# Global Energy Trends and the Challenge of Transforming the Global Energy System

**BACKGROUND PAPER BY THE**

**INTERNATIONAL ENERGY AGENCY FOR THE**

**12TH INTERNATIONAL ENERGY FORUM MINISTERIAL MEETING**

***Cancun, 29-31 March 2010***

## Key Points

- Oil market volatility, such as that seen in 2008, remains of concern to both government and industry leaders. Low price elasticity for both supply and demand can mean big price swings when the market is tight. Rendering supply and demand more responsive to price signals by facilitating investment and ensuring the more efficient feed-through of market prices could reduce the amplitude of price swings. The impact of market expectations for the future can also be amplified if they result in increased financial flows into commodities. More research is needed into physical/financial market linkages, alongside greater oversight of financial markets themselves and improved transparency on both physical and financial market drivers.
- Global energy use declined in late 2008 and 2009 for the first time since 1981. But, longer-term, current policies suggest world energy demand will increase by 40% by 2030 – up 1.5% per year. Under the IEA *World Energy Outlook* Reference Scenario, fossil fuels will remain the dominant energy source, accounting for 77% of the overall increase. 90% of incremental demand comes from non-OECD countries, led by China, India and the Middle East. Oil remains the single largest fuel.
- Increased investment in all parts of the energy value chain will be essential: $26 trillion (in 2008 dollars) by 2030, with 23% of this for oil and 20% for gas. Investment fell sharply in 2009, although recent company announcements suggest that many projects are now back on the drawing board. But our field-by-field analyses of oil and gas production profiles (published in 2008 and 2009, respectively) show that, just to make up for post-peak decline rates, huge additional investment will be needed in both sectors.
- By 2030, the Reference Scenario bears increasing risks for energy security and has alarming implications for greenhouse gas emissions. Many countries and regions become significantly more dependent on oil imports and, to a lesser degree, on gas. Furthermore, the growing concentration of demand in the transport sector – where price elasticity is low – risks increasing market volatility. We also see a rapid rise in $CO_2$ emissions (particularly from increased consumption of coal), reaching 40 Gt by 2030 – entailing an eventual mean global temperature rise of 6°C.
- We have modelled an alternative low-carbon scenario which affords a 50/50 chance of limiting the global temperature rise to 2°C (consistent with the Copenhagen Accord of December 2009). Stabilising greenhouse gases in the atmosphere at about 450 ppm $CO_2$ equivalent through a realistic combination of policy measures by governments leaves demand for all fuels (except coal) slightly higher in 2030 than today – but significantly lower than in our Reference Scenario. Nevertheless, the call on OPEC still reaches 48 mb/d – an increase of 11 mb/d over the level in 2008, while gas demand rises by 17% by 2030 with inter-regional gas trade also continuing to grow.
- Expanding access to modern energy for the world's poor remains a pressing matter. The IEA estimates that 1.5 billion people still lack access to electricity. With appropriate policies, universal electricity access could be achieved with additional annual investment worldwide of $35 bn (in 2008 dollars) through to 2030, or just 6% of the power sector investment projected under the Reference Scenario. The accompanying increase in primary energy demand and $CO_2$ emissions would be very modest.
- Both producers and consumers of energy face the urgent need to move to a more sustainable course for the global energy system. Ensuring this historic energy transition will not be possible without using all opportunities to enhance international cooperation and dialogue, where the International Energy Forum plays such an important role. Only that way can we help to ensure cleaner, more stable and secure energy markets for the future.

# *Global Energy Trends and the Challenge of Transforming the Global Energy System*

## Introduction

It has been a turbulent two years for the global energy sector since the last Ministerial meeting of the International Energy Forum (IEF) in April 2008. The crisis in financial markets and the economic recession reversed the growth in global energy demand and caused investment in the energy sector to plunge in 2009. While oil market volatility has subsequently receded, another roller-coaster for prices between September 2008 and June 2009, alongside a loss of public confidence in the functioning of financial markets, led to continuing concern about the relationship between physical and financial markets. Against a difficult economic backdrop, international efforts to combat climate change and global warming have intensified: the Copenhagen Accord reached in December 2009 sets a goal of limiting the global temperature increase to 2°C and implies a transformation in the way that the world produces and uses energy, but the policy debate is still open on how – and how quickly – this transformation can be realised.

The resulting uncertainty over perspectives for energy markets has affected all countries, including both energy consumers and energy producers. Energy investment needs to pick up quickly now that the current recession is ending to ensure continued and broadened access to reliable and secure energy – and to avoid a renewed tightening in supply as economies recover. Yet at the same time, policies and price signals need to encourage investments in a sustainable energy mix for the future, so that we do not lock in high-emissions technologies now that will make the fight against climate change much harder in the future.

The 12th IEF meeting presents an opportunity for Ministers to focus on a number of these pressing energy issues, from the dynamics driving energy markets, through the challenge of climate change and on to the continuing problem of energy poverty. But first it is important to review the trends underlying these recent developments, understand their implications for the future and then identify what action needs to be taken.

## Market and price volatility

In July 2008 -- only a few months after IEF Ministers met in Rome – marker crude prices breached $145 per barrel. By the end of the year they had plummeted to below $35 per barrel before rising again to around $70 by mid-2009. There were dramatic fluctuations also in natural gas prices, although the price trajectory differed by region and pricing mechanism, as well as in the markets for other fuels and products. This degree of intra-year volatility in global energy markets has been a matter of justifiable and deep concern for both governments and industry leaders and has prompted an animated debate about the causes.

Producers and consumers do not always have the same perspective on energy markets and finding explanations for price movements is never simple. In the view of the IEA, oil market fundamentals certainly played a central role in driving prices up and down: tight distillate supply and highly price-inelastic demand and supply combined to push up prices through to mid-2008, while the sudden weakening of demand in belated response to higher prices and, more importantly, the sudden deterioration in global economic conditions pushed prices back down through the rest of the year. Very low short-term price elasticities of demand and supply mean

that large and sudden changes in prices may be necessary to return the market to equilibrium in the event of even relatively small changes on either side of the market balance. Expectations about future market tightness likely contributed initially to stronger rises, while subsequent fears about the impact of the financial and economic crisis on oil demand in the medium term helped to drive prices lower.

At the same time, in today's markets oil is not only a physical commodity but is also a financial asset. The role of financial institutions in facilitating risk management by physical participants, in providing market liquidity and aiding price discovery, is well known. But there are also widespread concerns that actors in commodity financial markets played an amplifying role in driving oil prices to the record highs seen in summer 2008. While speculative activity may indeed augment prevailing price trends, the extent of this influence remains uncertain. Deeper and broader systematic reporting requirements for commodity financial trades are important to enable analysts to better discern the impact that financial markets have in energy price formation.

### *Oil price volatility; causes, impacts and potential remedies*

The IEA with the Institute of Energy Economics of Japan and the support of the Japanese Ministry of Economy, Trade and Industry held in Tokyo in February 2010 the third in a series of workshops on this issue. The workshop brought together around 85 participants, including financial market players, analysts, regulators, policy makers, oil producers and consumers (with strong participation from China and India) to discuss physical and financial market drivers, the impact of price volatility and potential policy responses.

