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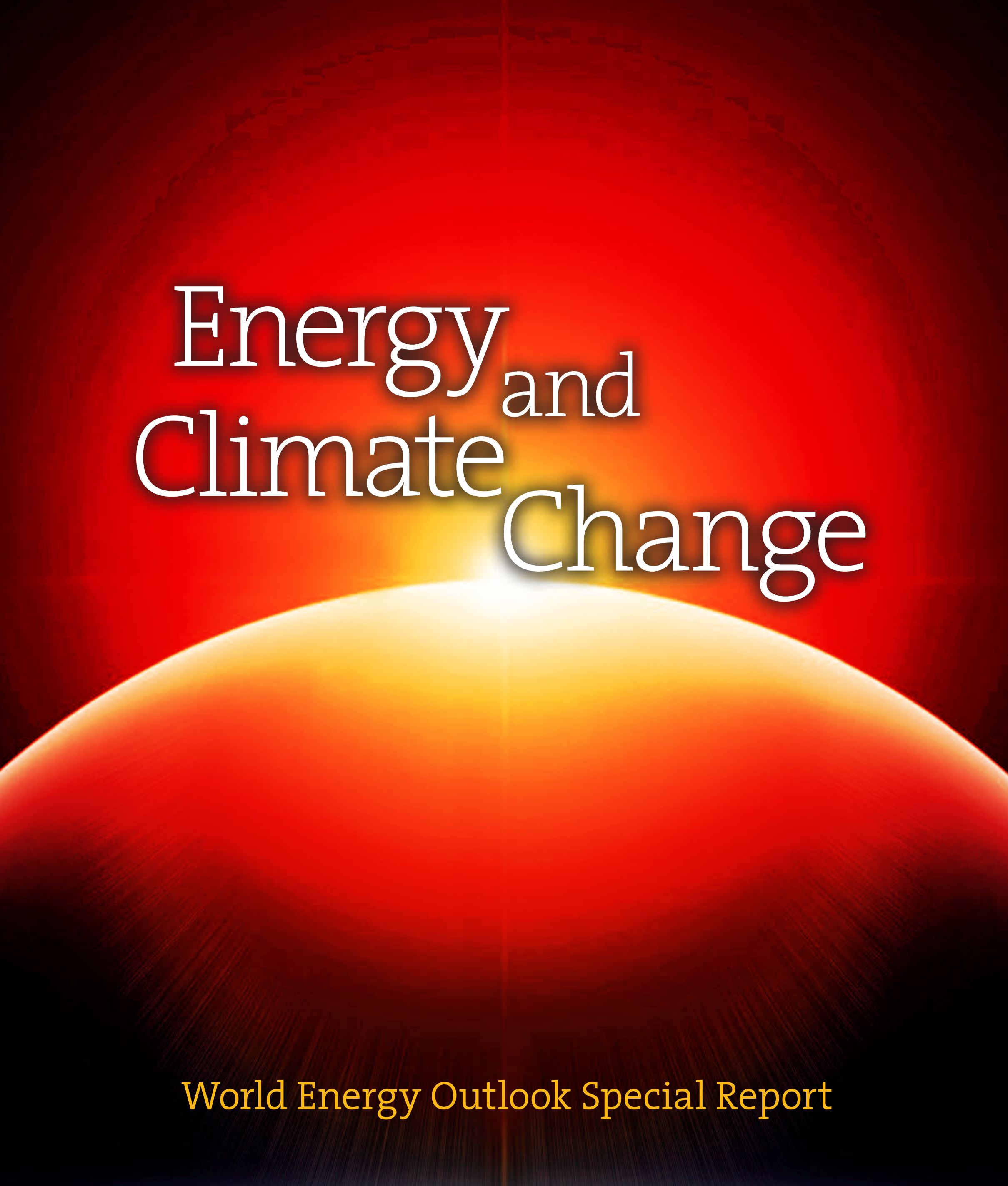

Energy and Climate Change

World Energy Outlook Special Report

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- 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.

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We face a moment of opportunity, but also of great risk. The world is counting on the UN climate talks in Paris later this year to achieve a global agreement that puts us on a more sustainable path. As IEA analysis has repeatedly shown that the cost and difficulty of mitigating greenhouse-gas emissions increases every year, time is of the essence. And it is clear that the energy sector must play a critical role if efforts to reduce emissions are to succeed. While we see growing consensus among countries that it is time to act, we must ensure that the steps taken are adequate and that the commitments made are kept.

In recent years, progress has been made in developing cleaner, more efficient energy technologies. Indeed, we are seeing signs that economic growth and energy-related emissions – which have historically moved in the same direction – are starting to decouple. The energy intensity of the global economy continued to decline in 2014 despite economic growth of over 3%. But increased effort is still needed if we are to keep open the possibility of limiting the rise in global mean temperature to 2 °C. The pledges – or Intended Nationally Determined Contributions (INDCs) – made by individual countries for the 21st UN Conference of the Parties (COP21) in December 2015 will determine whether this goal will remain attainable.

This special report, part of the *World Energy Outlook* series, assesses the effect of recent low-carbon energy developments and the INDCs proposed thus far. It finds that while global energy-related emissions slow as a result of the climate pledges, they still increase. To compensate, governments will need to ramp up efforts, reviewing their pledges regularly, setting realistic and attainable longer-term goals and tracking their progress. This report also proposes the adoption of five measures that would achieve a near-term peak in global energy-related emissions while maintaining momentum for stronger national efforts.

The next few months could be decisive in determining our energy and climate future. Will countries take on and abide by commitments that will make a meaningful impact? Will they agree to additional measures to spur further innovation and action? Achieving our goals is still possible, but the risk of failure is great: the more time passes without a deal, the more high-carbon energy infrastructure is locked in.

COP21 presents an opportunity we cannot afford to miss.

This publication is issued on my authority as Executive Director of the IEA.

Maria van der Hoeven
Executive Director
International Energy Agency

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ANNEXES

A major milestone in efforts to combat climate change is fast approaching. The importance of the 21st Conference of the Parties (COP21) – to be held in Paris in December 2015 – rests not only in its specific achievements by way of new contributions, but also in the direction it sets. There are already some encouraging signs with a historic joint announcement by the United States and China on climate change, and climate pledges for COP21 being submitted by a diverse range of countries and in development in many others. The overall test of success for COP21 will be the conviction it conveys that governments are determined to act to the full extent necessary to achieve the goal they have already set to keep the rise in global average temperatures below 2 degrees Celsius (°C), relative to pre-industrial levels.

Energy will be at the core of the discussion. Energy production and use account for two-thirds of the world's greenhouse-gas (GHG) emissions, meaning that the pledges made at COP21 must bring deep cuts in these emissions, while yet sustaining the growth of the world economy, boosting energy security around the world and bringing modern energy to the billions who lack it today. The agreement reached at COP21 must be comprehensive geographically, which means it must be equitable, reflecting both national responsibilities and prevailing circumstances. The importance of the energy component is why this *World Energy Outlook Special Report* presents detailed energy and climate analysis for the sector and recommends four key pillars on which COP21 can build success.

Energy and emissions: moving apart?

The use of low-carbon energy sources is expanding rapidly, and there are signs that growth in the global economy and energy-related emissions may be starting to decouple. The global economy grew by around 3% in 2014 but energy-related carbon dioxide (CO_2) emissions stayed flat, the first time in at least 40 years that such an outcome has occurred outside economic crisis. Renewables accounted for nearly half of all new power generation capacity in 2014, led by growth in China, the United States, Japan and Germany, with investment remaining strong (at $270 billion) and costs continuing to fall. The energy intensity of the global economy dropped by 2.3% in 2014, more than double the average rate of fall over the last decade, a result stemming from improved energy efficiency and structural changes in some economies, such as China. Around 11% of global energy-related CO_2 emissions arise in areas that operate a carbon market (where the average price is $7 per tonne of CO_2), while 13% of energy-related CO_2 emissions arise in markets with fossil-fuel consumption subsidies (an incentive equivalent to $115 per tonne of CO_2, on average). There are some encouraging signs on both fronts, with reform in sight for the European Union's Emissions Trading Scheme and countries including India, Indonesia, Malaysia and Thailand taking the opportunity of lower oil prices to diminish fossil-fuel subsidies, cutting the incentive for wasteful consumption.

The energy contribution to COP21

Nationally determined pledges are the foundation of COP21. Intended Nationally Determined Contributions (INDCs) submitted by countries in advance of COP21 may vary in scope but will contain, implicitly or explicitly, commitments relating to the energy sector. As of 14 May 2015, countries accounting for 34% of energy-related emissions had submitted their new pledges. A first assessment of the impact of these INDCs and related policy statements (such as by China) on future energy trends is presented in this report in an "INDC Scenario". This shows, for example, that the *United States'* pledge to cut net greenhouse-gas emissions by 26% to 28% by 2025 (relative to 2005 levels) would deliver a major reduction in emissions while the economy grows by more than one-third over current levels. The *European Union's* pledge to cut GHG emissions by at least 40% by 2030 (relative to 1990 levels) would see energy-related CO_2 emissions decline at nearly twice the rate achieved since 2000, making it one of the world's least carbon-intensive energy economies. *Russia's* energy-related emissions decline slightly from 2013 to 2030 and it meets its 2030 target comfortably, while implementation of *Mexico's* pledge would see its energy-related emissions increase slightly while its economy grows much more rapidly. China has yet to submit its INDC, but has stated an intention to achieve a peak in its CO_2 emissions around 2030 (if not earlier), an important change in direction, given the pace at which they have grown on average since 2000.

Growth in global energy-related GHG emissions slows, but there is no peak by 2030 in the INDC Scenario. The link between global economic output and energy-related GHG emissions weakens significantly, but is not broken: the economy grows by 88% from 2013 to 2030 and energy-related CO_2 emissions by 8% (reaching 34.8 gigatonnes). Renewables become the leading source of electricity by 2030, as average annual investment in non-hydro renewables is 80% higher than levels seen since 2000, but inefficient coal-fired power generation capacity declines only slightly. With INDCs submitted so far, and the planned energy policies in countries that have yet to submit, the world's estimated remaining carbon budget consistent with a 50% chance of keeping the rise in temperature below 2 °C is consumed by around 2040 – eight months later than is projected in the absence of INDCs. This underlines the need for all countries to submit ambitious INDCs for COP21 and for these INDCs to be recognised as a basis upon which to build stronger future action, including from opportunities for collaborative/co-ordinated action or those enabled by a transfer of resources (such as technology and finance). If stronger action is not forthcoming after 2030, the path in the INDC Scenario would be consistent with an average temperature increase of around 2.6 °C by 2100 and 3.5 °C after 2200.

What does the energy sector need from COP21?

National pledges submitted for COP21 need to form the basis for a "virtuous circle" of rising ambition. From COP21, the energy sector needs to see a projection from political leaders at the highest level of clarity of purpose and certainty of action, creating a clear expectation of global and national low-carbon development. Four pillars can support that achievement:

1. **Peak in emissions** – set the conditions which will achieve an early peak in global energy-related emissions.
2. **Five-year revision** – review contributions regularly, to test the scope to lift the level of ambition.
3. **Lock in the vision** – translate the established climate goal into a collective long-term emissions goal, with shorter-term commitments that are consistent with the long-term vision.
4. **Track the transition** – establish an effective process for tracking achievements in the energy sector.

Peak in emissions

The IEA proposes a bridging strategy that could deliver a peak in global energy-related emissions by 2020. A commitment to target such a near-term peak would send a clear message of political determination to stay below the 2 °C climate limit. The peak can be achieved relying solely on proven technologies and policies, without changing the economic and development prospects of any region, and is presented in a "Bridge Scenario". The technologies and policies reflected in the Bridge Scenario are essential to secure the long-term decarbonisation of the energy sector and their near-term adoption can help keep the door to the 2 °C goal open. For countries that have submitted their INDCs, the proposed strategy identifies possible areas for over-achievement. For those that have yet to make a submission, it sets out a pragmatic baseline for ambition.

The Bridge Scenario depends upon five measures:

- Increasing *energy efficiency* in the industry, buildings and transport sectors.
- Progressively reducing the use of the *least-efficient coal-fired power plants* and banning their construction.
- Increasing investment in *renewable energy technologies* in the power sector from $270 billion in 2014 to $400 billion in 2030.
- Gradual phasing out of *fossil-fuel subsidies* to end-users by 2030.
- Reducing *methane emissions* in oil and gas production.

These measures have profound implications for the global energy mix, putting a brake on growth in oil and coal use within the next five years and further boosting renewables. In the Bridge Scenario, coal use peaks before 2020 and then declines while oil demand rises to 2020 and then plateaus. Total energy-related GHG emissions peak around 2020. Both the energy intensity of the global economy and the carbon intensity of power generation improve by 40% by 2030. *China* decouples its economic expansion from emissions growth by around 2020, much earlier than otherwise expected, mainly through improving the energy efficiency of industrial motors and the buildings sector, including through standards for appliances and lighting. In countries where emissions are already in decline today, the decoupling of economic growth and emissions is significantly accelerated; compared with recent years, the pace of this decoupling is almost 30% faster in the *European Union* (due to improved energy efficiency) and in the *United States* (where renewables contribute one-third of the achieved emissions savings in 2030). In other regions, the link between economic growth and emissions growth is weakened significantly, but the relative importance of different measures varies. *India* utilises energy more efficiently, helping it to reach its energy sector targets and moderate emissions growth, while the reduction of methane releases from oil and gas production and reforming fossil-fuel subsidies (while providing targeted support for the poorest) are key measures in the *Middle East* and *Africa*, and a portfolio of options helps reduce emissions in *Southeast Asia*. While universal access to modern energy is not achieved in the Bridge Scenario, the efforts to reduce energy-related emissions do go hand-in-hand with delivering access to electricity to 1.7 billion people and access to clean cookstoves to 1.6 billion people by 2030.

