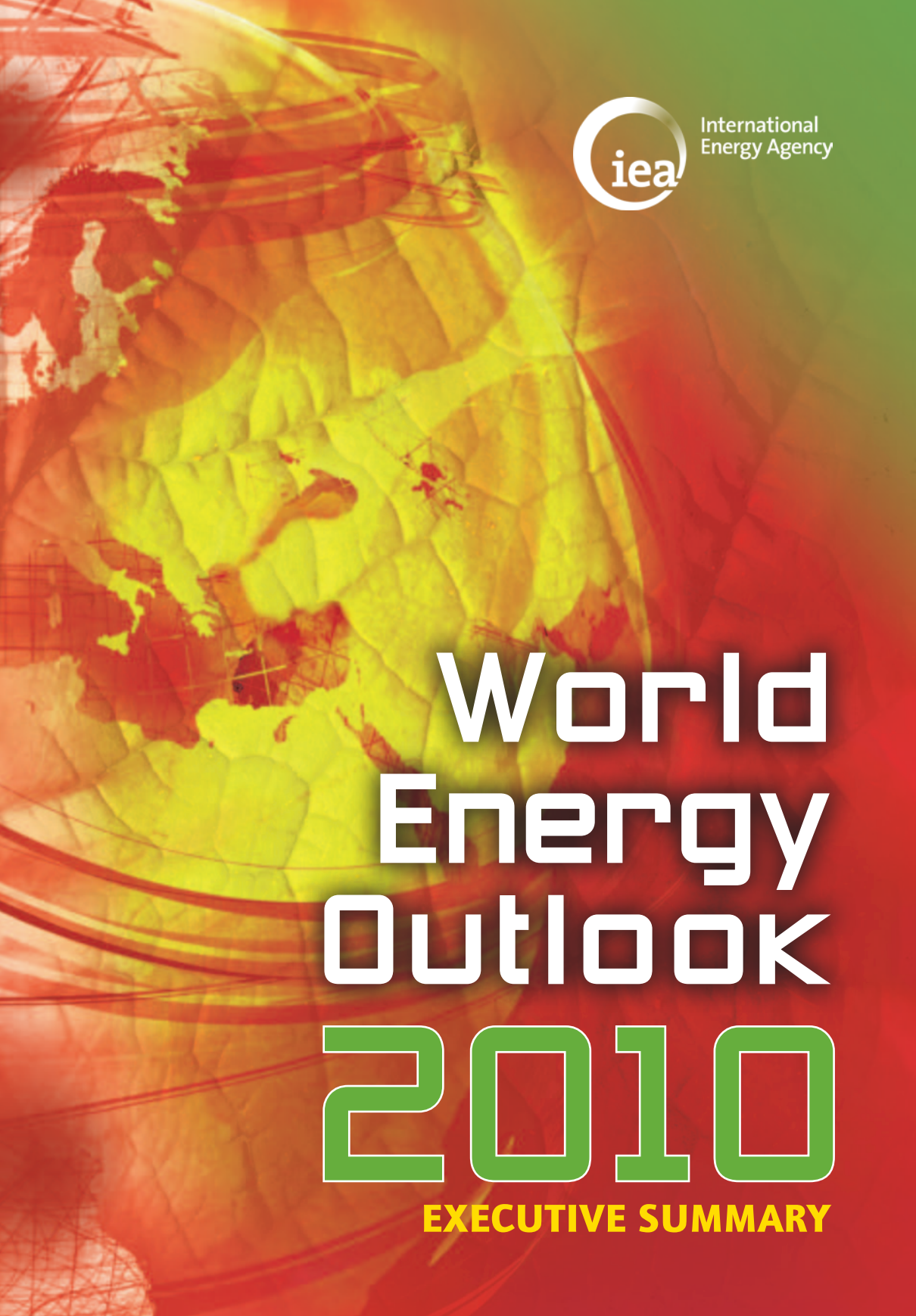
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World
Energy
Outlook
2010
EXECUTIVE SUMMARY

World Energy Outlook 2010

The world appears to be emerging from the worst economic crisis in decades. Many countries have made pledges under the Copenhagen Accord to reduce greenhouse-gas emissions. Commitments have also been made by the G-20 and APEC to phase out inefficient fossil-fuel subsidies. Are we, at last, on the path to a secure, reliable and environmentally sustainable energy system?

Updated projections of energy demand, production, trade and investment, fuel by fuel and region by region to 2035 are provided in the 2010 edition of the *World Energy Outlook* (*WEO*). It includes, for the first time, a new scenario that anticipates future actions by governments to meet the commitments they have made to tackle climate change and growing energy insecurity.