Price swings and cyclicality are to some degree an inevitable part of a capital intensive and long lead-time industry. Indeed, prices are perhaps the surest and timeliest data point available with which to gauge the current state of the market and expectations for where it may be headed in future. But although globally, economies may be more resilient now to swings in oil prices than they were 30-40 years ago, excessive price swings and volatility in key commodity markets can be detrimental to producers as well as consumers. They may derail investment plans and worsen budgetary pressures in emerging importing countries.

It is important to note that there are policies and measures that can dampen price swings and these relate to the physical markets as well as financial ones. The workshop pointed to the importance of better operating markets and improved visibility both on current conditions and expectations for the market in the future. Forecasting agencies have a responsibility to ensure that the uncertainties inherent in any prediction of the future are made clear. Clear signals to consumers via the medium of market-driven domestic prices are also important. The workshop also highlighted once again the critical issue of data transparency as paramount for a better understanding of oil market dynamics. Improved data on oil reserves, supply, demand, refining and stocks are all key to a better grasp of market fundamentals, notably in the emerging markets that are now taking on a predominant role. Clearly, the JODI exercise will play a central role in this.

Improved oversight of commodity futures and derivatives markets at national and international level will also be crucial to help deepen understanding of the role of financial flows in influencing prices, while remaining mindful of the vital role of speculative capital in facilitating risk management, market liquidity and price discovery. More research is required to better understand the links between the physical and financial market. And finally, while markets would benefit from a more level investment playing-field and a clearer view of supply potential from producers, so too consumers need to coordinate and provide unambiguous blueprints of where energy efficiency and environmental policies are headed.

Better functioning, more predictable markets are in the interests of both producers and consumers. Environmental imperatives and efficiency gains are a win-win scenario for both, so long as these are clearly flagged. Physical resources are plentiful and oil will remain a key part of the global energy mix for decades to come. Tighter and more volatile markets are not inevitable if there is a will to ensure that timely investment is forthcoming to meet more clearly delineated future demand levels.

**Longer-term energy trends: current policies point to the continued predominance of fossil fuels**

Any investigation of the perspectives for reducing volatility in energy markets and ensuring adequate, affordable, reliable and sustainable energy supply requires also a view on longer-term energy market trends and investment needs. The IEA *World Energy Outlook (WEO)* 2009 provides such an analytical framework: the *Outlook's* Reference Scenario is a baseline vision of how energy markets are likely to evolve if there are no new energy-policy interventions by governments, given assumptions about economic growth, population, energy prices and technology. This is most definitely *not a forecast* of what will happen; the IEA does not expect governments to do nothing. However, it does provide a picture of how energy markets would evolve if the underlying trends in energy demand and supply are not changed.

This scenario suggests that, even though global energy use decreased in late 2008 and 2009 for the first time on any significant scale since 1981, the world's demand for energy will quickly resume its long-term upward trend once recovery is underway on current policies. Global primary energy demand in 2030 is projected to reach 16.8 billion tonnes of oil equivalent (toe) — an overall increase of 40% on 2007 and an average annual increase of 1.5% per year.

***Overview of key oil price and GDP growth assumptions in the IEA World Energy Outlook 2009***

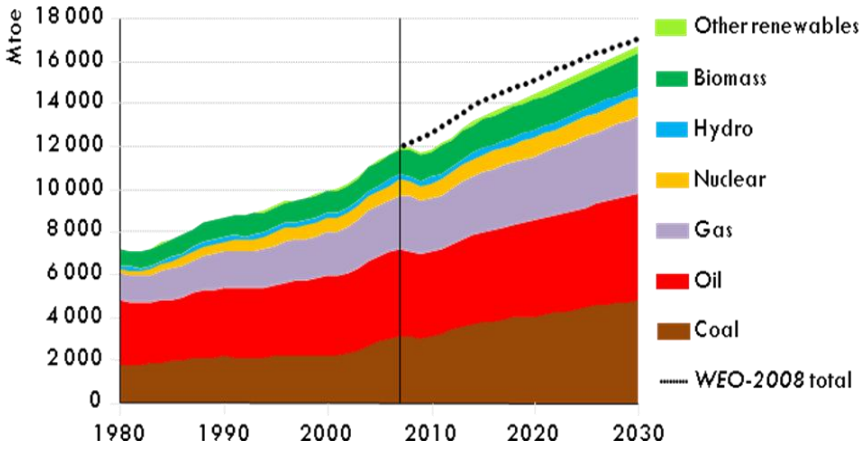
The average IEA crude oil import price, a proxy for international prices, is assumed in the Reference Scenario to fall from the 2008 level of $97 per barrel to around $60 per barrel in 2009 (roughly the level of mid-2009) and then recover with the economic recovery to reach $100 per barrel by 2020 and $115 per barrel by 2030 in year-2008 dollars. In nominal terms, prices roughly triple between 2009 and 2030, reaching almost $190 per barrel. In the alternative 450 Scenario (see below), prices are assumed to follow the same trajectory as in the Reference Scenario to 2015 and then remain flat to 2030, due to weaker demand. Prices are 10% lower than in the Reference Scenario in 2020 and 22% lower in 2030.

As always, there are acute risks to these assumptions on both sides: the timing and pace of economic recovery and, therefore, the rebound in oil demand remain highly uncertain, as do the levels of investment in oil production and refining capacity, and of dollar exchange rates.

The energy projections in the Outlook are also highly sensitive to underlying assumptions about GDP growth — the principal driver of demand for energy services. This Outlook took on board the latest available GDP growth projections from the IMF and the OECD; we assume that the global rate of growth for the period averages 3.1%. It starts much lower but recovers to 4.1% by 2015 and then turns down progressively through to 2030; this is a global average and the rates assumed for individual countries differ, with India and China expected to grow faster than other regions, followed by the Middle East.

Fossil fuels remain the dominant sources of primary energy worldwide in the Reference Scenario, accounting for almost 77% of the overall increase in energy demand between 2007 and 2030 (Figure 1). Oil is still the single largest fuel in the projected primary fuel mix in 2030, even though its share drops, from 34% to 30%. In volume terms, coal sees by far the biggest increase in demand over the projection period and it remains the second-largest fuel, its share increasing by two percentage points to 29%. The share of natural gas remains at around 21%. Non-hydro modern renewable energy technologies (including wind, solar, geothermal, tide and wave energy) see the fastest rate of increase in demand, but their share of total energy use still only nudges above 2% in 2030 — up from less than 1% today.