Five-year revision

A five-year cycle for the review of mitigation targets is needed to provide the opportunity for commitment to stronger climate ambition over time. The energy context in which climate goals are being set is changing rapidly as the cost and performance of many low-carbon technologies improves and countries start to see the success of their low-carbon policies. The strategy set out in the Bridge Scenario can keep the 2 °C climate goal within reach in the near-term, but goals beyond 2025 need to be strengthened in due course. Agreeing a mechanism at COP21 that will permit reviewing the level of ambition every five years will regularly shine a light on progress, and send a clearer message to investors of the long-term commitment to the full extent of the necessary decarbonisation.

Lock in the vision

Translating the 2 °C goal into subordinate targets, including a clear, collective long-term emissions goal, would provide greater ease and certainty in expressing future policy on a basis consistent with the longer term objective. Such targets would reinforce the need for the energy sector to adopt a long-term development pathway that is low carbon. Fostering the development of new technologies will be necessary in order to achieve the ultimate climate goal and, as set out in the "450 Scenario", measures beyond those in the Bridge Scenario could allow the necessary technologies to reach maturity before they need to be widely deployed. Early support of wind and solar technologies has played a pivotal role in driving down costs and achieving their large-scale deployment. A similar approach is needed to develop and deploy technologies that safeguard the reliability of power supply as the contribution of variable renewables increases (e.g. through energy storage), deliver additional emissions reductions in the power sector and industry (e.g. carbon capture and storage) and grow the share of alternative fuel vehicles in road transport. Investment in the 450 Scenario is only a little higher than other scenarios, but is oriented more strongly towards low-carbon energy supply and energy efficiency, emphasising the need for effective means to finance such investments (particularly in countries where such financing instruments may not yet exist).

Track the transition

There must be a strong process for tracking progress towards nationally determined mitigation goals. Evidence of tangible results will give the necessary confidence to all countries and energy sector stakeholders that everyone is acting in harmony. The related energy data systems are, in any case, essential to underpin domestic policy-making and identify those who are struggling with implementation and may need assistance. Details of the post-2020 reporting and accounting frameworks may not be settled at COP21, but the agreement should at least establish some high-level principles, including the need for rules for the measurement and reporting of emissions and the need to develop accounting rules for the different types of mitigation goals that are likely to be put forward by countries. Tracking progress towards energy sector decarbonisation is complex and requires a broader set of measurements than are collected and monitored in many countries today. In recognition of this need, a set of appropriate high-level metrics to track energy sector decarbonisation is proposed in the report.

Secure a legacy of energy change

Will 2015 be the year in which decision-makers are able to establish the much-needed climate for change? The answer cannot yet be known. But to assist the process beyond the recommendations in this report, the IEA will publish timely updates of its INDC analysis, incorporating new submissions, in the lead up to COP21. It will also submit the key findings of this report for endorsement by Ministers at their biennial meeting under IEA auspices (17-18 November 2015). Beyond COP21, the IEA will continue to assess the impact of national contributions and collective prospects as they are further developed, refined, revised and implemented, drawing on the wealth of energy data and indicators at its command.

A transformation of the world's energy system must become a uniting vision if the 2 °C climate goal is to be achieved. The challenge is stern, but a credible vision of the long-term decarbonisation of the sector is available to underpin shorter term commitments and the means to realise it can, ultimately, be collectively adopted. The world must quickly learn to live within its means if this generation is to pass it on to the next with a clear conscience.

Energy and climate: state of play

A climate for energy change?

Highlights

- The 21st Conference of the Parties of the UNFCCC meets in Paris in December 2015 with the aim of adopting a new global agreement to limit greenhouse-gas emissions. The ultimate objective already adopted by governments is to limit global warming to an average of no more than 2 °C, relative to pre-industrial levels. This must involve the transformation of the energy sector, as it accounts for roughly two-thirds of all anthropogenic greenhouse-gas emissions today.
- Global energy-related CO_2 emissions stayed flat in 2014 (at an estimated 32.2 Gt) despite an increase of around 3% in the global economy. This is the first time in at least 40 years that a halt or reduction in emissions has not been tied to an economic crisis. Across the OECD, emissions continued to decouple from economic growth in 2014. China's emissions figures give early signs of a weakening in the link between economic and emissions growth, albeit not yet a detachment.
- Renewable energy investment was flat in 2014 at $270 billion, with new capacity of 128 GW installed, representing almost half of total capacity additions. Wind power accounted for 37% and solar for almost another third. The first commercial power plant with CO_2 capture came online in 2014. Nuclear capacity of 74 GW was under construction at the end of 2014. Estimates for 2014 indicate that global energy intensity decreased by 2.3% relative to the previous year, more than twice the annual rate of the last decade.
- Carbon markets covered 11% of global energy-related emissions in 2014 and the average price was $7 per tonne of CO_2. In contrast, 13% of CO_2 emissions were linked to fossil-fuel use supported by consumption subsidies, equivalent to an implicit subsidy of $115 per tonne of CO_2. However, several countries, including India, Indonesia, Malaysia and Thailand, used the opportunity of lower oil prices to reform fossil-fuel subsidies.
- Over the past century, annual emission levels increased at an ever higher rate: the energy sector emitted as much CO_2 over the last 27 years as in all the previous years. The global distribution of CO_2 emissions has also shifted: at the beginning of the 20th century, emissions originated almost exclusively in the United States and Europe, while today together they account for less than 30%.
- Success at the UN climate summit in December 2015 hinges on how new national pledges to reduce emissions can be integrated into an international framework. As of 14 May 2015, Switzerland, European Union, Norway, Mexico, United States, Gabon, Russia, Liechtenstein and Andorra, together accounting for 34% of energy-related CO_2 emissions, had submitted their pledges.

Introduction

The world is at a critical juncture in its efforts to combat climate change. Since the first Conference of the Parties (COP) in 1995, greenhouse-gas (GHG) emissions have risen by more than one-quarter and the atmospheric concentration of these gases has increased steadily to 435 parts per million carbon-dioxide equivalent (ppm CO_2-eq) in 2012 (EEA, 2015).[1] The International Panel on Climate Change (IPCC) has concluded that, in the absence of fully committed and urgent action, climate change will have severe and irreversible impacts across the world. The international commitment to keep the increase in long-term average temperatures to below two degrees Celsius (2 °C), relative to pre-industrial levels, will require substantial and sustained reductions in global emissions (Box 1.1).

Box 1.1 ▷ Avoiding dangerous climate change: the 2 °C goal

The 196 Parties to the United Nations Framework Convention on Climate Change (UNFCCC) agreed a long-term global objective, as part of the package of decisions at COP16 in Cancun in December 2010. Under the Cancun Agreement, Parties formally recognised that they should take urgent action to meet the long-term goal of holding the increase in global average temperature below 2 °C relative to pre-industrial levels, and that deep cuts in global greenhouse-gas emissions are required to achieve this. The Cancun decision formalised the political agreement to a below 2 °C goal which had been made a year earlier at COP15 in Copenhagen by a smaller set of countries. The Cancun Agreement also set in motion a review of the adequacy of this newly established long-term global goal as a means of achieving the ultimate objective of the UNFCCC ("to avoid dangerous anthropogenic interference with the climate system"), and whether it should be further strengthened, including consideration of a 1.5 °C temperature goal. This review, to be concluded in 2015, will inform discussion of this issue in the COP21 process.

The long lifetime of greenhouse gases means that it is the cumulative build-up in the atmosphere that matters most. In its latest report, the Intergovernmental Panel on Climate Change (IPCC) estimated that to preserve a 50% chance of limiting global warming to 2 °C, the world can support a maximum carbon dioxide (CO_2) emissions "budget" of 3 000 gigatonnes (Gt) (the mid-point in a range of 2 900 Gt to 3 200 Gt) (IPCC, 2014), of which an estimated 1 970 Gt had already been emitted before 2014. Accounting for CO_2 emissions from industrial processes and land use, land-use change and forestry over the rest of the 21st century leaves the energy sector[2] with a carbon budget of 980 Gt (the mid-point in a range of 880 Gt to 1 180 Gt) from the start of 2014 onwards. The carbon legacy

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[1] This refers to the concentration of all greenhouse gases, including cooling aerosols.

[2] Energy sector in this chapter refers to energy supply, energy transformation (including power generation) and energy-consuming sectors (including buildings, industry, transport and agriculture).

that is locked-in by new development of fossil-fuelled energy infrastructure underlines the importance that attaches to success in achieving a step change in efforts to contain GHG emissions in the COP21 meeting to be held in Paris in December 2015.

The path towards a new agreement at COP21 began in 2009 with the attempt at COP15 in Copenhagen to develop a successor to the Kyoto Protocol, which was negotiated in 1997 and is still in effect but is expected to cover only 10% of global GHG emissions by 2020. While COP15 failed to achieve a binding treaty, it did result in some pivotal political outcomes: an agreed definition, subsequently universally adopted, of the objective to keep the long-term global average temperature increase below 2 °C; the principle that both developed and developing countries should undertake nationally appropriate actions to reduce emissions; and a commitment to make available $100 billion per year of public and private climate finance to developing countries by 2020, mainly through the Green Climate Fund.[3] Moreover, under the Copenhagen Accord, countries accounting for around 80% of GHG emissions made pledges to mitigation goals and actions for the period to 2020, marking a major improvement on the Kyoto Protocol.

Negotiations towards a new legal agreement for the post-2020 period started in 2011 at COP17 in Durban, South Africa. The new agreement is to apply to the 196 Parties to the UNFCCC and to be adopted by 2015. By 2014 at the time of COP20 in Lima, Peru, the new agreement was beginning to take shape. Countries agreed to communicate so-called Intended Nationally Determined Contributions (INDCs), their pledged actions under the new agreement, well in advance of COP21 and in a manner that is clear, transparent and facilitates understanding.

All UNFCCC Parties will come together at COP21 in December 2015 in an attempt to bring these negotiations to a successful conclusion. A strong agreement is required to provide a clear signal that all countries are committed to decarbonisation and to convince energy sector investors that they need to adopt low-carbon options. The submission by individual countries of their own climate contribution to the 2015 agreement (INDCs) will form the core "bottom-up" element of the climate deal to be agreed at COP21 (see Chapter 5). The INDCs will apply to a period starting in 2021 and are expected to represent "a progression beyond the current undertaking of that Party" (UNFCCC, 2015). This follows the Copenhagen Accord of 2009, in which participating countries for the first time pledged to undertake specific actions to mitigate GHG emissions. There is no agreed form regarding the structure or content of INDCs: guidance exists, but the actual scope – whether they are to include e.g. mitigation, adaptation, finance, technology development and transfer, and capacity-building components – is open. INDCs are generally expected to have a mitigation component, but they are likely to take a variety of forms, since they will reflect differences in national circumstances, capabilities and priorities.

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[3] As of mid-April 2015, $10.2 billion had been made available to the Fund. The UNFCCC estimates that total climate finance flows from developed to developing countries range from $40 to $175 billion per year (UNFCCC, 2014).

Such national contributions are to be embraced within an agreed framework covering such issues as the overall objective or long-term climate goal, the processes to be adopted for measuring, reporting and verifying emissions and accounting for the achievement of mitigation targets, a framework to promote adaptation efforts and a mechanism for the periodic review and strengthening of national targets. Enhanced support for developing countries is to be provided in the areas of capacity building, technology and provision of finance. However, there are significant issues yet to be resolved, such as how different stages of economic development should be reflected in the agreement, the legal nature of the targets adopted and what process will be followed to increase the level of ambition over time. Outside the formal negotiations, catalysing activity is also being pursued by, for example, companies, non-governmental organisations and financial institutions.

Against this background, this chapter reviews recent developments in the energy sector and in carbon markets and analyses energy sector CO_2 emissions in 2014 in the context of historical emissions trends. It concludes by providing an overview of the three scenarios that are used in subsequent chapters to illustrate the potential energy sector contribution to a successful outcome of the COP21 negotiations.

Energy sector and CO_2 emissions

Greenhouse-gas emissions from the energy sector represent roughly two-thirds of all anthropogenic greenhouse-gas emissions and CO_2 emissions from the sector have risen over the past century to ever higher levels. Effective action in the energy sector is, consequentially, essential to tackling the climate change problem. The remainder of this chapter concentrates on the energy sector, concluding by describing how we set about making future energy projections on the basis of present knowledge.

Recent developments

An important change in the energy sector from 2014 to 2015 has been the rapid drop in world oil prices and, to a lesser extent, natural gas and coal prices. After a prolonged period of high and relatively stable prices, oil dropped from over $100 per barrel in mid-2014 to below $50 in early-2015. Natural gas prices also declined, but the pace and extent depended on prevailing gas pricing mechanisms and other regional factors: in the United States they fell from $4 per million British thermal units (MBtu) in mid-2014 to below $3/MBtu in early-2015; German import prices moved below $8/MBtu from $8.5/MBtu during the summer of 2014, while average Japan liquefied natural gas (LNG) import prices (a weighted average of long-term contracts and spot trading) declined to around $15/MBtu from $16/MBtu in mid-2014. Coal prices in northwest Europe declined from $73 per tonne (t) in mid-2014 to around $60/t at the start of 2015 due to persistent overcapacity in the market. The projections in this *World Energy Outlook* (*WEO*) *Special Report* incorporate updated energy price trajectories that reflect recent developments. As a result, fossil-fuel prices in the near term are lower than in the *WEO-2014*, but we do not assume these lower prices will be permanent.