WEO-2010 shows:

- what more must be done and spent to achieve the goal of the **Copenhagen Accord** to limit the global temperature increase to 2°C and how these actions would **impact on oil markets**;
- how **emerging economies** – led by China and India – will increasingly **shape the global energy landscape**;
- what role **renewables** can play in a clean and secure energy future;
- what removing **fossil-fuel subsidies** would mean for energy markets, climate change and state budgets;
- the trends in **Caspian energy markets** and the implications for global energy supply;
- the prospects for **unconventional oil**; and
- how to give the entire global population **access to modern energy services**.

With extensive data, projections and analysis, *WEO-2010* provides invaluable insights into how the energy system could evolve over the next quarter of a century. The book is essential reading for anyone with a stake in the energy sector.

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International Energy Agency

World Energy Outlook 2010

EXECUTIVE SUMMARY

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its mandate is two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply and to advise member countries on sound energy policy.

The IEA carries out a comprehensive programme of energy co-operation among 28 advanced economies, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports.

The Agency aims to:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

IEA member countries:

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The European Commission also participates in the work of the IEA.

International Energy Agency

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The energy world faces unprecedented uncertainty. The global economic crisis of 2008-2009 threw energy markets around the world into turmoil and the pace at which the global economy recovers holds the key to energy prospects for the next several years. But it will be governments, and how they respond to the twin challenges of climate change and energy security, that will shape the future of energy in the longer term. The economic situation has improved considerably over the past 12 months, more than many dared to hope for. Yet the economic outlook for the coming years remains hugely uncertain, amid fears of a double-dip recession and burgeoning government budget deficits, making the medium-term outlook for energy unusually hard to predict with confidence. The past year has also seen notable steps forward in policy making, with the negotiation of important international agreements on climate change and on the reform of inefficient fossil-fuel subsidies. And the development and deployment of low-carbon technologies received a significant boost from stepped-up funding and incentives that governments around the world introduced as part of their fiscal stimulus packages. Together, these moves promise to drive forward the urgently needed transformation of the global energy system. But doubts remain about the implementation of recent policy commitments. Even if they are acted upon, much more needs to be done to ensure that this transformation happens quickly enough.

The outcome of the landmark UN conference on climate change held in December 2009 in Copenhagen was a step forward, but still fell a very long way short of what is required to set us on the path to a sustainable energy system. The Copenhagen Accord — with which all major emitting countries and many others subsequently associated themselves — sets a non-binding objective of limiting the increase in global temperature to two degrees Celsius (2°C) above pre-industrial levels. It also establishes a goal for the industrialised countries of mobilising funding for climate mitigation and adaptation in developing countries of $100 billion per year by 2020, and requires the industrialised countries to set emissions targets for the same year. This followed a call from G8 leaders at their July 2009 summit to share with all countries the goal of cutting global emissions by at least 50% by 2050. But the commitments that were subsequently announced, even if they were to be fully implemented, would take us only part of the way towards an emissions trajectory that would allow us to achieve the 2°C goal. That does not mean that the goal is completely out of reach. But it does mean that much stronger efforts, costing considerably more, will be needed after 2020. Indeed, the speed of the energy transformation that would need to occur after 2020 is such as to raise serious misgivings about the practical achievability of cutting emissions sufficiently to meet the 2°C goal.

The commitment made by G-20 leaders meeting in the US city of Pittsburgh in September 2009 to "rationalize and phase out over the medium term inefficient fossil-fuel subsidies that encourage wasteful consumption" has the potential to, at least partly, balance the disappointment at Copenhagen. This commitment was

made in recognition that subsidies distort markets, can impede investment in clean energy sources and can thereby undermine efforts to deal with climate change. The analysis we have carried out in collaboration with other international organisations at the request of G-20 leaders, and which is set out in this *Outlook*, shows that removing fossil-fuel consumption subsidies, which totalled $312 billion in 2009, could make a big contribution to meeting energy-security and environmental goals, including mitigating carbon-dioxide (CO_2) and other emissions.

Recently announced policies, if implemented, would make a difference

The world energy outlook to 2035 hinges critically on government policy action, and how that action affects technology, the price of energy services and end-user behaviour. In recognition of the important policy advances that have been made recently, the central scenario in this year's *Outlook* — the *New Policies Scenario* — takes account of the broad policy commitments and plans that have been announced by countries around the world, including the national pledges to reduce greenhouse-gas emissions and plans to phase out fossil-energy subsidies even where the measures to implement these commitments have yet to be identified or announced. These commitments are assumed to be implemented in a relatively cautious manner, reflecting their non-binding character and, in many cases, the uncertainty shrouding how they are to be put into effect. This scenario allows us to quantify the potential impact on energy markets of implementation of those policy commitments, by comparing it with a *Current Policies Scenario* (previously called the *Reference Scenario*), in which no change in policies as of mid-2010 is assumed, *i.e.* that recent commitments are not acted upon. We also present the results of the *450 Scenario*, which was first presented in detail in *WEO-2008*, which sets out an energy pathway consistent with the 2°C goal through limitation of the concentration of greenhouse gases in the atmosphere to around 450 parts per million of CO_2 equivalent (ppm CO_2-eq).