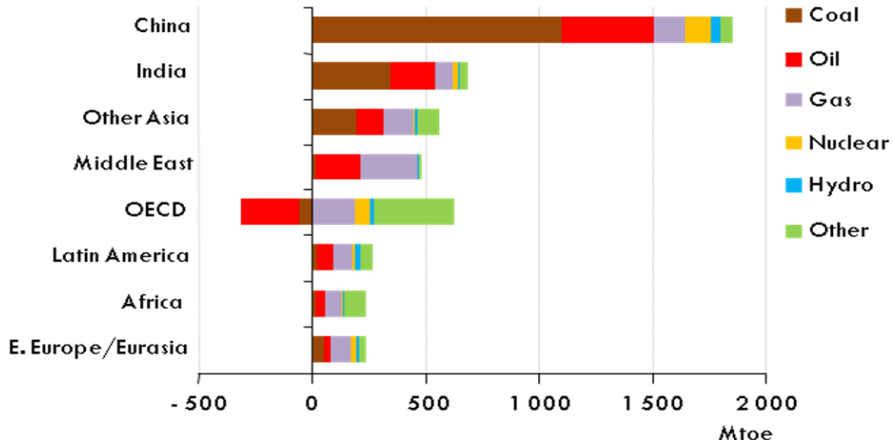
***Figure 1: World primary energy demand by fuel in the Reference Scenario***




The sources of incremental world primary energy demand during this period are overwhelmingly from outside the OECD: non-OECD countries account for over 90% of the increase between 2007 and 2030 and see their share of world demand grow from 52% to 63%. Non-OECD countries collectively overtook the OECD in 2005 as the biggest energy consumers: the increase in the share of non-OECD regions in world demand results from their more rapid economic and population growth, and comes despite the increases in real prices to final consumers that result from rising international prices and assumed reductions in subsidies. Industrialisation and urbanisation boost demand for modern commercial fuels.

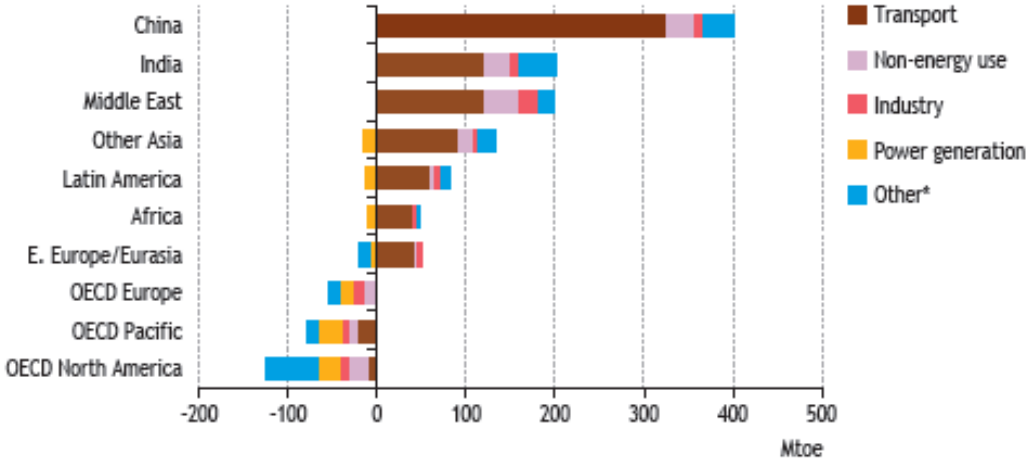
China and India are the main drivers of non-OECD demand growth, accounting for 39% and 16%, respectively, of the global increase in primary energy use (Figure 2). China's primary energy demand almost doubles between 2007 and 2030 to 3.8 billion toe — a far bigger increase than that of any other country or region. The bulk of the increase is in the form of coal, which remains the leading fuel for power generation. Non-OECD countries account for all of the increase in oil demand in 2007-2030 and overtake North America in terms of aggregate oil consumption. Outside of Asia, the Middle East sees the fastest rate of increase in energy demand, with a particularly sharp increase in demand for natural gas for power generation, for use in heavy industry and for feedstock.

***Figure 2: Incremental primary energy demand by fuel and region in the Reference Scenario, 2007-2030***



Transport accounts for 97% of the increase in world primary oil use between 2007 and 2030 (Figure 3). The transport sector is the main driver of oil demand in every region where demand grows. The exception is the OECD, where oil demand is projected to drop significantly in all three regions (North America, Europe and Pacific) due to major efficiency gains in the transport sector (which offset a further modest expansion of the car fleet) and continued switching away from oil in non-transport sectors. Nonetheless, based on demand per capita, the average annual energy consumption within the OECD remains significantly higher than in non-OECD countries in 2030 (4.4 toe in OECD versus 1.5 toe in non-OECD).

***Figure 3: Change in primary oil demand by region and sector in the Reference Scenario, 2007-2030***



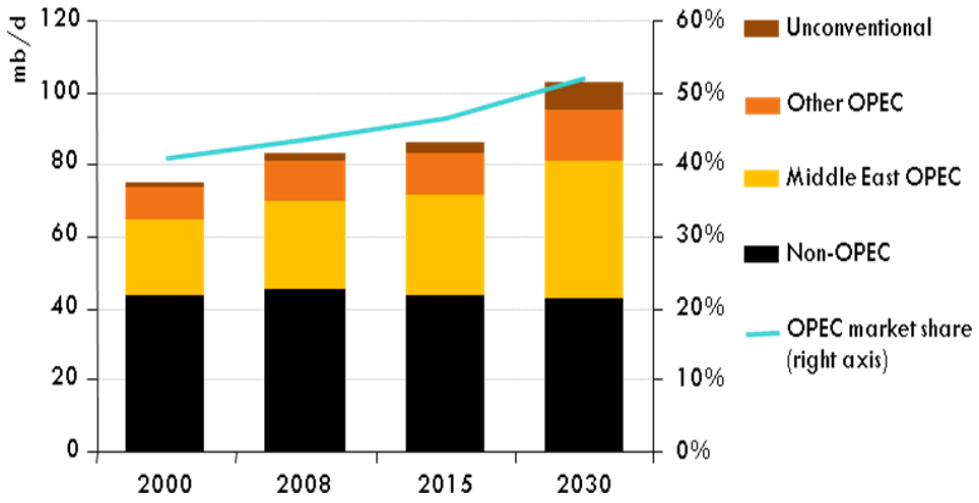

* Includes residential, services, agriculture and other energy sectors.

**An increased call on OPEC to meet the world's demand for oil**

Most of the projected increase in oil output to meet rising demand in the Reference Scenario comes from members of the Organization of the Petroleum Exporting Countries (OPEC), which hold the bulk of remaining proven oil reserves and ultimately recoverable resources. Their collective output of conventional crude oil, natural gas liquids (NGLs) and unconventional oil (mainly gas-to-liquids) rises from 36.3 mb/d in 2008 to just over 40 mb/d in 2015 and almost 54 mb/d in 2030 (Figure 4). As a result, OPEC's share of world oil production jumps from 44% now to 52% in 2030. It is also worth noting that by 2030 natural gas liquids (NGLs) would be equivalent to 20% of OPEC countries' total oil production – an increase in volume of nearly 4% per year.

Non-OPEC conventional production (crude oil and NGLs) is projected to peak around 2010 and then begin to decline slowly through to the end of the projection period. A continued decline in the number and size of new discoveries is expected to drive up marginal development costs. Production has already peaked in most non-OPEC countries and is expected to peak in most of the others before 2030 — despite an assumed steady increase in oil prices. Kazakhstan, Azerbaijan and Brazil are the only non-OPEC producing countries to see any significant increase in conventional output. However, the overall decline is more than offset by projections of rising output of unconventional oil. Unconventional sources of oil (mainly Canadian oil sands, extra-heavy oil, gas-to-liquids and coal-to-liquids) take a growing share of production, rising from 1.8 mb/d in 2008 to 7.4 mb/d in 2030.