At the global level, lower fossil-fuel prices are likely to act as a form of economic stimulus, which the International Monetary Fund (IMF) quantifies at between 0.3% and 0.7% of additional growth in global gross domestic product (GDP) in 2015 (IMF, 2015). Yet, so far regional impacts have varied hugely between net importers and exporters, large and small consumers and countries with fossil-fuel subsidy schemes and those without. Oil and gas exporters have seen their expectations of economic growth trimmed and many have revised government budgets as a result. For oil and gas companies, the drop in prices has prompted a significant reduction in planned upstream investments – estimated to be around 20% lower in 2015. Some countries, such as India, Indonesia, Malaysia and Thailand, have taken the opportunity provided by lower international oil prices to implement fossil-fuel subsidy reform (see Chapter 2), while tax reforms in China limited the pass through of oil price changes to consumers. Lower natural gas prices have improved the competitive position of gas *vis-à-vis* coal in some markets (mainly in Asia), although coal still has a cost advantage over gas. Despite lower fossil-fuel prices, there were no signs of weakening appetite for renewables in 2014: global investment in renewable-based power generation was $270 billion[4] and positive policy moves have continued in many countries. India has declared an aim to have an installed non-hydro renewable energy capacity of 175 gigawatts (GW) by 2022 (of which solar PV is 100 GW).

Renewable technologies are becoming increasingly cost competitive in a number of countries and circumstances, but public support schemes are still required to support deployment in many others. Renewables-based power generation capacity is estimated to have increased by 128 GW in 2014, of which 37% is wind power, almost one-third solar power and more than a quarter from hydropower (Figure 1.1). This amounted to more than 45% of world power generation capacity additions in 2014, consistent with the general upward trend in recent years. The growth in wind capacity continued to be led by onshore installations (although offshore has also grown rapidly). China remains the largest wind power market, with 20 GW of new capacity. Germany installed more than 5 GW of wind capacity, while US capacity additions bounced back from the very low levels of 2013 to almost 5 GW in 2014. Relatively high (but declining) costs for offshore wind and delays in the build-up of grid connections have resulted in delays to projects in some countries or the cutting of capacity targets (e.g. Germany), though other countries have responded by boosting their support to the industry (e.g. Japan, Korea and China). Solar photovoltaic (PV) expanded strongly in Asia, particularly in China and Japan, the Japanese expansion being supported by generous feed-in tariffs. Lower oil prices proved to be a challenge for other forms of renewable energy, including biofuels in transport and renewable heat, as the latter competes directly with natural gas heating (the price of which is still, in many cases, linked to the oil price). While biofuels face challenges arising from lower oil prices, some other developments served to improve their outlook: to counter current bleak prospects for biofuels in Brazil, the government increased the ethanol blending rate from 25% to 27% and that for biodiesel from 5% to 7%, and increased gasoline taxes, while Argentina and Indonesia raised their biofuel mandates.

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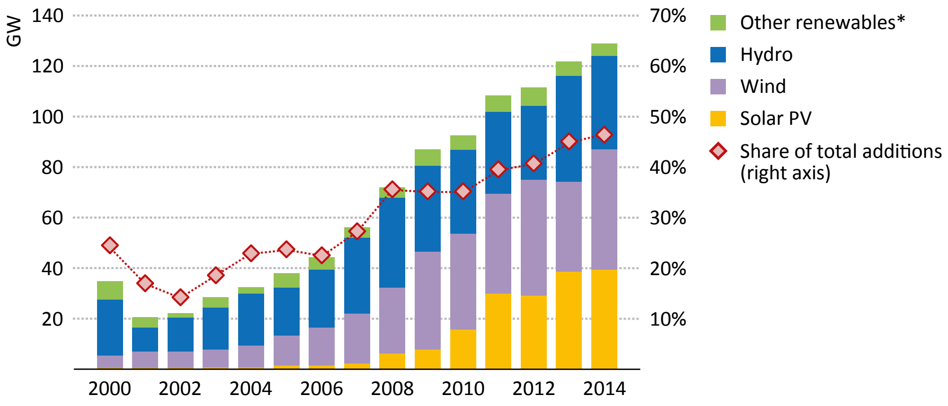
[4] Investment made over the construction period is allocated to the year a completed project begins operation, which may result in differences from other published estimates.

Figure 1.1 ▷ Global renewables-based power capacity additions by type and share of total capacity additions



* Includes geothermal, marine, bioenergy and concentrating solar power.

Nuclear power is the second-largest source of low-carbon electricity generation worldwide, after hydropower. Nearly all new nuclear construction in recent years has taken place in price-regulated markets or in markets where government-owned entities build, own and operate the plants. China continues to lead in new capacity additions, with 28 GW under construction at the end of 2014, while plants with a combined capacity of 46 GW are under construction in Russia, India, Korea, United States and several other countries. Japan has begun the necessary process to permit the restart of some of its nuclear capacity.

Carbon capture and storage (CCS) achieved an important milestone in 2014, with Boundary Dam unit 3 (net capacity of 120 megawatts) in Canada becoming the first commercial power plant to come online with CO_2 capture. The 22 large-scale CCS projects either in operation or under construction have a collective CO_2 capture capacity of around 40 million tonnes (Mt) per year (Global CCS Institute, 2015). The present pace of progress, however, falls short of that needed in order to achieve the pace and scale of CCS deployment necessary to achieve a 2 °C pathway (see Chapter 4).

Any period of lower energy prices can result in neglect of action to promote energy efficiency and the return of more profligate consumption. However, there is no evidence, as yet, that this is occurring. Preliminary estimates for 2014 indicate that global energy intensity – measured as the amount of energy required to produce a unit of GDP – decreased by 2.3% relative to the previous year, more than double the average rate of change over the last decade. This was the joint result of energy efficiency improvements and structural changes in the global economy. A major driver of the global change was the 8% reduction in energy intensity in China.[5]

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5. The change in primary energy intensity is higher than the official Chinese number (-5%) mainly because the IEA uses the energy content method and Chinese authorities use the partial substitution method for renewables.

Carbon markets

Putting a meaningful price on CO_2 emissions is viewed by many as integral to achieving the 2 °C climate goal. The current picture, however, reveals significant challenges relating to the geographic coverage of carbon markets, the prevailing price levels and, in some cases, the need for market reform. Carbon emissions trading schemes in operation in 2014 covered 3.7 Gt (11 %) of global energy-related CO_2 emissions and had an aggregate value of $26 billion.[6] The average price was around $7 per tonne of CO_2 (Figure 1.2). In contrast, 4.2 Gt (13%) of global energy-related CO_2 emissions from the use of fossil fuels receive consumption subsidies, with the implicit subsidy amounting to $115 per tonne of CO_2, on average.

The value of the European Union Emissions Trading Scheme (EU ETS), the world's largest carbon market, eclipsed that of all others combined in 2014, but was still worth only one-fifth of its own level in 2008. The EU ETS is a core element of the European Union's strategy to decarbonise its energy sector, but it continues to suffer from a massive surplus of allowances, which depresses prices and the incentive for low-carbon investments. Delay has been imposed on the auctioning of some allowances, but this will not be sufficient to overcome this problem and must be followed by structural reforms. In May 2015, the European Union agreed on a plan to introduce a Market Stability Reserve in 2019 that could withdraw allowances in times of surplus.

China's seven pilot carbon trading schemes are all operational and, taken together, mean that the country has the second-largest carbon market in the world (covering around 1.3 Gt of CO_2) and China is expected to introduce a national scheme by 2020. Prices in the Chinese markets are currently not high enough to significantly influence investment decisions. Korea's emissions trading scheme began operating in January 2015, covering 525 business entities and with a three-year cap of 1.7 Gt CO_2-eq. Kazakhstan launched an emissions trading scheme at the start of 2013, which covered around 155 Mt CO_2 in 2014 and resulted in an average price of around $2 per tonne of CO_2. In Japan, there are currently three cap-and-trade schemes in the prefectures of Tokyo, Saitama and Kyoto, which cover around 2% of Japan's emissions. In general, little trading is currently taking place in the emissions trading systems across Asia.

In North America, California's ETS has been part of the Western Climate Initiative (WCI) since 2007 and a formal link to Québec's scheme was established in 2014, creating a broader market. Since January 2015, the ETS covers around 85% of California's GHG emissions. The emissions cap applied under the Regional Greenhouse-Gas Initiative (RGGI) operated by states in the northeast United States was revised down by 45% in 2014 and will be reduced by a further 2.5% per year from 2015 to 2020. Elsewhere, low-priced international credits prompted a price collapse in New Zealand's ETS, while Australia abolished its carbon pricing mechanism.

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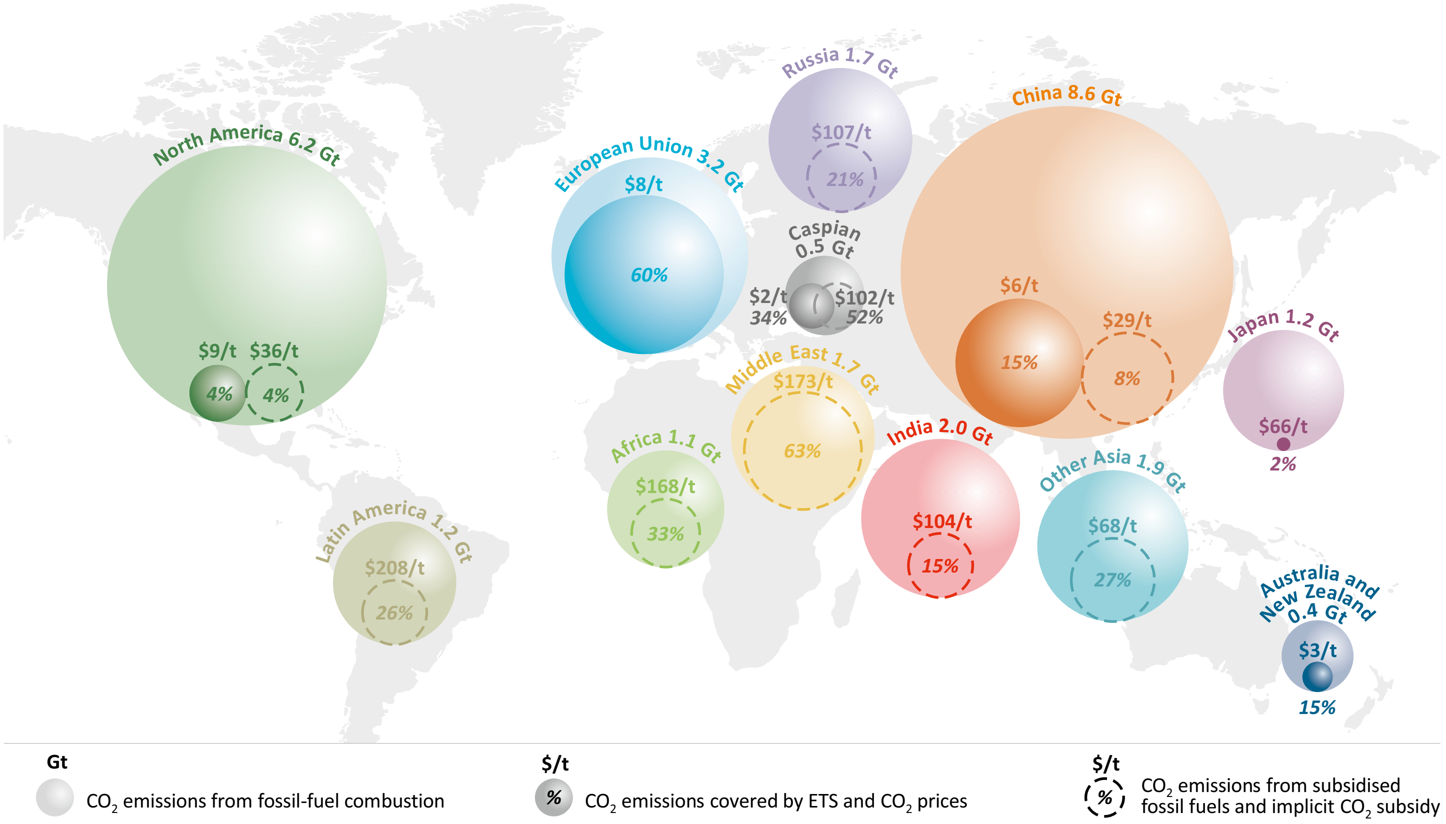
[6] Next to emission trading systems, other carbon pricing instruments, such as carbon taxes, exist or are planned in 39 national and 23 sub-national jurisdictions (World Bank, 2014).

Figure 1.2 ▷ Energy-related CO_2 emissions in selected regions, 2014

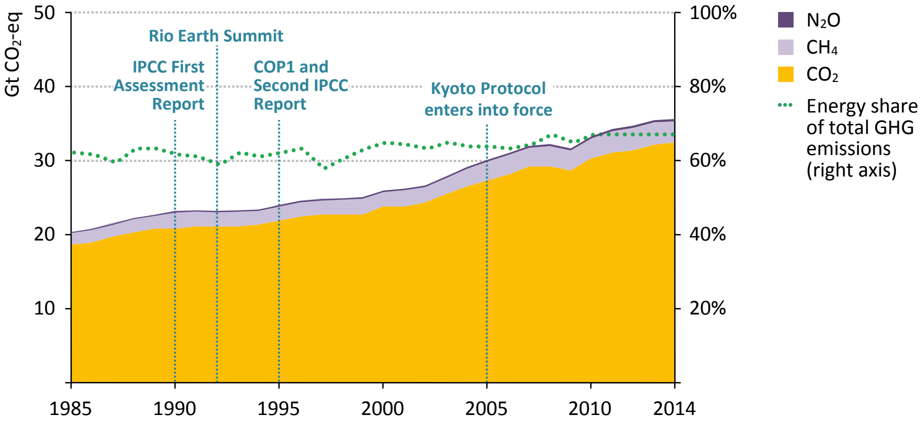


Notes: The implicit CO_2 subsidy is calculated as the ratio of the economic value of those subsidies to the CO_2 emissions released from subsidised energy consumption. ETS = emissions trading scheme.