The policy commitments and plans that governments have recently announced would, if implemented, have a real impact on energy demand and related CO_2 emissions. In the New Policies Scenario, world primary energy demand increases by 36% between 2008 and 2035, from around 12 300 million tonnes of oil equivalent (Mtoe) to over 16 700 Mtoe, or 1.2% per year on average. This compares with 2% per year over the previous 27-year period. The projected rate of growth in demand is lower than in the Current Policies Scenario, where demand grows by 1.4% per year over 2008-2035. In the 450 Scenario, demand still increases between 2008 and 2035, but by only 0.7% per year. Energy prices ensure that projected supply and demand are in balance throughout the *Outlook* period in each scenario, rising fastest in the Current Policies Scenario and slowest in the 450 Scenario. Fossil fuels — oil, coal and natural gas — remain the dominant energy sources in 2035 in all three scenarios, though their share of the overall primary fuel mix varies markedly. The shares of renewables and nuclear power are correspondingly highest in the 450 Scenario and lowest in the Current Policies Scenario. The range of outcomes — and therefore the uncertainty with respect to future energy use — is largest for coal, nuclear power and non-hydro renewable energy sources.

Emerging economies, led by China and India, will drive global demand higher

In the New Policies Scenario, global demand for each fuel source increases, with fossil fuels accounting for over one-half of the increase in total primary energy demand. Rising fossil-fuel prices to end users, resulting from upward price pressures on international markets and increasingly onerous carbon penalties, together with policies to encourage energy savings and switching to low-carbon energy sources, help to restrain demand growth for all three fossil fuels. Oil remains the dominant fuel in the primary energy mix during the *Outlook* period, though its share of the primary fuel mix, which stood at 33% in 2008, drops to 28% as high prices and government measures to promote fuel efficiency lead to further switching away from oil in the industrial and power-generation sectors, and new opportunities emerge to substitute other fuels for oil products in transport. Demand for coal rises through to around 2020 and starts to decline towards the end of the *Outlook* period. Growth in demand for natural gas far surpasses that for the other fossil fuels due to its more favourable environmental and practical attributes, and constraints on how quickly low-carbon energy technologies can be deployed. The share of nuclear power increases from 6% in 2008 to 8% in 2035. The use of modern renewable energy — including hydro, wind, solar, geothermal, modern biomass and marine energy — triples over the course of the *Outlook* period, its share in total primary energy demand increasing from 7% to 14%. Consumption of traditional biomass rises slightly to 2020 and then falls back to just below current levels by 2035, with increased use of modern fuels by households in the developing world.

Non-OECD countries account for 93% of the projected increase in world primary energy demand in the New Policies Scenario, reflecting faster rates of growth of economic activity, industrial production, population and urbanisation. China, where demand has surged over the past decade, contributes 36% to the projected growth in global energy use, its demand rising by 75% between 2008 and 2035. By 2035, China accounts for 22% of world demand, up from 17% today. India is the second-largest contributor to the increase in global demand to 2035, accounting for 18% of the rise, its energy consumption more than doubling over the *Outlook* period. Outside Asia, the Middle East experiences the fastest rate of increase, at 2% per year. Aggregate energy demand in OECD countries rises very slowly over the projection period. Nonetheless, by 2035, the United States is still the world's second-largest energy consumer behind China, well ahead of India (in a distant third place).

It is hard to overstate the growing importance of China in global energy markets. Our preliminary data suggest that China overtook the United States in 2009 to become the world's largest energy user. Strikingly, Chinese energy use was only half that of the United States in 2000. The increase in China's energy consumption between 2000 and 2008 was more than four times greater than in the previous decade. Prospects for further growth remain strong, given that China's per-capita consumption level remains low, at only one-third of the OECD average, and that it is the most populous nation on the planet, with more than 1.3 billion people. Consequently, the global energy projections in this *Outlook* remain highly sensitive to the underlying assumptions for the key variables that drive energy demand in China, including prospects for economic

growth, changes in economic structure, developments in energy and environmental policies, and the rate of urbanisation. The country's growing need to import fossil fuels to meet its rising domestic demand will have an increasingly large impact on international markets. Given the sheer scale of China's domestic market, its push to increase the share of new low-carbon energy technologies could play an important role in driving down their costs through faster rates of technology learning and economies of scale.

Will peak oil be a guest or the spectre at the feast?