*Figure 4: Oil production by source in the Reference Scenario*




***Unconventional gas production: a game-changer in North America – and elsewhere?***

The rapid rise in production of unconventional gas resources in the United States and Canada – alongside evidence that output held up remarkably well even as gas prices fell in 2009 – has transformed the gas market outlook both in North America and in other parts of the world. Tight gas, coal-bed methane and shale gas have followed different routes from initial discovery to commercial exploitation, but the common factor has been the successful deployment of technologies that enable these resources to be produced at costs similar to those of conventional gas. In the Reference Scenario, total unconventional production worldwide rises in this scenario from 367 bcm in 2007 to 629 bcm in 2030, with much of the increase coming from the United States and Canada. Unconventional gas accounted for over 50% of total US gas production in 2008 and this share is projected to rise to around 60% by 2030.

This boom in unconventional gas production, together with the recession's effect on demand, is contributing to a glut of gas supply and the likelihood of an increase in spare gas transportation capacity, both for LNG and for pipelines, over the next few years. Although a resumption in gas demand growth from 2010 will eventually erode this spare capacity, in the shorter term the 'gas glut' could have far-reaching implications for the structure of gas markets and trade, and (assuming a gradual increase in oil prices over the same period) could put pressure on the way that gas prices are contractually linked to oil prices in continental Europe and Asia-Pacific.

Another uncertainty is the extent to which the experience of North America can be replicated in other parts of the world endowed with unconventional resources. Outside North America, unconventional gas resources are only starting to be appraised in any detail and production is still small. Some regions, including China, India, Australia and Europe, are thought to hold large resources, but their large-scale development will depend on gaining access to land for drilling operations, availability of water and infrastructure, and environmental regulations.

**Production declines from existing oil and gas fields plus high energy demand equals a formidable investment challenge**

Energy investment initially fell sharply in 2009 in the face of a tougher financing environment, weaker final demand and lower cash flow. In the oil and gas sector, many companies announced cutbacks in capital spending, as well as project delays and cancellations, mainly as a result of lower prices and cash flow, and demand uncertainties. After October 2008, over 20 planned large-scale upstream oil and gas projects, involving around 2 mb/d of oil production capacity,

were deferred or cancelled, mainly among the Canadian oil sands, although company announcements towards the end of 2009 and in early 2010 suggest that some of these projects are back on the drawing board after oil prices remained in a relatively steady price range of $60-80 per barrel and prospects for global economic recovery have improved. Upstream spending also shows signs of rising again in 2010 and falling costs in 2009 provided somewhat of an offset to lower spending.

The consequences of the temporary cutbacks in spending for the adequacy of oil and gas supply capacity in the medium term are uncertain. The risk of tightening capacity appears greatest for oil, although the outlook depends on how quickly demand recovers as the global economy emerges from recession and how investment levels rebound in the coming years. Our medium term market analysis however suggests that amid persistent constraints on the pace at which new productive capacity can be added, the path of economic recovery remains critical to oil market fundamentals through mid-decade: a reversion to trend global GDP growth of 3.2% per annum for 2009-2014 could see OPEC spare capacity fall back towards 3.5 mb/d by 2014, whereas 30% lower GDP growth in the event of a weaker recovery could see current levels of spare capacity between 6-7 mb/d being retained throughout. Moreover, a combination of accelerated investment and enhanced efficiency gains could also conceivably help sustain more comfortable levels of spare capacity, even with higher economic growth.

Taking a longer view to 2030, increased investment in all parts of the energy value chain will be essential if we are to avoid the prospect of renewed capacity shortages and market volatility. In the Reference Scenario, total cumulative energy investment requirements amount to $26 trillion (in year-2008 dollars) in the period 2008-2030, equal on average to $1.1 trillion per year. Over half of all investment is needed in non-OECD countries, where demand and production are projected to increase fastest. Total investment in the oil sector is 23% of the total ($5.9 trillion) mostly in the upstream to replace capacity that will become obsolete; investment in gas accounts for 20% ($5.1 trillion). The greatest overall needs are in the power sector ($13.7 trillion), with around half of this sum required for electricity generation and half for transmission and distribution networks.

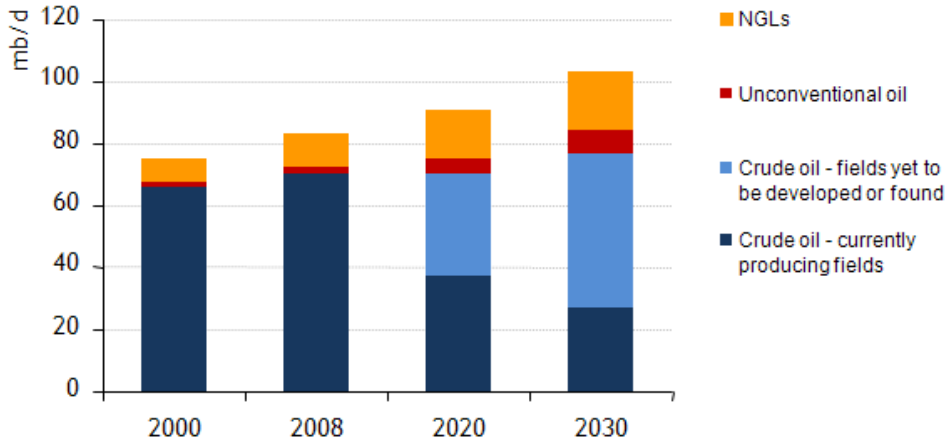
The size of the investment challenge in the oil and gas sectors is given a clearer focus by IEA analysis into decline rates for production from existing fields. Since the last International Energy Forum, the IEA has conducted detailed field-by-field analysis of oil and gas production trends. The analysis for oil was published in the 2008 *World Energy Outlook* and that for gas in the 2009 *WEO*.

The future rate of decline in output from producing oilfields as they mature is a critical determinant of the amount of new capacity and investment that will be needed to meet projected demand. We estimate that the average production-weighted observed decline rate worldwide is currently 6.7% per year for oil fields that have passed their production peak. This figure is derived from our analysis of production at 800 fields, including all 54 super-giants (holding more than 5 billion barrels) in production today. Decline rates are lowest for the biggest fields: they average 3.4% for super-giant fields, 6.5% for giant fields and 10.4% for large fields. Observed decline rates vary markedly by region; they are lowest in the Middle East and highest in the North Sea.