Historical energy emissions trends

One indicator of the scale of the challenge to the energy sector is the fact that the total volume of global energy sector CO_2 emissions over the past 27 years matched the total level of all previous years. Fossil fuels continue to meet more than 80% of total primary energy demand and over 90% of energy-related emissions are CO_2 from fossil-fuel combustion (Figure 1.3). Since 2000, the share of coal has increased from 38% to 44% of energy-related CO_2 emissions, the share of natural gas stayed flat at 20% and that of oil declined from 42% to 35% in 2014. While smaller in magnitude (and less long-lasting in the atmosphere, though with higher global warming potential), methane (CH_4) and nitrous oxide (N_2O) are other powerful greenhouse gases emitted by the energy sector. Methane accounts for around 10% of energy sector emissions and originates mainly from oil and gas extraction, transformation and distribution. Much of the remainder is nitrous oxide emissions from energy transformation, industry, transport and buildings.

Figure 1.3 ▷ **Global anthropogenic energy-related greenhouse-gas emissions by type**

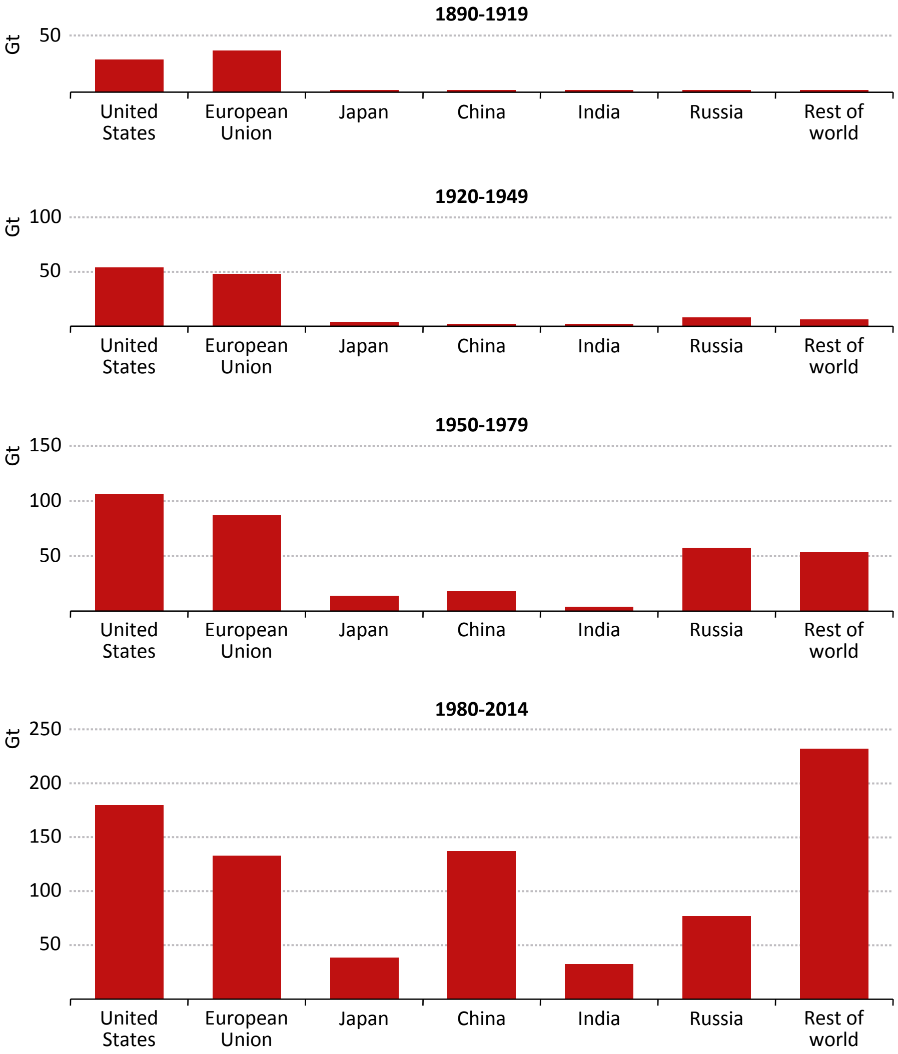


Notes: CO_2 = carbon dioxide, CH_4 = methane, N_2O = nitrous oxide. CH_4 has a global warming potential of 28 to 30 times that of CO_2, while the global warming potential of N_2O is 265 higher than that of CO_2.

Sources: IEA and EC/PBL (2014).

The global distribution of GHG emissions has shifted with changes in the global economy (Figure 1.4). At the beginning of the 20th century, energy-related CO_2 emissions originated almost exclusively in Europe and the United Sates. This ratio dropped to around two-thirds of total emissions by the middle of the century and today stands at below 30%.

Figure 1.4 ▷ **Cumulative energy-related CO_2 emissions by region**

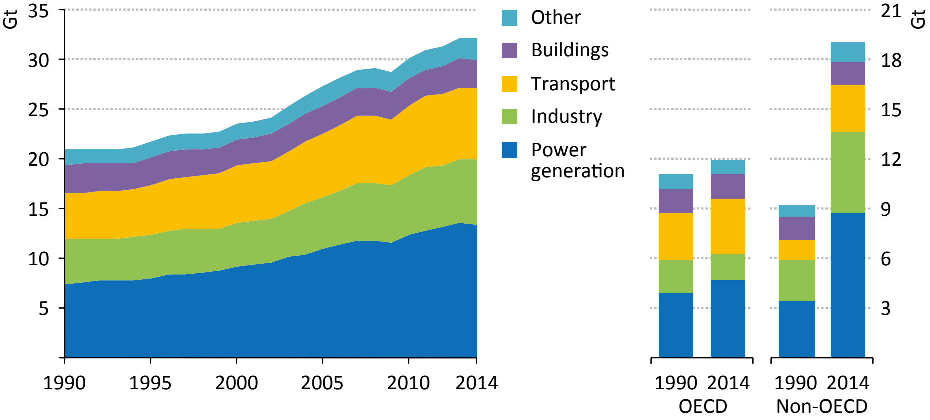


Notes: Emissions for the European Union prior to 2004 represent the combined emissions of its current member states. Emissions for Russia prior to 1992 represent emissions from the Union of Soviet Socialist Republics. Rest of world includes international bunkers.

Sources: Marland, Boden and Andres (2008) and IEA (2014a).

Over the past two-and-a-half decades, global CO_2 emissions increased by more than 50% (Figure 1.5). While emissions increased by 1.2% per year in the last decade of the 20th century, the average annual rate of increase between 2000 and 2014 accelerated to 2.3%, particularly driven by a rapid rise in CO_2 emissions in power generation in countries outside the OECD: since the start of the 21st century, emissions from electricity and heat generation in emerging and developing countries have doubled, with around two-thirds of this increase coming from China. CO_2 emissions from the industry sector in these countries doubled from 1990 to today being driven by large increases in the production of energy-intensive materials, such as cement and steel. In the same period, total CO_2 emissions from the industrial sector in OECD countries fell by a quarter, though these countries still lead global emissions from the transport and buildings sectors. For transport, this is due to the higher level of vehicle ownership in OECD countries even though, over the past 15 years, CO_2 emissions from transport doubled in non-OECD countries as a result both of higher levels of private vehicle ownership and strong growth in freight traffic. For buildings, the higher level of emissions in OECD countries is because most non-OECD countries are located in more temperate climates, requiring lower levels of space heating.

Figure 1.5 ▻ **Global energy-related CO_2 emissions by sector and region**



Notes: "Other" includes agriculture, non-energy use (except petrochemical feedstock), oil and gas extraction and energy transformation. International bunkers are included in the transport sector at the global level but excluded from the regional data.

A large share of energy-related CO_2 emissions comes from a small number of countries. In 2012, three countries – China, United States and India – gave rise to almost half of global CO_2 emissions from fossil-fuel combustion, while ten countries[7] accounted for around two-thirds (IEA, 2014a). Since 1990, total emissions in the United States and Japan have increased slightly, while they declined by about a fifth in the European Union. After a fall of almost 30% in emissions from Russia in the early 1990s, the emissions increase thereafter has remained limited. In 2006, China overtook the United States as the biggest CO_2 emitter, while India overtook Russia as the fourth-largest emitter in 2009 (Figure 1.6).

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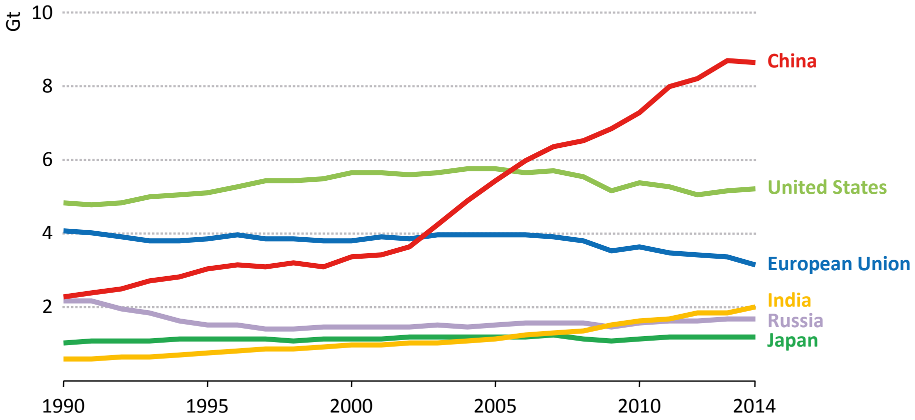
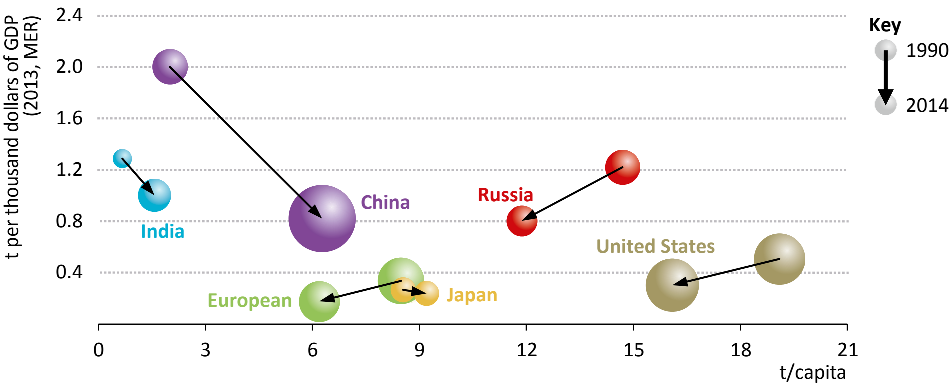
[7] The ten countries are China, United States, India, Russia, Japan, Germany, Korea, Canada, Iran and Saudi Arabia.

Figure 1.6 ▷ Energy-related CO_2 emissions by selected region



Even though CO_2 emissions increased almost three-fold in China and two-and-a-half times in India between 1990 and 2014, per-capita emissions in both countries are still below the average level in OECD countries. China's per-capita emissions in 2014 reached 6.2 tonnes, matching the level of the European Union, but a third lower than the OECD average (Figure 1.7). India's per-capita emissions were 1.6 tonnes in 2014, or about 10% of the level in the United States and 25% of the level in China. Significant differences across regions exist, not only in terms of per-capita emissions but also in terms of CO_2 emissions per unit of economic output. While all of the major regions reduced the CO_2 intensity of their economy, China emitted 0.82 tonnes CO_2 per thousand dollars of economic output in 2014, which compares to 0.3 tonnes in the United States and 0.18 tonnes in the European Union.

Figure 1.7 ▷ Energy-related CO_2 emissions per capita and CO_2 intensity by selected region

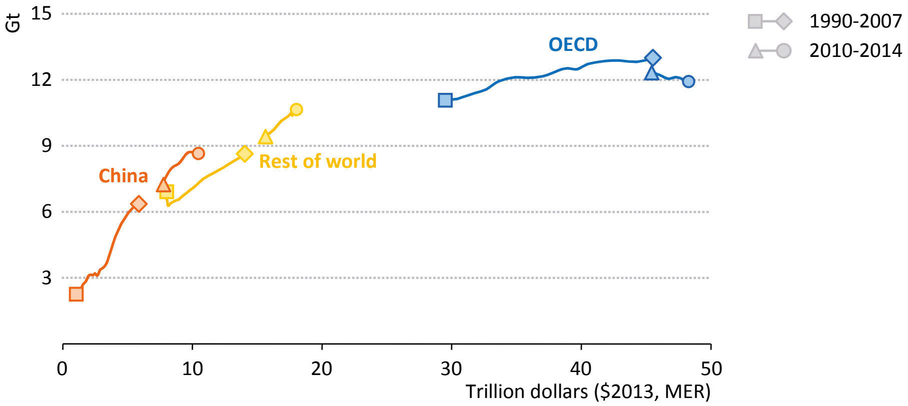


Notes: Bubble area indicates total annual energy-related CO_2 emissions. MER = market exchange rate.