The oil price needed to balance oil markets is set to rise, reflecting the growing insensitivity of both demand and supply to price. The growing concentration of oil use in transport and a shift of demand towards subsidised markets are limiting the scope for higher prices to choke off demand through switching to alternative fuels. And constraints on investment mean that higher prices lead to only modest increases in production. In the New Policies Scenario, the average IEA crude oil price reaches $113 per barrel (in year-2009 dollars) in 2035 — up from just over $60 in 2009. In practice, short-term price volatility is likely to remain high. Oil demand (excluding biofuels) continues to grow steadily, reaching about 99 million barrels per day (mb/d) by 2035 — 15 mb/d higher than in 2009. All of the net growth comes from non-OECD countries, almost half from China alone, mainly driven by rising use of transport fuels; demand in the OECD falls by over 6 mb/d. Global oil production reaches 96 mb/d, the balance of 3 mb/d coming from processing gains. Crude oil output reaches an undulating plateau of around 68-69 mb/d by 2020, but never regains its all-time peak of 70 mb/d reached in 2006, while production of natural gas liquids (NGLs) and unconventional oil grows strongly.

Total OPEC production rises continually through to 2035 in the New Policies Scenario, boosting its share of global output to over one-half. Iraq accounts for a large share of the increase in OPEC output, commensurate with its large resource base, its crude oil output catching up with Iran's by around 2015 and its total output reaching 7 mb/d by 2035. Saudi Arabia regains from Russia its place as the world's biggest oil producer, its output rising from 9.6 mb/d in 2009 to 14.6 mb/d in 2035. The increasing share of OPEC contributes to the growing dominance of national oil companies: as a group, they account for all of the increase in global production between 2009 and 2035. Total non-OPEC oil production is broadly constant to around 2025, as rising production of NGLs and unconventional oil offsets a fall in that of crude oil; thereafter, total non-OPEC output starts to drop. The size of ultimately recoverable resources of both conventional and unconventional oil is a major source of uncertainty for the long-term outlook for world oil production.

Clearly, global oil production will peak one day, but that peak will be determined by factors affecting both demand and supply. In the New Policies Scenario, production in total does *not* peak before 2035, though it comes close to doing so. By contrast, production does peak, at 86 mb/d, just before 2020 in the 450 Scenario, as a result of weaker demand, falling briskly thereafter. Oil prices are much lower as a result. The message is clear: if governments act more vigorously than currently planned to encourage

more efficient use of oil and the development of alternatives, then demand for oil might begin to ease soon and, as a result, we might see a fairly early peak in oil production. That peak would not be caused by resource constraints. But if governments do nothing or little more than at present, then demand will continue to increase, supply costs will rise, the economic burden of oil use will grow, vulnerability to supply disruptions will increase and the global environment will suffer serious damage.

Unconventional oil is abundant but more costly

Unconventional oil is set to play an increasingly important role in world oil supply through to 2035, regardless of what governments do to curb demand. In the New Policies Scenario, output rises from 2.3 mb/d in 2009 to 9.5 mb/d in 2035. Canadian oil sands and Venezuelan extra-heavy oil dominate the mix, but coal-to-liquids, gas-to-liquids and, to a lesser extent, oil shales also make a growing contribution in the second half of the *Outlook* period. Unconventional oil resources are thought to be huge — several times larger than conventional oil resources. The rate at which they will be exploited will be determined by economic and environmental considerations, including the costs of mitigating their environmental impact. Unconventional sources of oil are among the more expensive available: they require large upfront capital investment, which is typically paid back over long periods. Consequently, they play a key role in setting future oil prices.

The production of unconventional oil generally emits more greenhouse gases per barrel than that of most types of conventional oil, but, on a well-to-wheels basis, the difference is much less, as most emissions occur at the point of use. In the case of Canadian oil sands, well-to-wheels CO_2 emissions are typically between 5% and 15% higher than for conventional crude oils. Mitigation measures will be needed to reduce emissions from unconventional oil production, including more efficient extraction technologies, carbon capture and storage and, with coal-to-liquids plants, the addition of biomass to the coal feedstock. Improved water and land management, though not unique to unconventional sources, will also be required to make the development of these resources and technologies more acceptable.

China could lead us into a golden age for gas

Natural gas is certainly set to play a central role in meeting the world's energy needs for at least the next two-and-a-half decades. Global natural gas demand, which fell in 2009 with the economic downturn, is set to resume its long-term upward trajectory from 2010. It is the only fossil fuel for which demand is higher in 2035 than in 2008 in all scenarios, though it grows at markedly different rates. In the New Policies Scenario, demand reaches 4.5 trillion cubic metres (tcm) in 2035 — an increase of 1.4 tcm, or 44%, over 2008 and an average rate of increase of 1.4% per year. China's demand grows fastest, at an average rate of almost 6% per year, and the most in volume terms, accounting for more than one-fifth of the increase in global demand to 2035. There is potential for Chinese gas demand to grow even faster than this, especially if coal use is restrained for environmental reasons. Demand in the

Middle East increases almost as much as projected in China. The Middle East, which is well-endowed with relatively low-cost resources, leads the expansion of gas production over the *Outlook* period, its output doubling to 800 billion cubic metres (bcm) by 2035. Around 35% of the global increase in gas production in the New Policies Scenario comes from unconventional sources — shale gas, coalbed methane and tight gas — in the United States and, increasingly, from other regions, notably Asia-Pacific.

