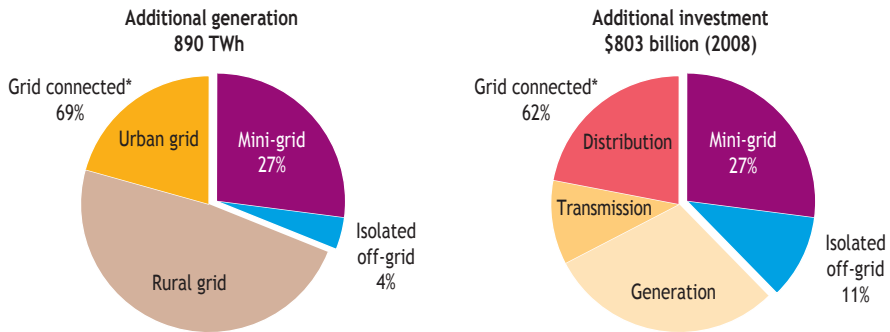
Relative to the Reference Scenario, global electricity generation in the UEAC is less than 3% higher in 2030, an increase of 890 TWh. Around 70% of the additional supply is projected to be based on grid extensions, which remain the cheapest option in all countries, while development of mini-grids accounts for 27% and isolated off-grid generation for 4% (Figure 2.11). Almost 90% of the incremental supply is required in just two regions, Sub-Saharan Africa (448 TWh) and South Asia (316 TWh).

Additional power-sector investment worldwide of \$35 billion per year on average is required in the UEAC in 2008-2030. This increase is equivalent to just 6% of the annual average global investment in the power sector in the Reference Scenario, or around one-quarter of the annual investment required in China's power sector in the *Outlook* period. Almost 85% of the incremental investment to meet the UEAC is needed in Sub-Saharan Africa and South Asia.

The task of achieving universal access to electricity is, clearly, formidable but it would contribute substantially to the alleviation of poverty. The required investment is most unlikely to be driven by the private sector, as in those countries in which electricity access is the lowest there is often no market and there are no guarantees. Urban circumstances are more favourable to prospective private finance, but there are still formidable obstacles. Providing full access means providing electricity to those who are so poor that they have no means to pay. For these people, the only solution is for the service to be provided by governments or the international community as an investment in future social and income benefits.

Compared to the Reference Scenario, in the UEAC there is an increase in global energy-related CO₂ emissions of just 1.3% by 2030 – less than the current emissions of the United Kingdom. This increase is disproportionately modest compared with the number of people affected, as initial consumption levels are less than 1% of the global per-capita average. Similarly, providing universal electricity access is unlikely to lead to a deterioration in other forms of energy security, as global oil and gas balances remain essentially unchanged. If the generation fuel mix to supply the additional demand were that of the 450 Scenario (see Introduction and Part B), the increase in energy-related global CO₂ emissions would be a mere 0.9% by 2030.

Figure 2.11 • Incremental electricity generation and investment in the Universal Electricity Access Case, 2008-2030



* Covers generation, transmission and distribution for both urban and rural grids.

Reliance on traditional biomass

Cooking a meal, a daily and routine task, can be a difficult chore and a danger to human health in some parts of the world. Today 2.5 billion people, or 37% of the world's population rely on biomass¹¹ as their primary fuel for cooking. Over half of those people live either in India or Sub-Saharan Africa.

Reliance on biomass often results in regular exposure to harmful emissions of carbon monoxide, hydrocarbons and particulate matter. The World Health Organization (WHO) estimates that 1.5 million premature deaths occur each year due to indoor air pollution from the use of solid fuels: it is estimated that indoor air pollution causes about 36% of lower respiratory infections and 22% of chronic respiratory disease (WHO, 2006). Women and children suffer most from indoor air pollution, because traditionally they are responsible for household chores. Also in regions reliant on biomass, women and children are typically responsible for fuel collection, an exhausting task that can result in long-term physical damage.

As incomes increase, fuel switching occurs from biomass to modern forms of energy, such as LPG or kerosene, and then gas and electricity. Nonetheless, higher income does not guarantee access to modern fuels. Limited availability and reliability of supply of alternative fuels can prevent or limit the transition.

In the Reference Scenario, the number of people depending on biomass for cooking is expected to rise to around 2.7 billion in 2020, before stabilising close to that level for the remainder of the *Outlook* period. However, these global trends mask significant changes at the country/regional level. The number of people depending on biomass increases steadily in Sub-Saharan Africa, from 608 million today to 765 million in 2030, by which time 30% of the people using biomass worldwide live in the region. In developing Asia, the number of people using biomass increases from 678 million today to 731 million in 2030. In contrast, in China the number of people reliant on biomass has already peaked and continues to decline through to 2030. In India the number of people depending on biomass declines after 2020 as the country (like China) experiences a gradual transition towards modern fuels.

11. Biomass includes animal dung, roots, agriculture residues and fuel wood.