This analysis underlines the need for huge investments to explore for and develop more reserves, not only to meet additional demand but primarily to combat decline at existing fields. An additional 63 mb/d of gross capacity — the equivalent of over five times that of Saudi Arabia

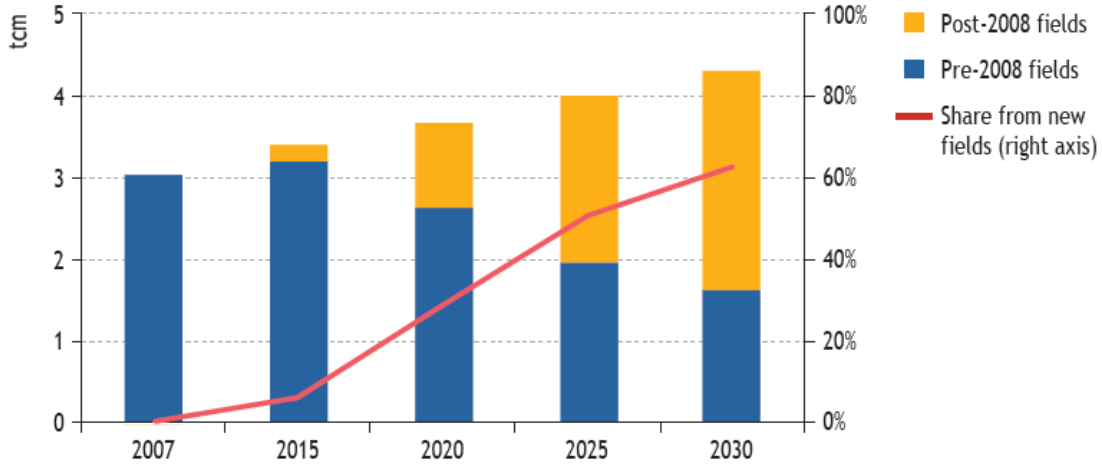
today — needs to be brought on stream between 2007 and 2030 to meet Reference Scenario projections. A faster rate of decline than projected here would sharply increase upstream investment needs and oil prices. Figure 5 below also shows the significant role played by natural gas liquids in allowing producers to meet growing global demand.

***Figure 5: World oil production by source in the Reference Scenario***




In the gas sector, too, the rate of decline in production from existing gas fields is the prime factor determining the amount of new capacity and investment needed to meet projected demand. We conducted a detailed, field-by-field analysis of the historical gas-production trends of nearly 600 fields, accounting for 55% of global production. Decline rates for gas fields once they have passed their peak are lower for the largest fields and higher for offshore fields than for onshore fields of similar size. Based on these figures and estimates of the size and age distribution of gas fields worldwide, the global production-weighted decline rate is 7.5% per year for all gas fields beyond their peak. This analysis indicates that the total gross capacity that needs to be added by 2030 in Reference Scenario is more than 2,700 bcm (Figure 6), which is around four times current Russian production. By then, only about one-third of total output comes from currently producing fields in the Reference Scenario, despite continuing investment in them.

***Figure 6: World natural gas production by field vintage in the Reference Scenario***



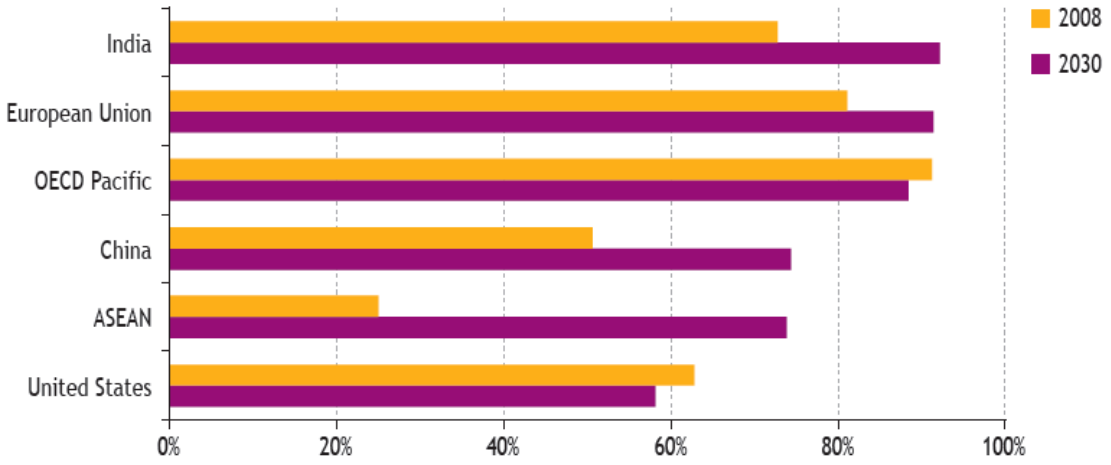

Note: Field vintage refers to the first year of significant production.

**Our current path puts us on course for increasing energy security concerns and alarming climate risks**

The energy outlook to 2030 envisioned by the Reference Scenario implies increasing risks to global energy security and alarming consequences for greenhouse emissions and our climate. Many countries and regions become significantly more reliant on oil imports, both in absolute terms and as a share of demand. The most dramatic shifts in oil import dependence are outside the OECD (Figure 7). In 2008, China passed a milestone with its oil imports exceeding domestic production for the first time; by 2030, China's net imports in the Reference Scenario are projected to reach 12 mb/d, comparable in volume to the current imports of the United States. The increase in dependence is also striking 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. This implies also an increasingly high level of spending on imports, with China overtaking the United States soon after 2025 to become the world's biggest spender on oil and gas imports, while India surpasses Japan around 2020 to become the world's third largest importer.

Dependence on imports in itself does not necessarily mean less secure energy supplies (just as self-sufficiency does not guarantee uninterrupted supply) and increased trade could bring mutual economic benefits. At the same time, the prevalence and seriousness of major oil-supply disruptions could grow as the world becomes increasingly dependent on supply sourced from a smaller 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. These choke points are typically in places that cannot easily be bypassed.

***Figure 7: Dependence on net oil imports by major region / country in the Reference Scenario***




The structure of the world's demand for oil in the Reference Scenario also increases the risk of continued market volatility. A growing concentration of oil demand in the transport sector is set to magnify the vulnerability of importing countries to price spikes. Opportunities for substituting

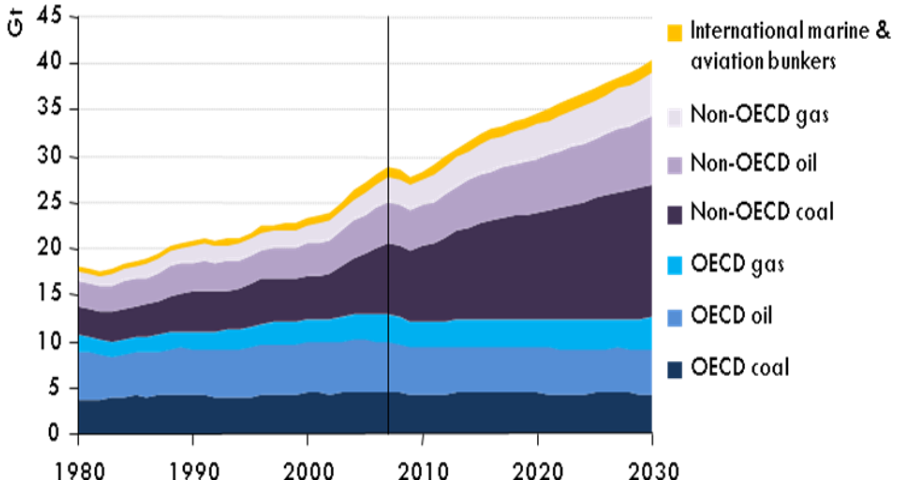
oil-based fuels in existing vehicles are limited and fuel demand tends to change very little in the near term in response to price increases. So for a given supply reduction, the price adjustment needed to bring global demand back into equilibrium is expected to increase. In other words, oil-price volatility will tend to rise as changes in the structure of demand lead to reduced price elasticities in global markets.