The glut of global gas-supply capacity that has emerged as a result of the economic crisis (which depressed gas demand), the boom in US unconventional gas production and a surge in liquefied natural gas (LNG) capacity, could persist for longer than many expect. Based on projected demand in the New Policies Scenario, we estimate that the glut, measured by the difference between the volumes actually traded and total capacity of inter-regional pipelines and LNG export plants, amounted to about 130 bcm in 2009; it is set to reach over 200 bcm in 2011, before starting a hesitant decline. This glut will keep the pressure on gas exporters to move away from oil-price indexation, notably in Europe, which could lead to lower prices and to stronger demand for gas than projected, especially in the power sector. In the longer term, the increasing need for imports — especially in China — will most likely drive up capacity utilisation. In the New Policies Scenario, gas trade between all *WEO* regions expands by around 80%, from 670 bcm in 2008 to 1 190 bcm in 2035. Well over half of the growth in gas trade takes the form of LNG.

A profound change in the way we generate electricity is at hand

World electricity demand is expected to continue to grow more strongly than any other final form of energy. In the New Policies Scenario, it is projected to grow by 2.2% per year between 2008 and 2035, with more than 80% of the increase occurring in non-OECD countries. In China, electricity demand triples between 2008 and 2035. Over the next 15 years, China is projected to add generating capacity equivalent to the current total installed capacity of the United States. Globally, gross capacity additions, to replace obsolete capacity and to meet demand growth, amount to around 5 900 gigawatts (GW) over the period 2009-2035 — 25% more than current installed capacity; more than 40% of this incremental capacity is added by 2020.

Electricity generation is entering a period of transformation as investment shifts to low-carbon technologies — the result of higher fossil-fuel prices and government policies to enhance energy security and to curb emissions of CO_2. In the New Policies Scenario, fossil fuels — mainly coal and natural gas — remain dominant, but their share of total generation drops from 68% in 2008 to 55% in 2035, as nuclear and renewable sources expand. The shift to low-carbon technologies is particularly marked in the OECD. Globally, coal remains the leading source of electricity generation in 2035, although its share of electricity generation declines from 41% now to 32%. A big increase in non-OECD coal-fired generation is partially offset by a fall in OECD countries. Gas-fired generation grows in absolute terms, mainly in the non-OECD, but maintains a stable share of world electricity generation at around 21% over the *Outlook* period. The share of nuclear power in generation increases only marginally, with more than 360 GW of new additions over the period and extended lifetime for several plants.

Globally, the shift to nuclear power, renewables and other low-carbon technologies is projected to reduce the amount of CO_2 emitted per unit of electricity generated by one-third between 2008 and 2035.

The future of renewables hinges critically on strong government support

Renewable energy sources will have to play a central role in moving the world onto a more secure, reliable and sustainable energy path. The potential is unquestionably large, but how quickly their contribution to meeting the world's energy needs grows hinges critically on the strength of government support to make renewables cost-competitive with other energy sources and technologies, and to stimulate technological advances. The need for government support would increase were gas prices to be lower than assumed in our analysis.

The greatest scope for increasing the use of renewables in absolute terms lies in the power sector. In the New Policies Scenario, renewables-based generation triples between 2008 and 2035 and the share of renewables in global electricity generation increases from 19% in 2008 to almost one-third (catching up with coal). The increase comes primarily from wind and hydropower, though hydropower remains dominant over the *Outlook* period. Electricity produced from solar photovoltaics increases very rapidly, though its share of global generation reaches only around 2% in 2035. The share of modern renewables in heat production in industry and buildings increases from 10% to 16%. The use of biofuels grows more than four-fold between 2008 and 2035, meeting 8% of road transport fuel demand by the end of the *Outlook* period (up from 3% now). Renewables are generally more capital-intensive than fossil fuels, so the investment needed to provide the extra renewables capacity is very large: cumulative investment in renewables to produce electricity is estimated at $5.7 trillion (in year-2009 dollars) over the period 2010-2035. Investment needs are greatest in China, which has now emerged as a leader in wind power and photovoltaic production, as well as a major supplier of the equipment. The Middle East and North Africa region holds enormous potential for large-scale development of solar power, but there are many market, technical and political challenges that need to be overcome.