Energy-related CO_2 emissions in 2014

The growth trend in global energy-related CO_2 emissions stalled in 2014 with an estimated total of 32.2 Gt, unchanged from the preceding year. This occurred even with the world economy growing by around 3% in the same year. Across the OECD as a whole, emissions fell by 1.8% while the economy grew by 1.8%, on average. This continues the clear break between economic growth and energy-related emissions growth that has been observed in the OECD in recent years reflecting increased deployment of renewables and enhanced efforts to increase energy efficiency (Figure 1.8).

Figure 1.8 ▷ **Energy-related CO_2 emission levels and GDP by selected region**

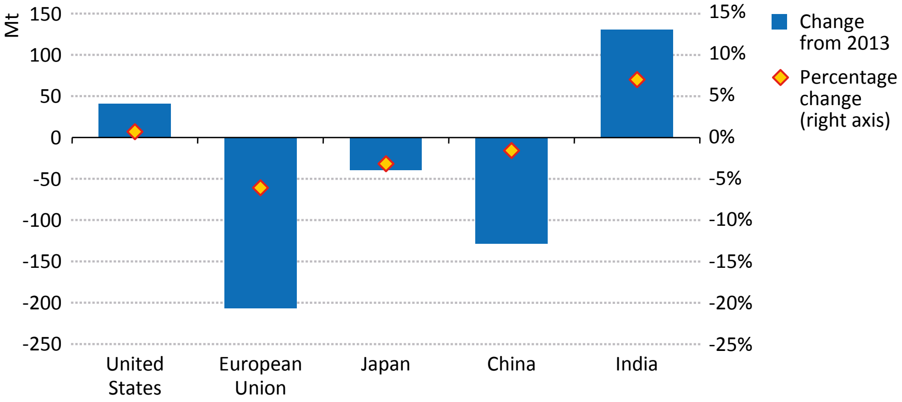


Note: MER = market exchange rate.

Energy-related CO_2 emissions in the European Union dropped by more than 200 Mt (over 6%), as demand for all fossil fuels declined: natural gas demand declined by 12%, partly due to the mild winter, while power generation from non-hydro renewables grew by 12% as they continued to benefit from active decarbonisation policies (Figure 1.9). Japan's CO_2 emissions are estimated to have been down by around 3% in 2014 relative to 2013, mainly due to lower oil demand; but LNG imports remained at a comparably high level, as a consequence of the shutdown of Japan's nuclear capacity. In the United States, energy-related CO_2 emissions in 2014 were 41 Mt higher (less than 1%) than the previous year but were around 10% below their peak in 2005 (5.7 Gt). Emissions from the power sector in the United States were down, due to an 11% increase in generation from non-hydro renewables and only a limited increase in electricity demand, while there was an increase in natural gas use in industry and buildings.

Placed in the context of recent trends, China's emission figures in 2014 are also consistent with a weakening of the link between economic growth and increased emissions, though it is not yet broken. Emissions in China declined in 2014 for the first time since 1999, registering a drop of around 130 Mt (1.5%).[8] Demand for coal, which has seen extraordinary growth in China in recent decades, declined by around 3%, an outcome that is partly cyclical and partly structural. On the one hand, there was tremendous growth in hydropower generation in 2014 (22%), mainly due to a particularly wet year. On the other hand, power generation from wind and solar increased by 34% and demand for natural gas grew by 9%, both suggesting demand for coal may be suppressed on a more sustained basis. Overall, low-carbon forms of power generation accounted for one-quarter of China's electricity supply in 2014, up from around one-fifth in 2013. In parallel, there are signs that economic growth in the future will be dominated by consumption, particularly for services, rather than investment in energy-intensive industries, which characterised the picture in the past.

Figure 1.9 ▷ **Change in energy-related CO_2 emissions by selected region, 2013-2014**



CO_2 emissions outside the OECD and China were up by around 290 Mt in 2014, led by increased use of coal for power generation in India and Southeast Asia. Indeed, across most emerging and developing countries, the relationship between economic growth and emissions growth remains strong as these countries are in the energy-intensive process of building up their capital stock.

The signs of a decoupling between energy-related emissions and economic growth in some parts of the world are encouraging – for the first time in 40 years, a halt or reduction in total global emissions has not been associated with an economic crisis. However, definitive conclusions cannot be drawn from the data for a single year. Part of the reduction in emissions in 2014 in the European Union, for example, was due to warmer weather which significantly reduced CO_2 emissions related to heating. Nonetheless, there are positive signs that committed climate action has the potential to achieve such a decoupling, creating a

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[8] The National Bureau of Statistics in China is in the process of revising its historical coal use upwards. This revision has not been incorporated within this study as a full energy balance is not yet available. While this revision will change the absolute level of emissions, it is not expected to affect significantly the relative change *vis-à-vis* 2013.

world economy which does not rely on ever greater consumption of fossil fuels, achieving deep cuts in GHG emissions but also supporting economic growth, boosting energy security and bringing energy services to the billions who, today, have no such access.

Projecting future developments

This *World Energy Outlook Special Report* has the pragmatic purpose of arming COP21 negotiators with the energy sector material they need to achieve success in Paris in December 2015. To that end, it continues the established *WEO* practice of using scenarios to illustrate the implications of different policy choices on energy markets and climate change. Three scenarios, differing in their assumptions about the evolution of government policies, are presented: the Intended Nationally Determined Contributions (INDC) Scenario, the Bridge Scenario and the 450 Scenario.[9] The Current Policies Scenario and the New Policies Scenario, familiar to readers of the annual *World Energy Outlook*, are not referenced in this report but will again be part of the *WEO-2015*, to be published in November 2015. The starting year for the projections is 2014, as reliable market data for all countries were, in most instances, available only up to 2013 at the time the modelling work was completed.

The ***INDC Scenario*** represents a preliminary assessment of the implications of the submitted INDCs and statements of intended INDC content for some countries. All INDCs that had been formally submitted to the UNFCCC Secretariat by 14 May 2015 (including Switzerland, European Union, Norway, Mexico, United States, Gabon, Russia, Liechtenstein and Andorra), which collectively represent 34% of global energy-related CO_2 emissions, have been analysed in order to evaluate their overall implications (Table 1.1). Where countries (such as China and India) have made statements indicating the likely content of an INDC yet to be delivered (or otherwise announcing plans to reduce emissions), these declarations have been taken as the basis for evaluating their implications. A range of country experts have been consulted to help ensure the accuracy of the INDC analysis. For those countries that have not submitted an INDC and have not publicly stated its likely content nor specified policies for the entire energy sector, the INDC Scenario includes the policies defined in the New Policies Scenario of *WEO-2014*, that is cautious implementation of the policies then announced or already in application (see Chapter 2 for details and Annex A for policy assumptions).[10]

Over the course of 2015 more countries are expected to submit their INDCs. This means that the INDC Scenario in its current form reflects the lower limits of the global climate efforts likely to underlie the climate summit in December 2015. One purpose of this analysis is to provide policymakers with a sound basis on which to consider further action. An update, including the latest INDCs, will be published in November 2015 for the IEA Ministerial meeting.

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[9] Tables containing detailed projection results by scenario, region, fuel and sector are available at *www.worldenergyoutlook.org/energyclimate.*

[10] The INDC Scenario is not compared with the WEO Current Policies Scenario or the New Policies Scenario as such a comparison would be biased to the extent that it would only stress recent progress made by countries but not previous efforts that are already incorporated in the Current and/or New Policies Scenario.

Table 1.1 ▷ Greenhouse-gas emissions reduction goals in submitted INDCs

UNFCCC Party	Intended Nationally Determined Contribution (INDC)
Switzerland	Reduce GHG emissions by 50% below 1990 levels by 2030 (35% below by 2025).
European Union	Reduce EU domestic GHG emissions by at least 40% below 1990 levels by 2030.
Norway	Reduce GHG emissions by at least 40% compared with 1990 levels by 2030.
Mexico	Reduce GHG and short-lived climate pollutant emissions unconditionally by 25% by 2030 with respect to a business-as-usual scenario.
United States	Reduce net GHG emissions by 26% to 28% below 2005 levels by 2025.
Gabon	Reduce CO_2, CH_4, N_2O emissions by at least 50% with respect to a reference scenario by 2025.
Russia	Reduce anthropogenic GHG emissions by 25% to 30% below 1990 levels by 2030 subject to the maximum possible account of absorptive capacity of forests.
Liechtenstein	Reduce GHG emissions by 40% compared with 1990 by 2030.
Andorra	Reduce GHG emissions by 37% with respect to a business-as-usual scenario by 2030.

Note: This table contains all contributions that had been submitted to the UNFCCC by 14 May 2015 and is in the order in which they have been submitted.

One measure of the success of COP21 will be the extent to which it carries to energy sector stakeholders a conviction that the sector is destined to change. An important symbol of such change would be achieving a peak in global energy-related GHG emissions. Identifying ways to facilitate such an achievement at an early date is the purpose of the ***Bridge Scenario*** (see Chapter 3 for details). The objective is to facilitate adoption by each country or region individually and using only existing technology of a pragmatic near-term strategy that is compatible with the same level of development and economic growth that underlies the energy sector policies and climate pledges which are reflected in the INDC Scenario. For countries which have already submitted their INDCs, the objective is to identify policies which permit yet higher levels of climate ambition. For countries which have not yet brought forward their INDCs, the purpose is to support ambitious target setting. This scenario is not, in itself, a pathway to the 2 °C target – additional technology and policy needs for such a pathway are set out in the 450 Scenario. But it indicates a strategy for near-term action as a bridge to higher levels of decarbonisation at a later stage compatible with the 2 °C goal.

The ***450 Scenario*** takes a different approach (see Chapter 4 for details). It adopts a specified outcome – achievement of the necessary action in the energy sector to serve the internationally adopted goal to limit the rise in long-term average global temperature (with a likelihood of around 50%) to 2 °C – and illustrating steps by which that might be achieved. Near-term policy assumptions for the period to 2020 draw on measures that were defined in the *Redrawing the Energy-Climate Map: WEO Special Report* (IEA, 2013), and welcomed by energy ministers who attended the IEA Ministerial meeting in 2013. Significant action beyond these measures and before 2020 is less likely, as this is the earliest date by which any agreement reached at COP21 could be expected to take effect.

In the period after 2020, it is assumed in the 450 Scenario that one of the main deficiencies of current climate policy is remedied: a CO_2 price is adopted in the power generation and industry sectors in OECD countries and other major economies, at a level high enough to make investment in low-carbon technologies commercially attractive. This policy is implemented first in OECD countries and then progressively extended to other major economies. We assume that fossil-fuel subsidies are totally removed by 2040 in all regions except the Middle East (where some element of subsidisation is assumed to remain) and that CO_2 pricing is extended to the transport sector everywhere, accelerating energy efficiency improvements. There is also a further extension of the scope and rigour of minimum energy performance standards in the transport and buildings sectors. In this scenario, the concentration of greenhouse gases in the atmosphere peaks by around the middle of this century.[11] The level of this peak is above 450 parts per million (ppm), a level still compatible with the achievement of the 2 °C objective. The concentration of greenhouse gases stabilises after 2100 at around 450 ppm.

The projections in all scenarios are sensitive to the underlying assumptions about the rate of GDP growth in each region. World GDP is assumed to grow at an average annual rate of 3.5% from 2013 to 2040. This means that the global economy is about two-and-a-half times the present level at the end of the projection period. The Bridge Scenario is built on the foundation that it is compatible with the level of development and economic growth that underlies current energy sector policies and climate pledges. The level of population, another important driver for the demand for energy services in all scenarios, is projected to grow by 0.9% per year on average, from an estimated 7.1 billion in 2013 to 9.0 billion in 2040.[12]

While the assumptions on economic and population growth are the same, energy price paths vary across the three scenarios, in part due to differences in the strength of policies to address energy security and environmental challenges, and their respective impacts on supply and demand. The extent of carbon pricing schemes and the level of CO_2 prices vary across the scenarios, according to the assumed degree of policy intervention to curb growth in CO_2 emissions. It is assumed in each scenario that all existing carbon trading schemes and taxes are retained and that the price of CO_2 rises throughout the projection period. In the INDC Scenario, the CO_2 price in the European Union increases from less than $8/tonne in 2014 to $53/tonne (in year-2013 dollars) in 2030, while for China it is assumed that a national CO_2 price is introduced in 2020, rising to $23/tonne by 2030. In the 450 Scenario, it is assumed that carbon pricing is eventually adopted in all OECD countries and that CO_2 prices in most of these markets reach $140/tonne in 2040. Several major non-OECD countries are also assumed to put a price on carbon in the 450 Scenario, with prices rising to a slightly lower level in 2040 than in OECD countries.

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[11] A peak in atmospheric greenhouse-gas concentrations is delayed compared to a peak in emissions because of the long atmospheric lifetime of some greenhouse gases.

[12] Full details of the assumptions and methodology underlying all *WEO* scenarios presented here can be found in model documentation (IEA, 2014b) and online at *www.worldenergyoutlook.org/weomodel*.