Market developments in the Reference Scenario would also have an impact on natural gas security, including rising import dependence in some of the key consuming and emerging markets and the globalisation of the gas market. Despite the short-term implications of the 'gas glut' (see box on unconventional gas production), gas demand resumes its long-term upwards trend in line with the assumed resumption of global economic growth from 2010 and both the European Union and developing Asia are expected to require a big increase in import volumes. 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. These effects can be mitigated in part by the growing share of liquefied natural gas (LNG) in global gas supply; LNG cargoes can be diverted at short notice to offset a sudden loss of supply from another source, but the majority of trade in gas will nonetheless continue to be through fixed pipeline infrastructure.

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. 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 new generation and transmission infrastructure sometimes causes delays and increases risks and costs for investors, and in some cases may totally prevent new investment. Regulatory complexity and uncertainty, especially as markets integrate over larger geographic areas, is a further inhibition.

Considerations of energy security alone are sufficient to warn us of the perils of continuing along a 'business-as-usual' path. But these factors seem small in comparison to the potential implications of our current path for greenhouse gas emissions and the global climate. The Reference Scenario sees a continued rapid rise in energy-related $CO_2$ 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 $CO_2$ emissions are projected to reach 34.5 Gt in 2020 and 40.2 Gt in 2030 — an average rate of growth of 1.5% per year over the full projection period. Per-capita emissions in OECD countries outstrip those of non-OECD countries by a factor of four, but this gap is closing rapidly. In the Reference Scenario, non-OECD countries account for all of the growth in emissions to 2030 (Figure 8); 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.

**Figure 8: Energy-related $CO_2$ emissions by fuel and region in the Reference Scenario**




The rapid increase in 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. According to our analysis, the greenhouse gas concentrations implied by the Reference Scenario would result in an eventual mean global temperature increase of up to 6 degrees Celsius. Studies summarised by the Intergovernmental Panel on Climate Change suggest that a temperature rise of this magnitude would lead almost certainly to massive climatic change and irreparable damage to the planet's biosphere.

### *The low-carbon technology challenge*

Many low-carbon technologies needed to bring the world on to a more sustainable energy future currently have higher costs than the incumbent technologies. It is only through technology learning from research, development, demonstration and deployment that these costs can be reduced and the technologies become economic. New technologies require, at some stage, both the push of research, development and demonstration and the pull of market deployment. Often, and particularly when a rapid transition is required, both the push and the pull have to be organised or supported by governments.

Some low-carbon technologies (such as onshore wind, biomass, third-generation nuclear power, hybrid vehicles and many energy-efficiency technologies) are already commercially available — but their widespread diffusion remains dependent on supportive policy measures. Several other technologies are not yet available for deployment (e.g. ultra-high efficiency or ultra-low cost PV devices and fourth generation nuclear power) and although they are not expected to be commercialised before 2030, they need research, development and demonstration now. The IEA's latest analysis on the prospects for different technologies will be published this summer in Energy Technology Perspectives 2010.

To help guide efforts to enhance the development and deployment of promising technologies, the IEA is developing a series of technology roadmaps. These roadmaps provide a solid analytical footing that enables the international community to move forward on specific low-carbon technologies. By taking a long-term perspective they also help to address the danger that activities or policies implemented in the short run do not contribute effectively to long term goals. Each roadmap outlines a vision for a particular technology from today to 2050, and identifies milestones – for technology development, financing, policy and public engagement – that need to be achieved to realise the technology's full potential. International collaboration will be critical to achieve these goals. The IEA is therefore also working with other international organisations on a low-carbon energy technology platform that will bring together policy makers, business representatives and technology experts from around the world to learn from each other how to design and implement strategies to accelerate the spread of roadmap technologies.

**An alternative low-carbon scenario: impact on future energy markets**

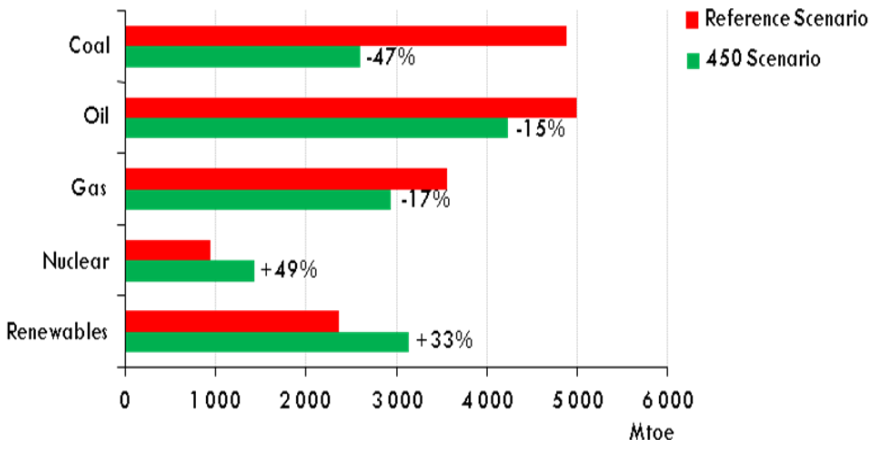
Although opinion is mixed on what might be considered a sustainable, long-term level of annual $CO_2$ emissions for the energy sector, the Copenhagen Accord recognises the need to limit the global temperature increase to below 2°C. To limit to 50% the probability of a global average temperature increase in excess of 2°C, the concentration of greenhouse gases in the atmosphere would need to be stabilised at a level around 450 ppm $CO_2$-equivalent.

In the *World Energy Outlook* 2009 we have shown how this objective could be achieved through radical and co-ordinated policy action across all regions in what we call the 450 Scenario. In this scenario, global energy-related $CO_2$ emissions peak at 30.9 Gt just before 2020 and decline thereafter to 26.4 Gt in 2030 — 2.4 Gt below the 2007 level and 13.8 Gt below that in the Reference Scenario. These reductions result from a plausible combination of policy instruments — notably carbon markets, sectoral agreements and national policies and measures — tailored to the circumstances of specific sectors and groups of countries. Only by taking advantage of mitigation potential in all sectors and regions can the necessary emission reductions be achieved.

In the 450 Scenario, primary energy demand grows by 20% between 2007 and 2030 – a reduction of around 14% compared with the Reference Scenario (Figure 9). End-use efficiency makes the largest contribution to $CO_2$ emissions abatement in the 450 Scenario by 2030, accounting for over half of total savings, followed by measures to 'de-carbonise' the power sector.

With the exception of coal, demand for all fuels is higher in 2030 than in 2007. Fossil fuels comprise 68% of global primary demand in 2030, down from over 80% in 2007; the share of zero-carbon fuels increases from 19% to 32% in 2030.