Although renewables are expected to become increasingly competitive as fossil-fuel prices rise and renewable technologies mature, the scale of government support is set to expand as their contribution to the global energy mix increases. We estimate that government support worldwide for both electricity from renewables and for biofuels totalled $57 billion in 2009, of which $37 billion was for the former. In the New Policies Scenario, total support grows to $205 billion (in year-2009 dollars), or 0.17% of global GDP, by 2035. Between 2010 and 2035, 63% of the support goes to renewables-based electricity. Support per unit of generation on average worldwide drops over time, from $55 per megawatt-hour (MWh) in 2009 to $23/MWh by 2035, as wholesale electricity prices increase and their production costs fall due to technological learning. This does not take account of the additional costs of integrating them into the network, which can be significant because the variability of some types of renewables, such as wind and solar energy. Government support for renewables can, in principle,

be justified by the long-term economic, energy-security and environmental benefits they can bring, though attention needs to be given to the cost-effectiveness of support mechanisms.

The use of biofuels — transport fuels derived from biomass feedstock — is expected to continue to increase rapidly over the projection period, thanks to rising oil prices and government support. In the New Policies Scenario, global biofuels use increases from about 1 mb/d today to 4.4 mb/d in 2035. The United States, Brazil and the European Union are expected to remain the world's largest producers and consumers of biofuels. Advanced biofuels, including those from lignocellulosic feedstocks, are assumed to enter the market by around 2020, mostly in OECD countries. The cost of producing biofuels today is often higher than the current cost of imported oil, so strong government incentives are usually needed to make them competitive with oil-based fuels. Global government support in 2009 was $20 billion, the bulk of it in the United States and the European Union. Support is projected to rise to about $45 billion per year between 2010 and 2020, and about $65 billion per year between 2021 and 2035. Government support typically raises costs to the economy as a whole. But the benefits can be significant too, including reduced imports of oil and reduced CO_2 emissions — if sustainable biomass is used and the fossil energy used in processing the biomass is not excessive.

Unlocking the Caspian's energy riches would enhance the world's energy security

The Caspian region has the potential to make a significant contribution to ensuring energy security in the rest of the world, by increasing the diversity of oil and gas supplies. The Caspian region contains substantial resources of both oil and natural gas, which could underpin a sizeable increase in production and exports over the next two decades. But potential barriers to the development of these resources, notably the complexities of financing and constructing transportation infrastructure passing through several countries, the investment climate and uncertainty over export demand, are expected to constrain this expansion to some degree. In the New Policies Scenario, Caspian oil production grows strongly — especially over the first 15 years of the projection period; it jumps from 2.9 mb/d in 2009 to a peak of around 5.4 mb/d between 2025 and 2030, before falling back to 5.2 mb/d by 2035. Kazakhstan contributes all of this increase, ranking fourth in the world for output growth in volume terms to 2035 after Saudi Arabia, Iraq and Brazil. Most of the incremental oil output goes to exports, which double to a peak of 4.6 mb/d soon after 2025. Caspian gas production is also projected to expand substantially, from an estimated 159 bcm in 2009 to nearly 260 bcm by 2020 and over 310 bcm in 2035. Turkmenistan and, to a lesser extent, Azerbaijan and Kazakhstan drive this expansion. As with oil, gas exports are projected to grow rapidly, reaching nearly 100 bcm in 2020 and 130 bcm in 2035, up from less than 30 bcm in 2009. The Caspian has the potential to supply a significant part of the gas needs of Europe and China, which emerges as a major new customer, enhancing their energy diversity and security.

Domestic energy policies and market trends, beyond being critical to the Caspian's social and economic development, have an influence on world prospects by determining the volumes available for export. Despite some improvement in recent years, the region remains highly energy-intensive, reflecting continuing gross inefficiencies in the way energy is used (a legacy of the Soviet era), as well as climatic and structural economic factors. If the region were to use energy as efficiently as OECD countries, consumption of primary energy in the Caspian as a whole would be cut by one-half. How quickly this energy-efficiency potential might be exploited hinges largely on government policies, especially on energy pricing (all the main Caspian countries subsidise at least one form of fossil energy), market reform and financing. In the New Policies Scenario, total Caspian primary energy demand expands progressively through the *Outlook* period, at an average rate of 1.4% per year, with gas remaining the predominant fuel. Kazakhstan and Turkmenistan see the fastest rates of growth in energy use, mainly reflecting more rapid economic growth.

Copenhagen pledges are collectively far less ambitious than the overall goal

The commitments that countries have announced under the Copenhagen Accord to reduce their greenhouse-gas emissions collectively fall short of what would be required to put the world onto a path to achieving the Accord's goal of limiting the global temperature increase to 2°C. If countries act upon these commitments in a cautious manner, as we assume in the New Policies Scenario, rising demand for fossil fuels would continue to drive up energy-related CO_2 emissions through the projection period. *Such a trend would make it all but impossible to achieve the 2°C goal*, as the required reductions in emissions after 2020 would be too steep. In that scenario, global emissions continue to rise through the projection period, though the rate of growth falls progressively. Emissions jump to just under 34 gigatonnes (Gt) in 2020 and over 35 Gt in 2035 – a 21% increase over the 2008 level of 29 Gt. Non-OECD countries account for all of the projected growth in world emissions; OECD emissions peak before 2015 and then begin to fall. These trends are in line with stabilising the concentration of greenhouse gases at over 650 ppm CO_2-eq, resulting in a likely temperature rise of more than 3.5°C in the long term.