The energy sector impact of national pledges

Determined to make a climate contribution

Highlights

- The Intended Nationally Determined Contributions (INDCs) submitted by countries in advance of COP21 are to form the core of collective and increasingly ambitious climate action. A first assessment of the impact of INDCs on the energy sector is presented here in an "INDC Scenario". An update, including the latest INDCs, will be published in November 2015, during the IEA Ministerial meeting.
- In the INDC Scenario, national pledges have a positive impact in slowing the growth in global energy-related emissions but they continue to rise from 2013 to 2030. The link between economic growth and energy-related GHG emissions weakens, with the global economy growing by 88% and energy-related CO_2 emissions by 8% (reaching 34.8 Gt). The share of fossil fuels in the world energy mix declines but is still around 75% in 2030. The rate of growth in coal and oil demand slows but volumetric demand does not decline, while gas use marches higher. Renewables become the leading source of electricity by 2030, but subcritical coal-fired capacity declines only slightly. The carbon intensity of the power sector improves by 30%.
- The United States achieves major cuts in energy-related GHG emissions by 2025 in the INDC Scenario. The US power sector delivers 60% of the savings (renewables and coal-to-gas switching) and fuel-economy standards in transport much of the rest. In the European Union, a strong shift to renewables and greater energy efficiency sees fossil fuel use drop by more than 20% by 2030, making it one of the world's least carbon-intensive energy economies. Russia's energy-related CO_2 emissions decline slightly and it meets its 2030 target comfortably. Mexico's energy-related CO_2 emissions increase slightly but at a much slower rate than the economy.
- The growth in China's energy-related CO_2 emissions slows and then peaks around 2030. Though it remains the largest emitter by far in 2030, the energy sector diversifies, becoming more efficient as well as less carbon intensive. India makes a push to build-up renewables capacity and improves energy efficiency, in parallel with efforts to make modern energy available to more of the population and improve reliability of supply. Very rapid growth in energy demand boosts related CO_2 emissions by around 65% by 2030, but per-capita levels remain low.
- Neither the scale nor the composition of energy sector investment in the INDC Scenario is suited to move the world onto a 2 °C path. The estimated remaining carbon budget consistent with a 50% chance of keeping below 2 °C is consumed by around 2040 – only eight months later than expected in the absence of INDCs. If stronger action is not forthcoming, the INDC Scenario is judged to be consistent with a global temperature increase of around 2.6 °C in 2100 and 3.5 °C after 2200.

Energy and GHG emissions trends in the INDC Scenario

What impact will the Intended Nationally Determined Contributions (INDCs) submitted by governments have on the energy sector and its related greenhouse-gas (GHG) emissions? Will they be sufficient to put the world on track to meet the 2 degree Celsius (°C) climate goal or, at least, provide a satisfactory foundation upon which to build increasingly ambitious action? For this *World Energy Outlook Special Report*, the IEA has undertaken a first assessment of newly declared government intentions, with the results presented through an "INDC Scenario" (defined in Chapter 1 and Annex A).[1]

As shown in Chapter 1, energy production and use accounts for around two-thirds of global GHG emissions today, of which carbon dioxide (CO_2) is the great majority (Table 2.1). As of 14 May 2015, countries accounting for 34% of global energy-related emissions had submitted their INDCs. Some other countries such as China had not submitted their INDCs but had otherwise clarified their intended post-2020 actions on climate change. These INDCs and stated policy intentions (together with previous policy declarations by countries which have yet to disclose their latest intentions) provide a basis upon which to conduct an initial assessment of their impact on future energy and emissions trends. While this assessment can only be indicative rather than definitive, it still provides crucial insights for decision makers in the preparations for the climate summit in December 2015. The IEA will publish timely updates of INDC analysis, incorporating new INDC submissions, in the lead up to COP21.

Table 2.1 ▷ **Global energy- and process-related greenhouse-gas emissions in the INDC Scenario** (Gt CO_2-eq)

	2013	2020	2025	2030
Energy-related:				
Carbon dioxide (CO_2)	32.2	33.9	34.3	34.8
Methane (CH_4)	3.0	3.1	3.1	3.1
Nitrous oxide (N_2O)	0.3	0.3	0.4	0.4
Process-related:				
Carbon dioxide (CO_2)	2.0	2.2	2.2	2.3
Total	**37.5**	**39.5**	**40.0**	**40.6**

In the INDC Scenario, annual global energy- and process-related GHG emissions grow from 37.5 gigatonnes of carbon-dioxide equivalent (Gt CO_2-eq) in 2013 to 40.6 Gt CO_2-eq by 2030. If stronger action were not forthcoming after 2030, the emissions path in the INDC Scenario

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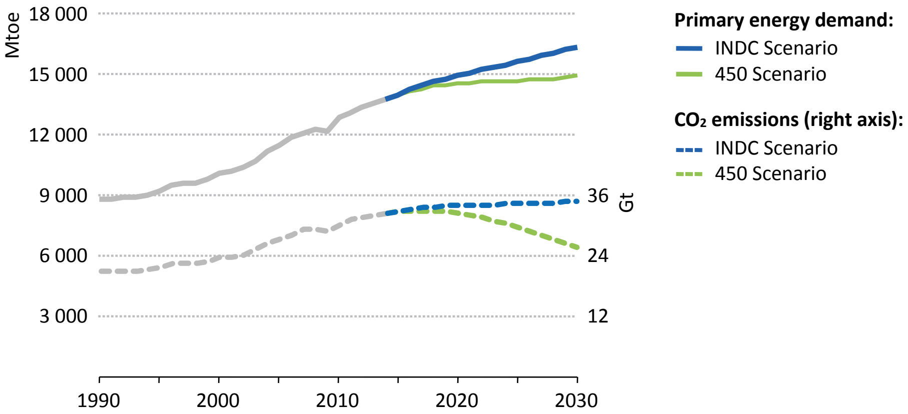
[1] Tables containing detailed projection results for the INDC Scenario by region, fuel and sector are available at *www.worldenergyoutlook.org/energyclimate*.

is estimated to be consistent with a 50% probability of an average long-term global temperature increase of around 2.6 °C in 2100 and 3.5 °C in the longer term (after 2200).[2] This global average translates into higher average temperatures over land – 4.3 °C over land in the northern hemisphere (where the majority of the world's population lives) – and higher still in urban areas. The INDCs fall short of the action necessary to meet the 2 °C climate goal; but they could form the basis for more ambitious action to decarbonise the global energy system (see Chapter 3 for ways that countries can take further action at no net economic cost).

There is no peak in sight for world energy-related CO_2 emissions in the INDC Scenario: they are projected to be 8% higher than 2013 levels in 2030 (reaching 34.8 gigatonnes [Gt]), while primary energy demand grows by around 20% (Figure 2.1) and the global economy is around 88% larger. In a 450 Scenario – which reflects a pathway consistent with around a 50% chance of meeting the 2 °C climate goal – energy-related CO_2 emissions are already in decline by 2020. By 2030, there is around a 9 Gt gap between energy-related emissions in the INDC Scenario and the 450 Scenario.

Figure 2.1 ▷ **Global primary energy demand and related CO_2 emissions by scenario**



Note: Mtoe = million tonnes of oil equivalent; Gt = gigatonnes.

The transition away from fossil fuels is gradual in the INDC Scenario, with the share of fossil fuels in the world's primary energy mix declining from more than 80% today to around three-quarters in 2030 (Figure 2.2). World demand for coal shows signs of

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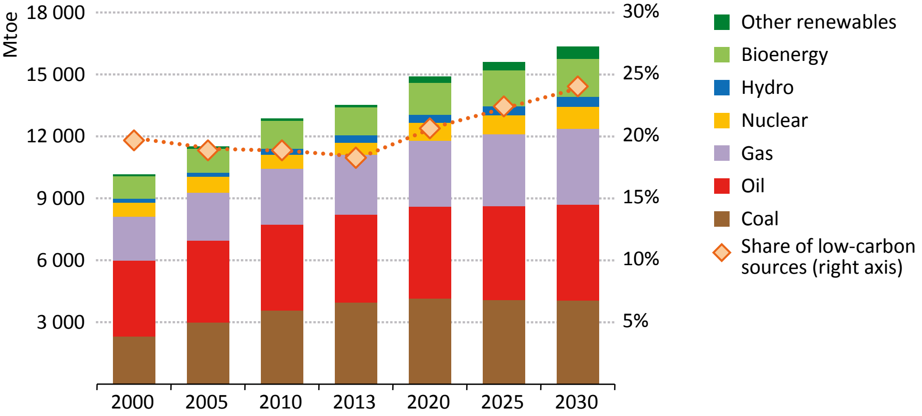
[2] The temperature estimate has been derived with MAGICC6, a climate carbon cycle model. The emissions trajectory post-2050 is between the representative concentration pathways (RCP) 4.5 and RCP 6 Scenarios from the IPCC's 5th Assessment Report.

reaching a plateau by around 2020; but there are differing trends across OECD and non-OECD regions, with the former declining and the latter continuing to increase. Global emissions from coal use increase only slightly, relative to today, and are around 14.5 Gt in 2030. Global oil demand reaches 99 million barrels per day (mb/d) in 2030, around 9% higher than today, with actions in the INDC Scenario helping to slow demand growth in the transport sector. World natural gas demand increases by around 30% by 2030, helping to suppress growth in emissions when acting as a substitute for other fossil fuels but adding to emissions when acting as a substitute for renewables and nuclear. By 2030, coal accounts for 41% of energy-related CO_2 emissions, oil for 34% and natural gas for 25%. While significant hydropower potential remains in some regions, the global expansion of hydropower capacity is relatively modest. Solar and wind capacity increase more rapidly. All low-carbon options collectively account for around one-quarter of primary energy demand in 2030.

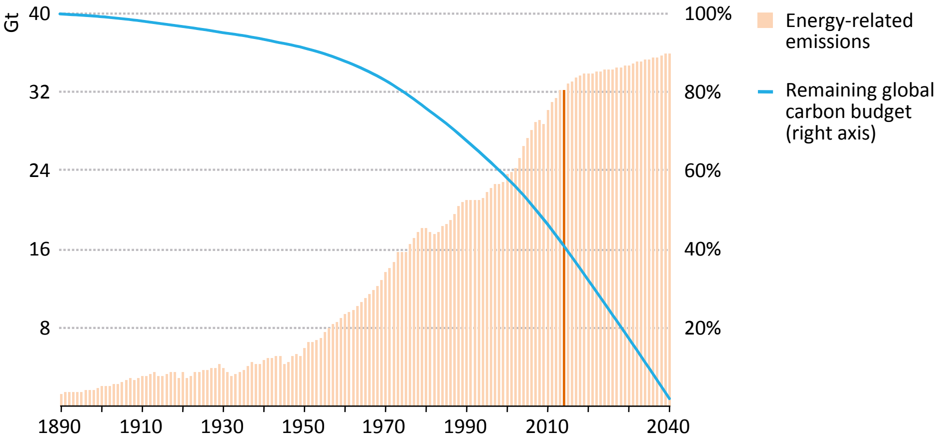
Figure 2.2 ▹ Global primary energy demand by type in the INDC Scenario



Note: "Other renewables" includes wind, solar (photovoltaic and concentrating solar power), geothermal, and marine.

The projected path for energy-related emissions in the INDC Scenario means that, based on IPCC estimates, the world's remaining carbon budget consistent with a 50% chance of keeping a temperature increase of below 2 °C would be exhausted around 2040, adding a grace period of only around eight months, compared to the date at which the budget would be exhausted in the absence of INDCs (Figure 2.3). This date is already within the lifetime of many existing energy sector assets: fossil-fuelled power plants often operate for 30-40 years or more, while existing fossil-fuel resources could, if all developed, sustain production levels far beyond 2040. If energy sector investors believed that not only new investments but also existing fossil-fuel operations would be halted at that critical point, this would have a profound effect on investment even today.

Figure 2.3 ▷ Global energy-related CO_2 emissions in the INDC Scenario and remaining carbon budget for a >50% chance of keeping to 2 °C



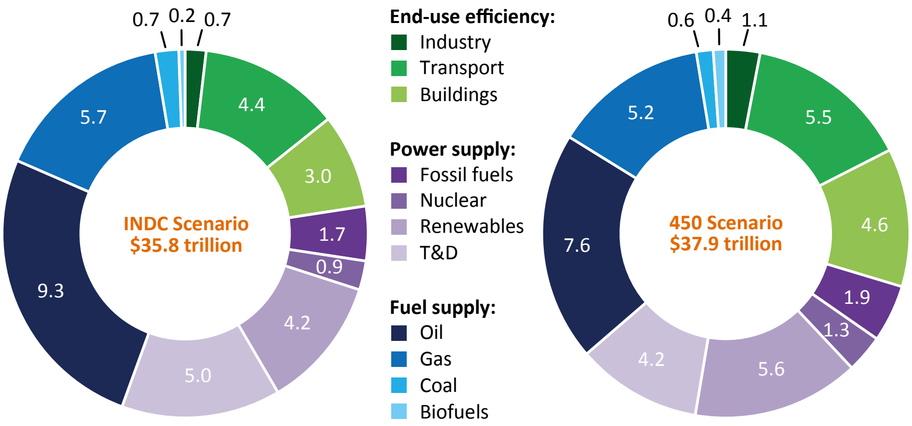
Sources: IPCC and IEA data; IEA analysis.