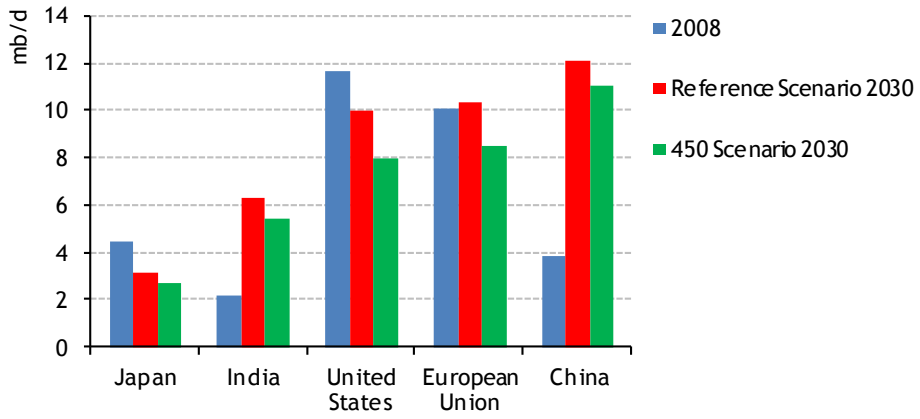
***Figure 9: World primary energy demand by fuel in the two scenarios***




Demand for oil grows on average by just 0.2% per year, reaching 89 mb/d in 2030. By 2020, an assumed sectoral agreement on carbon intensity in new passenger light-duty vehicles is responsible for two-thirds of global oil savings. After 2020, the development of second-generation biofuels achieves additional savings, alongside more widespread use of electric vehicles and plug-in hybrids.

The biggest savings in oil consumption, relative to the Reference Scenario, come in the United States, the European Union, China and the Middle East. By 2030, oil imports to the United States, the European Union and Japan are significantly lower than in 2007; imports into China and India continue to grow, but much less quickly than in the Reference Scenario (Figure 10).

***Figure 10: Net oil imports in selected regions by scenario***




In the 450 Scenario, world primary gas demand grows by 17% between 2007 and 2030, but is 17% lower in 2030 compared with the Reference Scenario. Measures to encourage energy savings, by improving the efficiency of gas use and encouraging low-carbon technologies, reduce gas demand and more than offset the enhanced competitiveness of gas against coal and oil in power generation and end-use applications that results from higher carbon prices and regulatory instruments. Inter-regional gas trade continues to grow, with Europe, China and India all importing significantly more than they do today (Table 1).

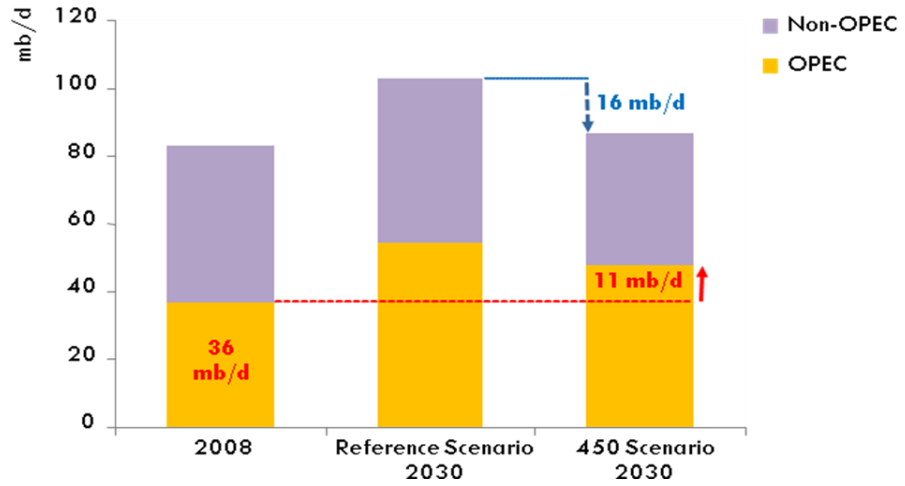
***Table 1: Net natural gas imports in key importing regions by scenario (bcm)***

| | 2007 Imports | 2020 Ref. Scenario Imports | 2020 450 Scenario Imports | 2030 Ref. Scenario Imports | 2030 450 Scenario Imports |
|---|---|---|---|---|---|
| United States | 114 | 50 | 78 | 43 | 61 |
| European Union | 312 | 425 | 391 | 516 | 428 |
| Japan | 97 | 99 | 88 | 106 | 94 |
| China | 4 | 49 | 40 | 117 | 91 |
| India | 10 | 28 | 24 | 52 | 63 |

**On the supply side**, lower global oil demand results in a lower oil price than in the Reference Scenario (see box on key *World Energy Outlook* assumptions, page 5). Coupled with the assumed introduction of $CO_2$ emissions targets in OECD and EU countries, this makes production in higher-cost fields uneconomic, particularly in the OECD and EU. Unconventional oil production

grows but only to 4.2 mb/d, 44% lower than in the Reference Scenario. By contrast, the economics of OPEC production remain largely unchanged, and OPEC output reaches 48 mb/d in 2030, an increase of 11 mb/d over 2008 levels (Figure 11).

***Figure 11: Oil production in the Reference and 450 Scenarios.***




**Investment needs and benefits of the 450 Scenario**

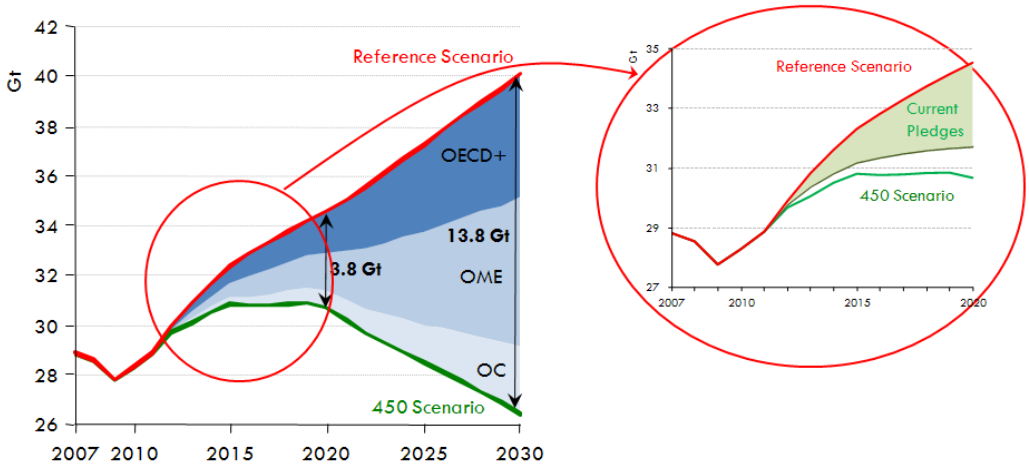
The 450 Scenario requires additional global investment in low-carbon energy technologies of close to $10.5 trillion in the period 2010-2030, relative to the Reference Scenario. Over 45% of these incremental investment needs are in the transport sector, much of which represents purchases of more efficient light-duty vehicles, in particular hybrid and electric cars. There is also additional investment of $1.75 trillion in power generation. Of the total investment in power generation (which amounts to $7.95 trillion, 28% higher than in the Reference Scenario), 60% goes to renewables, 16% to nuclear and 7% to carbon capture and storage. Other incremental investments are needed to improve the efficiency of buildings ($2.55 trillion), of industry ($1.05 trillion) and there is also a further $400 billion required for biofuels production, primarily for second-generation technologies.