The 2°C goal can only be achieved with vigorous implementation of commitments in the period to 2020 and much stronger action thereafter. According to climate experts, in order to have a reasonable chance of achieving the goal, the concentration of greenhouse gases would need to be stabilised at a level no higher than 450 ppm CO_2-eq. The 450 Scenario describes how the energy sector could evolve were this objective to be achieved. It assumes implementation of measures to realise the more ambitious end of target ranges announced under the Copenhagen Accord and more rapid implementation of the removal of fossil-fuel subsidies agreed by the G-20 than assumed in the New Policies Scenario. This action results in a significantly faster slowdown in global energy-related CO_2 emissions. In the 450 Scenario, emissions reach a peak of 32 Gt just before 2020 and then slide to 22 Gt by 2035. Just ten emissions-abatement measures in five regions – the United States, the European Union, Japan, China and India – account

for around half of the emission reductions throughout the *Outlook* period needed in this scenario compared with the Current Policies Scenario. While pricing carbon in the power and industry sectors is at the heart of emissions reductions in OECD countries and, in the longer term, other major economies (CO_2 prices reach $90-120 per tonne in 2035), fossil-fuel subsidies phase-out is a crucial pillar of mitigation in the Middle East, Russia and parts of Asia. The power-generation sector's share of global emissions drops from 41% today to 24% by 2035, spearheading the decarbonisation of the global economy. By contrast, the transport sector's share jumps from 23% to 32%, as it is more costly to cut emissions rapidly than in most other sectors.

Cutting emissions sufficiently to meet the 2°C goal would require a far-reaching transformation of the global energy system. In the 450 Scenario, oil demand peaks just before 2020 at 88 mb/d, only 4 mb/d above current levels, and declines to 81 mb/d in 2035. There is still a need to build almost 50 mb/d of new capacity to compensate for falling production from existing fields, but the volume of oil which has to be found and developed from new sources by 2035 is only two-thirds that in the New Policies Scenario, allowing the oil industry to shelve some of the more costly and more environmentally sensitive prospective projects. Coal demand peaks before 2020, returning to 2003 levels by 2035. Among the fossil fuels, demand for natural gas is least affected, though it too reaches a peak before the end of the 2020s. Renewables and nuclear make significant inroads in the energy mix, doubling their current share to 38% in 2035. The share of nuclear power in total generation increases by about 50% over current levels. Renewable-based generation increases the most, reaching more than 45% of global generation — two-and-a-half times higher than today. Wind power jumps to almost 13%, while the combined share of solar PV and CSP reaches more than 6%. Carbon capture and storage plays an important role in reducing power-sector emissions: by 2035, generation from coal plants fitted with CCS exceeds that from coal plants not equipped with this technology, accounting for about three-quarters of the total generation from all CCS fitted plants. Biofuels and advanced vehicles also play a much bigger role than in the New Policies Scenario. By 2035, about 70% of global passenger-car sales are advanced vehicles (hybrids, plug-in hybrids and electric cars). Global energy security is enhanced by the greater diversity of the energy mix.

Failure at Copenhagen has cost us at least $1 trillion…

Even if the commitments under the Copenhagen Accord were fully implemented, the emissions reductions that would be needed after 2020 would cost more than if more ambitious earlier targets had been pledged. The emissions reductions that those commitments would yield by 2020 are such that much bigger reductions would be needed thereafter to get on track to meet the 2°C goal. In the 450 Scenario in this year's *Outlook*, the additional spending on low-carbon energy technologies (business investment and consumer spending) amounts to $18 trillion (in year-2009 dollars) more than in the Current Policies Scenario in the period 2010-2035, and around $13.5 trillion more than in the New Policies Scenario. The additional spending compared with the Current Policies Scenario to 2030 is $11.6 trillion — about $1 trillion more than we estimated last year. In addition, global GDP would be reduced in 2030 by 1.9%,

compared with last year's estimate of 0.9%. These differences are explained by the deeper, faster cuts in emissions needed after 2020, caused by the slower pace of change in energy supply and use in the earlier period.