The power sector continues to be the world's dominant fossil-fuel consumer and source of energy-related CO_2 emissions in the INDC Scenario, accounting for 42% of the energy sector total in 2013, with a decrease to just below 40% in 2030. A push towards renewables in many markets and greater levels of efficiency, in the power sector and in the use of electricity, both play an important role in helping to mitigate power sector emissions in the INDC Scenario. Renewables expand across regions, but the nature of this expansion varies. In the United States and the European Union, it occurs largely at the expense of ageing fossil-fuelled capacity that is retired. In China, India and many other developing countries, expansion of renewable capacity goes hand-in-hand with efforts to expand energy supply also from other sources, to keep up with rapidly increasing demand. In Brazil, reliance on hydropower shifts gradually towards increased use of wind, solar and biomass. In Africa, renewables play an important role in increasing access to energy, both to those on the main grid and those who benefit from distributed forms of electricity supply. In the Middle East, the uptake of renewables helps to stem the increase in domestic use of fossil fuels in the power sector. The global carbon intensity of the power sector improves in the INDC Scenario – going from 528 grammes of CO_2 per kilowatt-hour (g CO_2/kWh) in 2013 to 370 g CO_2/kWh in 2030 – as the oldest, least efficient and often most polluting fossil-fuelled plants are retired and more efficient and more low-carbon supply enters the system. Carbon capture and storage (CCS), a potentially important abatement option, achieves no more than marginal penetration to 2030 (see Chapter 4 for more on CCS).

Increased efficiency measures across sectors in the INDC Scenario reduce the energy used to provide energy services, without reducing the services themselves. For example, both the fuel efficiency of new passenger light-duty vehicles (PLDVs) and their average emissions per kilometre improve significantly by 2030, the latter declining by around half. Despite these improvements, the transport sector accounts for nearly half of the projected increase in global energy-related CO_2 emissions to 2030. Oil consumption in the sector goes from 49 mb/d in 2013 to 57 mb/d in 2030, while the transition towards alternative vehicles is barely underway in the INDC Scenario and continues to face a number of challenges relating to costs, refuelling infrastructure and consumer preferences. (See Chapter 4 for more on electric vehicles.)

Neither the scale nor the composition of energy sector investment in the INDC Scenario is suited to move the world onto a 2 °C path. Cumulative investment in fossil-fuel supply accounts for close to 45% of the energy sector total, while low-carbon energy supply accounts for 15% (Figure 2.4). Global investment in fossil-fuelled power generation capacity declines over time, to stand at around $100 billion in 2030, but investment in coal-fired plants still accounts for more than half of the total at that time. Investment in renewable-based power supply remains relatively stable over the period to 2030, averaging $260 billion per year, with ongoing reductions in unit costs masking higher levels of deployment. Global investment in nuclear power remains concentrated in just a few markets. On the demand side, around $8 trillion is invested in energy efficiency from 2015 to 2030 in the INDC Scenario.[3] One-third of this is spent by motorists on more efficient cars, while more than another third is on improved efficiency in buildings (mainly insulation, efficient appliances and lighting) and the rest is split between energy efficiency in industry and road freight.

Figure 2.4 ▷ Cumulative global energy sector investments by sector in the INDC and 450 Scenarios, 2015-2030 (trillion dollars, 2013)



Note: T&D is transmission and distribution.

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[3] Energy efficiency investment is defined as the additional expenditure made by energy users to improve the performance of their energy-using equipment above the average efficiency level of that equipment in 2012.

Under a 2 °C path (represented here by the 450 Scenario), cumulative energy sector investment is only a little higher (around 6%), but the composition of this investment is significantly different. Investment in fossil-fuel supply is lower than in the INDC Scenario (the extent varies across the fuels), even though it is still a major part of overall energy sector investment. Capital allocation in the power sector increases and moves towards low-carbon options, i.e. renewables, CCS and nuclear (collectively $2.2 trillion higher). (Increased investment in CCS acts as an enabler to investment in fossil-fuel supply and related power generation capacity, serving as a form of asset protection strategy.) The largest shift in investment is on the demand side (and so focused on the energy consumers rather than producers), with cumulative energy efficiency investment increasing by more than $3 trillion. Companies invest in more efficient trucks, while households buy more efficient appliances, building insulation and improved space heating and cooling equipment. (See Chapter 5 for how COP21 could help re-orient energy sector investment.)

The INDC process is a valuable means to aggregate national contributions into collective global action towards the 2 °C goal, representing a solid basis for building ambition, even if not yet sufficient in themselves to achieve the climate goal. (See Chapter 3 for the presentation of a “Bridge Scenario”, which highlights a series of immediately practicable steps that can enhance energy sector action at no net economic cost.)

Regional trends

While OECD countries have accounted for a major share of historical energy-related emissions, this picture has been changing rapidly in recent decades and continues to shift in the INDC Scenario, with the non-OECD share of total global emissions increasing from less than 60% in 2013 to nearly 70% in 2030. In per-capita terms, however, levels in the OECD (7 tonnes CO_2/capita per year) are projected to still far-exceed the average non-OECD per-capita level – the OECD level being nearly double the non-OECD average in 2030 – although significant national disparities occur within both groups (Figure 2.5).

United States

Within its INDC, the United States declares its intention to reduce its net GHG emissions[4] to 26% to 28% below 2005 levels in 2025 and to make best efforts to achieve the upper end of this range. This builds on its commitment in the Copenhagen Accord to reduce emissions to 17% below 2005 levels by 2020. The US INDC sets the 2025 target in the context of a longer range, collective intention to move to a low-carbon global economy as rapidly as possible, and keep the United States on a path to achieving 80% reductions or more by 2050. Energy and climate policies introduced in recent years are already having a material impact on the projected emissions trajectory for the United States and the INDC target builds on a number of existing and proposed plans and policies, such as the Climate Action Plan, the

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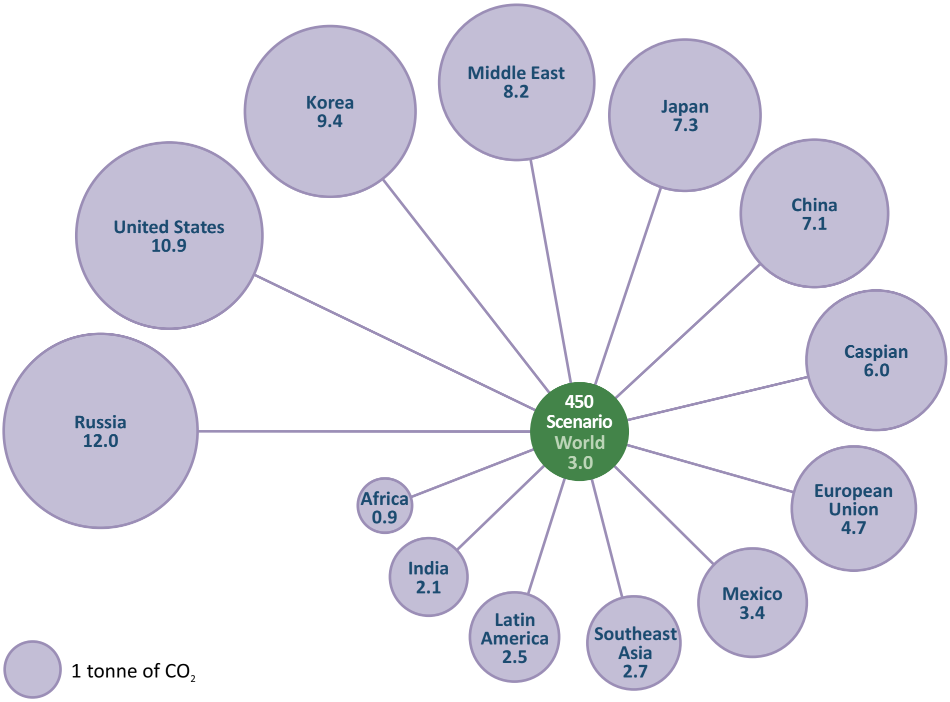
[4] Net greenhouse-gas emissions include emissions from land use, land-use change and forestry (LULUCF), which are a net sink in the United States, meaning that emissions from LULUCF are negative.

Clean Power Plan,[5] tax credits for wind and solar, state-level renewable portfolio standards, a goal to reduce methane emissions from the oil and gas sector, vehicle fuel-economy standards, energy conservation standards and targets to reduce hydrofluorocarbons. There have also been important market developments, most notably the emergence of large-scale shale gas production.

Figure 2.5 ▷ Energy-related CO_2 emissions per capita by selected region in the INDC Scenario and world average in the 450 Scenario, 2030



As of 2013, the United States was around 35% of the way towards the lower-end (26%) of its 2025 emissions reduction target, while seeing its economy grow by around 10% since 2005. Between 2005 and 2013, net GHG emissions were reduced by 547 million tonnes of carbon-dioxide equivalent (Mt CO_2-eq), at a pace of around 60 Mt CO_2-eq per year. Energy-related CO_2 emissions accounted for all of the net reductions, with around 60% coming from the power sector, mainly as a result of lower natural gas prices encouraging coal-to-gas switching, increasing contributions from renewables and, to a much lesser extent, coal plants being retired in anticipation of the Mercury and Air Toxics Standards

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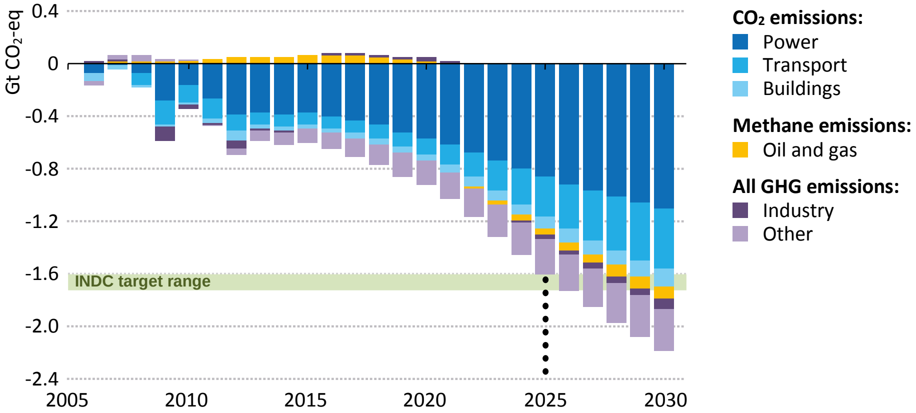
[5] The US Environmental Protection Agency (EPA) has proposed a Clean Power Plan for Existing Power Plants and Carbon Pollution Standards for New, Modified and Reconstructed Power Plants. The EPA is expected to issue final rules in mid-2015.

(in effect as of April 2015) and other environmental regulations. In end-use sectors, the transport sector delivered by far the largest emissions reductions, achieved by tightening fuel-economy standards, followed by industry and buildings.

Meeting the target set by the United States requires further cuts in energy sector emissions; but these can be achieved under existing authorities (Figure 2.6). In the INDC Scenario, net GHG emissions fall by nearly an additional 1.1 Gt from 2013 to 2025, to meet the lower-end of the overall reductions target (a 26% reduction), with the pace of these reductions projected to increase over time. Based on current INDCs, the United States is projected to deliver the largest absolute reduction in energy-related CO_2 emissions of any country in the world from 2013 to 2025. However, even with a 20% reduction, average CO_2 emissions per capita remain among the highest levels in the world. At the same time, primary energy demand in the United States remains broadly flat, while the population increases by 30 million and the economy grows by around $6 trillion ($2013, purchasing power parity [PPP] terms).

Figure 2.6 ▷ United States economy-wide greenhouse-gas emissions reductions relative to 2005 in the INDC Scenario



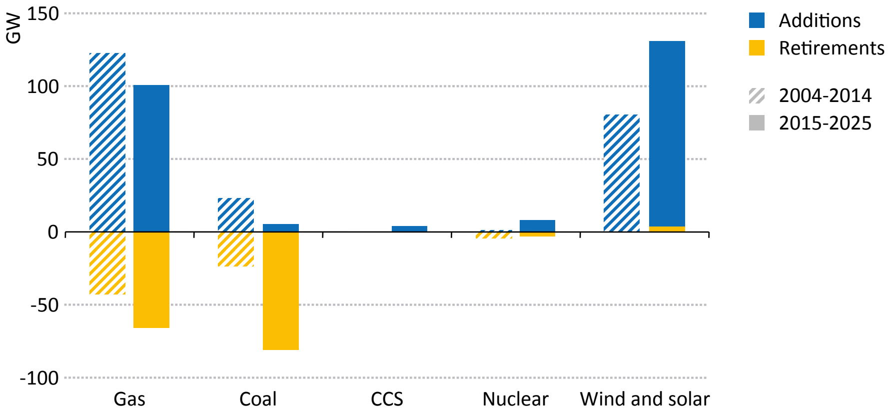
Notes: INDC target range reflects the US INDC intention to reduce GHG emissions 26% to 28% below 2005 levels in 2025. Power, transport and buildings show change in CO_2 emissions, oil and gas shows the change in CH_4 emissions from oil and gas production and its transportation (presented in CO_2-eq terms). Industry (including industrial process emissions) and "Other" show the change in all GHG emissions, including agriculture and waste.

Emissions from the energy sector in the United States are on a clear declining trajectory in 2025, led by reductions from coal and oil, and a stabilisation in those from natural gas at levels only a little higher than today. US oil demand remains relatively flat through to 2020, but starts to drop after this date – around 2% per year – due largely to tightening fuel-economy standards and increasing use of biofuels. By 2025, oil demand is 1.6 mb/d lower than in 2013 and it is projected to continue to decline thereafter. A combination of fuel-economy standards and biofuels acting on demand and higher domestic oil production sees US net oil imports decline from 7.3 mb/d in 2013 to 4 mb/d by 2025 and the related import bill drop from $283 billion to around $165 billion. Natural gas demand is showing signs of peaking by 2025, but the decline in coal and oil emissions means that gas still becomes the largest source of energy-related CO_2 emissions around 2030 (overtaking oil). The share of low-carbon energy in the primary energy mix goes from 16% today to 21% in 2025, led by bioenergy, wind, solar and hydropower. As for all countries, the relatively long lifetime of many energy sector assets means that the way in which the United States meets the 2025 target will influence its room for additional decarbonisation in the longer term.