The primary, immeasurable benefit of this Scenario is to humanity as a whole, by avoiding precipitate climate change. But there are also benefits to the energy sector that can be quantified in financial terms and considered against the substantial additional investment requirements. These benefits accrue in terms of savings on energy bills, energy security benefits and sharp reductions in air pollution relative to the Reference Scenario. For example, the oil and gas import bills of China and India are around 30% lower in the 450 Scenario compared to the Reference Scenario, both because of reduced import levels and because fossil-fuel prices are assumed to be lower. The reductions in air pollution are estimated to produce around $100 billion in savings on the cost of pollution control as well as very substantial health benefits.

### *How do Copenhagen pledges compare to the 450 Scenario?*

The IEA welcomes the Copenhagen Accord, which provides guidance on the next steps towards a legally-binding agreement on climate change. The Accord provides a clear environmental goal of limiting the increase in global temperature to below 2 degrees Celsius, calls for emissions to peak as early as possible as well as a collective commitment by developed countries to financially support developing country actions in mitigation and adaptation, and lays out the foundation for support to developing country actions, over and above their unilateral actions.

***Figure 12: Copenhagen pledges and the emission trajectory in the 450 Scenario***




However, IEA calculations show that emission reduction pledges to date fall short of what is needed to limit the long-term concentration of greenhouse gases in the atmosphere to 450 parts per million (ppm) of $CO_2$-equivalent, in line with a 2 degrees Celsius increase (Figure 12). Preliminary analysis by the IEA indicates that current pledges put us on track for a 550 ppm scenario, which is likely to see a long-term temperature rise of around 3 degrees Celsius.

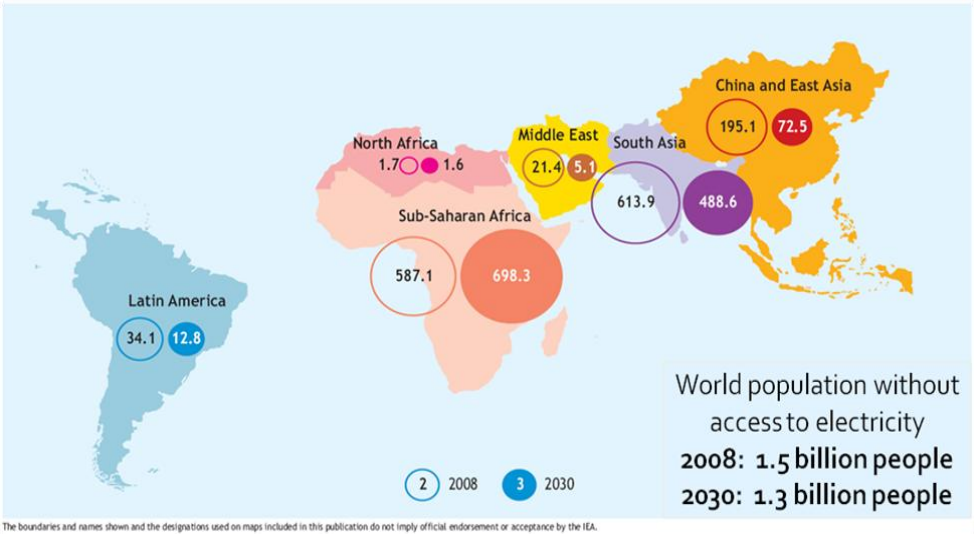
Producing countries are understandably concerned about how such a shift in global policies might affect demand for their exports and their revenues. But even in the 450 Scenario, global oil and gas demand continue to increase from today's levels. The effect on revenues for oil and gas exporters is mitigated in part by the increased availability of oil and gas for export as producing countries themselves take measures to curb domestic fossil-fuel use. So cumulative OPEC oil-export revenues in the 450 Scenario are projected at $23 trillion (in 2008 US dollars) between 2008 and 2030. This is $4 trillion less than in the Reference Scenario, but this figure should be weighed against the benefits enumerated above, which also accrue to citizens in producing countries.

**Expansion of access to energy is essential, under any scenario**

Expanding access to modern energy for the world's poor remains a pressing matter. We estimate that 1.5 billion people still lack access to electricity — well over one-fifth of the world's population. Some 85% of those people live in rural areas, mainly in Sub-Saharan Africa and South Asia. Since the issue of energy poverty was 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.

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. This is a decline of only around 200 million from today's figure. Unfortunately, this figure masks an increase in the number of people without electricity in Africa during this period (Figure 13).

**Figure 13: Number of people without access to electricity in the Reference Scenario (millions)**




Expanding access to modern energy is a necessary condition for human development. With appropriate policies, government and international support, universal electricity access by 2030 could be achieved. Additional power-sector investment worldwide of $35 billion per year on average would be required 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 to 2030. Almost 85% of the incremental investment would be needed in Sub-Saharan Africa and South Asia.

Compared to the Reference Scenario, this would result in higher global energy demand – but by less than 3%. Likewise, there would be an increase in global energy-related $CO_2$ emissions – but by 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, the increase in energy-related global $CO_2$ emissions would be a mere 0.9% by 2030.

### Importance of continued dialogue

Both producers and consumers of energy face the urgent need to move to a more sustainable course for the global energy system. We all share an interest in developing an energy system that can continue to support economic and human development while safeguarding the welfare and livelihoods of future generations.

The global economic recession has interrupted long-term energy trends and temporarily curbed the growth in greenhouse gas emissions; it has not changed the underlying picture or altered the underlying risks. Even as we continue to rely on fossil fuels for a large part of our future energy supply, only a major shift towards investment in greater efficiency and towards low-carbon technologies can bring about the transformation that we need. The 450 Scenario provides a vision of the policies and commitments that are required; and we can see that recent policy initiatives and pledges made in the framework of the Copenhagen Accord are an important step in the right direction. But much more needs to be done to get close to the emissions path consistent with stabilisation of the concentration of greenhouse gases in the atmosphere at 450 ppm and limiting the rise in global temperatures to *only* 2 degrees Celsius. The task of reaching this emissions path cannot be postponed: with every year that passes, the possibility to reach these climate goals becomes narrower and the costs of transforming the energy sector increase. Given the urgency of the situation, and the failure of markets to account for externalities like climate change and the difficulties that nascent technologies face in competing with established ones, governments must take the lead in charting this new path.

Undertaking such an energy transition will not be possible without using all opportunities to enhance international cooperation and dialogue. The International Energy Forum can help by developing ways for producers and consumers of energy to exchange information more effectively, by enhancing mutual understanding of policies and market perceptions as well as by furthering the common interest in promoting transparent, well-functioning energy markets. The IEA reaffirms its strong commitment to continue working with the IEF and our other partners in the Joint Oil Data Initiative and to extend our joint work to natural gas. We see our participation in the IEF and our dialogue with OPEC and other international partners as cornerstones of our efforts to ensure cleaner, more stable and secure energy markets for the future.