...though reaching the Copenhagen goal is still (just about) achievable

The modest nature of the pledges to cut greenhouse-gas emissions under the Copenhagen Accord has undoubtedly made it less likely that the 2°C goal will actually be achieved. Reaching that goal would require a phenomenal policy push by governments around the world. An indicator of just how big an effort is needed is the rate of decline in carbon intensity – the amount of CO_2 emitted per dollar of GDP – required in the 450 Scenario. Intensity would have to fall in 2008-2020 at twice the rate of 1990-2008; between 2020 and 2035, the rate would have to be almost four times faster. The technology that exists today could enable such a change, but such a rate of technological transformation would be unprecedented. And there are major doubts about the implementation of the commitments for 2020, as many of them are ambiguous and may well be interpreted in a far less ambitious manner than assumed in the 450 Scenario. A number of countries, for instance, have proposed ranges for emissions reductions, or have set targets based on carbon or energy intensity and/or a baseline of GDP that differs from that assumed in our projections. Overall, we estimate that the uncertainty related to these factors equates to 3.9 Gt of energy-related CO_2 emissions in 2020, or about 12% of projected emissions in the 450 Scenario. It is vitally important that these commitments are interpreted in the strongest way possible and that much stronger commitments are adopted and acted upon after 2020, if not before. Otherwise, the 2°C goal would probably be out of reach for good.

Getting rid of fossil-fuel subsidies is a triple-win solution

Eradicating subsidies to fossil fuels would enhance energy security, reduce emissions of greenhouse gases and air pollution, and bring economic benefits. Fossil-fuel subsidies remain commonplace in many countries. They result in an economically inefficient allocation of resources and market distortions, while often failing to meet their intended objectives. Subsidies that artificially lower energy prices encourage wasteful consumption, exacerbate energy-price volatility by blurring market signals, incentivise fuel adulteration and smuggling, and undermine the competitiveness of renewables and more efficient energy technologies. For importing countries, subsidies often impose a significant fiscal burden on state budgets, while for producers they quicken the depletion of resources and can thereby reduce export earnings over the long term. Fossil-fuel consumption subsidies worldwide amounted to $312 billion in 2009, the vast majority of them in non-OECD countries. The annual level fluctuates widely with changes in international energy prices, domestic pricing policy and demand: subsidies were $558 billion in 2008. Only a small proportion of these subsidies go to the poor. Considerable momentum is now building globally to cut fossil-fuel subsidies. In September 2009, G-20 leaders committed to phase out and rationalise inefficient

fossil-fuel subsidies, a move that was closely mirrored in November 2009 by APEC leaders. Many countries are now pursuing reforms, but steep economic, political and social hurdles will need to be overcome to realise lasting gains.

Reforming inefficient energy subsidies would have a dramatic effect on supply and demand in global energy markets. We estimate that a universal phase-out of all fossil-fuel consumption subsidies by 2020 — ambitious though it may be as an objective — would cut global primary energy demand by 5%, compared with a baseline in which subsidies remain unchanged. This amounts to the current consumption of Japan, Korea and New Zealand combined. Oil demand alone would be cut by 4.7 mb/d by 2020, equal to around one-quarter of current US demand. Phasing out fossil-fuel consumption subsidies could represent an integral building block for tackling climate change: their complete removal would reduce CO_2 emissions by 5.8%, or 2 Gt, in 2020.

Energy poverty in the developing world calls for urgent action

Despite rising energy use across the world, many poor households in developing countries still have no access to modern energy services. The numbers are striking: we estimate that 1.4 billion people — over 20% of the global population — lack access to electricity and that 2.7 billion people — some 40% of the global population — rely on the traditional use of biomass for cooking. Worse, our projections suggest that the problem will persist in the longer term: in the New Policies Scenario, 1.2 billion people still lack access to electricity in 2030 (the date of the proposed goal of universal access to modern energy services), 87% of them living in rural areas. Most of these people will be living in sub-Saharan Africa, India and other developing Asian countries (excluding China). In the same scenario, the number of people relying on the traditional use of biomass for cooking *rises* to 2.8 billion in 2030, 82% of them in rural areas.

Prioritising access to modern energy services can help accelerate social and economic development. The UN Millennium Development Goal of eradicating extreme poverty and hunger by 2015 will not be achieved unless substantial progress is made on improving energy access. To meet the goal, an additional 395 million people need to be provided with electricity and an additional one billion provided with access to clean cooking facilities. To meet the much more ambitious goal of achieving universal access to modern energy services by 2030, additional spending of $36 billion per year would be required. This is equal to less than 3% of the global investment in energy-supply infrastructure projected in the New Policies Scenario to 2030. The resulting increase in energy demand and CO_2 emissions would be modest: in 2030, global oil demand would be less than 1% higher and CO_2 emissions a mere 0.8% higher compared with the New Policies Scenario. To get close to meeting either of these goals, the international community needs to recognise that the projected situation is intolerable, commit itself to effect the necessary change and set targets and indicators to monitor progress. The Energy Development Index, presented in this *Outlook*, could provide a basis for target-setting and monitoring. A new financial, institutional and technological framework is required, as is capacity building at the local and regional levels. Words are not enough — real action is needed now. We can and must get there in the end.

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