Power sector

In the INDC Scenario, electricity demand in the United States increases by just 9% from 2013 to 2025, as energy efficiency efforts slow growth over time. Power sector CO_2 emissions are projected to be 865 million tonnes (Mt) lower in 2025 (relative to 2005 levels). This decline is largely driven by policies linked in some way to the Clean Power Plan (which aims to reduce power sector CO_2 emissions to 30% below 2005 levels by 2030) and efforts to improve power sector efficiency and end-use efficiency (reducing electricity demand). Coal-fired capacity declines by more than 20% by 2025 (Figure 2.7), as new additions are limited to the highest efficiency, CCS-ready technologies and the oldest and least-efficient existing capacity is retired. However, on a 2 °C path, the long-term trajectory for coal hangs heavily on the development and deployment of CCS technology, which, if pursued successfully, could secure a more positive outlook for coal while remaining consistent with climate goals (see Chapter 4).

Figure 2.7 ▷ United States power generation capacity additions and retirements in the INDC Scenario



Wind leads the growth in renewables-based capacity in the United States in the INDC Scenario, averaging over 6 gigawatts (GW) per year to 2025, while solar technologies average around 5 GW per year, with solar photovoltaic (PV) accounting for the vast majority.

Coal's share of total electricity generation drops by 17 percentage points (to 23%) by 2025. Continuing to benefit from relatively low fuel prices, gas-fired generation takes up half of the share surrendered by coal and renewables collectively the remainder. Renewables-based electricity generation expands from around 13% of the total in 2013 to more than one-fifth by 2025, often supported by policies, such as renewable portfolio standards, tax credits and the need for emissions reductions to comply with the Clean Power Plan, but also as a result of their increasing competitiveness (as unit costs decrease). Overall, low-carbon electricity generation increases from around one-third today to 40% in 2025, with the carbon intensity of the power sector dropping by around 30%.

End-use sectors

Total final energy consumption in the United States is projected to be at a level similar to 2013 in 2025, while the related emissions decline. In the transport sector, tougher fuel-economy standards for passenger vehicles and heavy trucks build on the improvements that have already been achieved, making the sector the second-largest contributor to emissions reductions in the INDC Scenario (310 Mt – 17% – lower in 2025 than 2005). US Corporate Average Fuel Economy (CAFE) standards for PLDVs (54.5 miles per gallon [23.2 kilometres per litre] by 2025) significantly reduce oil demand, while policies to reduce average on-road fuel consumption by trucks help push emissions per kilometre down by around one-quarter, relative to 2013. From 2020 onwards, total transport emissions in the United States decline by around 2% per year, on average. In line with the targets set in the Renewable Fuel Standard Program, demand for biofuels increases by 80% to reach 1.1 mb/d in 2025, of which around 90% is ethanol and the remainder biodiesel. In the same time frame, the United States sees sales of electric vehicles (including plug-in hybrids and battery-electric vehicles) increase to around 1.5 million, while the use of natural gas for fleet vehicles and trucks also sees significant growth from today's low levels.

Energy efficiency plays an important role across other end-use sectors, with a combination of policies serving to tighten existing efficiency standards, encourage greater adoption of energy-efficient equipment (such as tax credits for energy-efficient equipment in buildings) and help to push efficiency levels higher through innovation. For example, several large industrial energy users have committed to reduce their energy intensity by 25% over a ten-year period under the Better Buildings, Better Plants Program, while the long-standing Energy Star Program continues to improve energy efficiency for appliances, through research, labelling and communication.

Other gases

Methane emissions accounted for nearly 15% of US GHG emissions in 2013, of which around 30% came from the production, transmission and distribution of oil and natural gas. Methane emissions from the oil and gas sector increased by around 50 Mt CO_2-eq from 2005 to 2013, meaning that there is a need to save nearly 100 Mt CO_2-eq to meet the low end of the stated US policy goal (40% to 45% reductions by 2025, relative to 2012 levels). To do this requires a combination of actions including regulation and monitoring, investment to upgrade infrastructure and implementation of best practices. (See Chapter 3 for more on minimising methane releases from upstream oil and gas operations.) Reductions of hydrofluorocarbons in industry (in line with targets) and other gases across different parts of the energy sector together help to reduce emissions by around 240 Mt CO_2-eq in 2025. One large uncertainty relating to net GHG emissions in the United States in 2025 is the contribution of forestry and land-use change. While these sectors have the potential to become a larger emissions sink, it is difficult to tap this potential through conventional policy measures and their contribution is therefore held within the range given in the US Climate Action Report (US Department of State, 2014).

Investment

In the INDC Scenario, energy supply investment in the United States averages around $255 billion per year through to 2025, nearly 30% higher than the average since 2000. This reflects the need to replace ageing power plants that are due to retire and a continuation of the shift in power sector investment ($86 billion per year to 2025) away from coal and towards gas and renewables. Upstream oil and gas continue to require significant investment (around $125 billion per year collectively), while coal supply investment gradually declines. Projected investment in energy efficiency (around $100 billion per year) is a clear step up from historical levels. Efficiency investment increases in industry, but investment in CCS does not grow significantly by 2025. Efficiency investments in transport double over the period to 2025, while investments in buildings increase even more rapidly, accounting for around 55% of all efficiency investments in the United States to that year.

European Union

The INDC of the European Union (EU) sets out a binding target to reduce domestic GHG emissions by at least 40% in 2030, compared with 1990 levels. The target is based on the European Union's 2030 framework for energy and climate policies, which also sets out targets to increase the share of renewable energy to at least 27% (of final energy consumption) and to improve energy efficiency by at least 27% (relative to a projected reference level in 2030); but these elements are not formally part of the EU INDC. The European Union's own assessment of the effects of the 2030 framework indicates that CO_2 emissions from the energy sector will fall by around 37% and non-CO_2 greenhouse gases by around 55% (EC, 2014).[6] The 2030 framework builds on the target to reduce EU GHG emissions by 20% by 2020, which the EU is on track to meet, with energy sector CO_2 emissions in 2014 being around 22% below 1990 levels and per-capita emissions 27% lower. At the same time, the economy has grown by almost 50%, reflecting the continued decoupling of emissions from economic growth. Both the 2020 and 2030 emissions targets represent important milestones towards the EU's long-term objective of cutting emissions by at least 80% by 2050.

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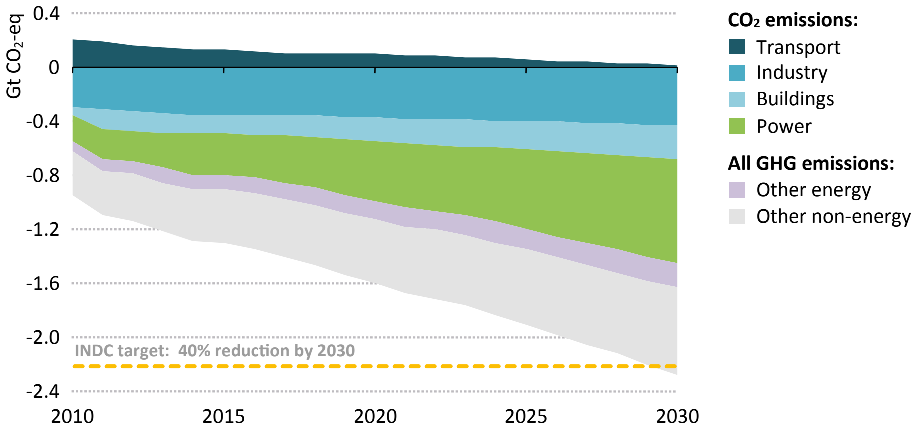
6. The INDC for the European Union states that policy on how to include land use, land-use change and forestry into the 2030 greenhouse-gas mitigation framework will be established as soon as technical conditions allow and in any case before 2020.

In the INDC Scenario, the European Union's energy-related CO_2 emissions fall from above 3.3 Gt in 2013 to 2.4 Gt by 2030, declining at nearly double the average annual rate observed since 2000 (Figure 2.8). Per-capita levels drop to 4.7 tonnes of CO_2 by 2030, almost half the level of 1990. In parallel, primary energy demand declines by 10% and the EU economy expands by one-third. Emissions from coal drop to 530 Mt in 2030, while gas and oil are both around 950 Mt. The projections in the INDC Scenario reflect the re-orientation of the EU's energy system that is already underway, with the share of low-carbon energy sources growing from 27% of primary energy demand in 2013 to 37% in 2030. As the share of fossil fuels declines, the relative weighting between the fossil fuels also moves towards gas. Natural gas imports grow by around 18% from 2013 to 2030 (to nearly 360 billion cubic metres), with the related import bill rising to about $155 billion. The role of nuclear power declines in some countries, pulling its share of the regional energy mix down slightly over time. While the EU's potential for large hydropower has already been largely harnessed, there is a major expansion in its use of wind, solar and bioenergy in the INDC Scenario.

Figure 2.8 ▻ **European Union greenhouse-gas emissions reductions relative to 1990 in the INDC Scenario**

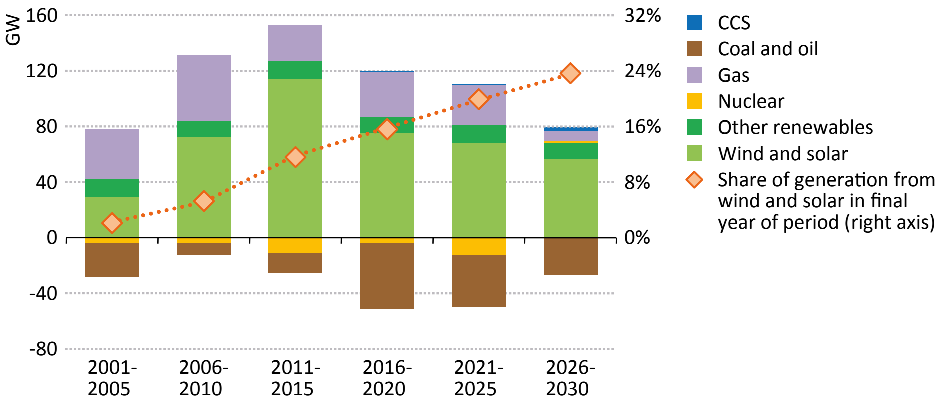


Notes: Emissions from land-use, land-use change and forestry (LULUCF) are excluded. Industry includes industrial CO_2 process emissions. Exceptionally, transport includes emissions from international aviation.

Power sector

Electricity demand in the European Union increases by around 10% by 2030 in the INDC Scenario. Growth is led by the residential and services sectors, while industrial demand starts to decline in the 2020s. Renewables account for more than half of the European Union's power generation capacity in 2030 in the INDC Scenario (Figure 2.9). Coal-fired capacity declines by nearly 40%, to stand at around 120 GW, while gas-fired capacity increases by one-third, to reach 300 GW. The carbon intensity of the EU's power sector halves by 2030. Around one-quarter of total generation at that time is from variable renewables (wind and solar), highlighting the need to invest in greater levels of interconnection (to help handle the variability of supply across a broader base), as well as in upgraded distribution networks and metering, and considering the relative merits of demand-side management options. The effective technical and market integration of variable renewables with other forms of supply will be an important future challenge for the EU, as for many countries around the world. (See Chapter 4 for more on the integration of variable renewables in the power system.) The EU strategy proposes increased interconnection across national markets, as a means to support such integration and energy security more generally.

Figure 2.9 ▷ European Union net capacity additions by type and share of electricity from variable renewables in the INDC Scenario

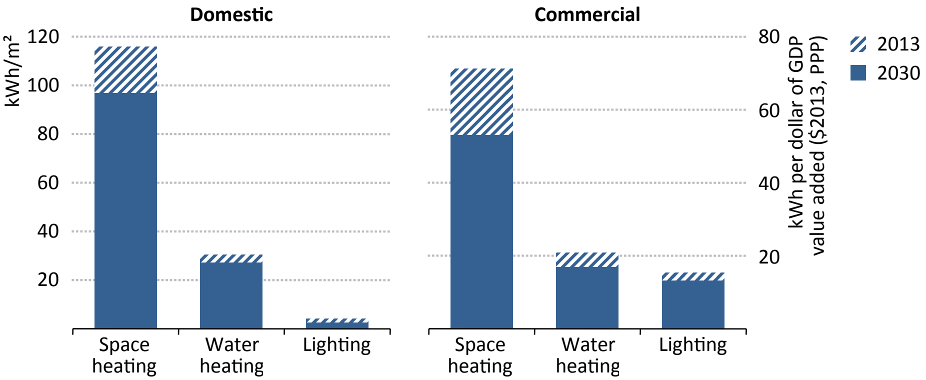


End-use sectors

In the INDC Scenario, energy demand in end-use sectors declines slightly (6%) in the European Union to 2030, while the related GHG emissions drop by around 20%. The European Union has been a leading proponent of policies to increase efficiency and reduce emissions in the transport sector, such as through increasingly strict fuel-economy standards and policies to encourage modal shifts for passengers and freight. Alternative fuels, such as biofuels and electricity, are projected to see significant growth (but from low levels), and oil-based fuels remain dominant in the transport sector in 2030. Obstacles to the greater use of alternative transport fuels include, but are not limited to, the high upfront costs of electric vehicles and sustainability concerns affecting biofuels. In industry, it is not possible to use energy carriers other than fossil fuels for all process heat applications and there is (as yet) no viable alternative to oil-based petrochemical feedstock – a challenge facing all regions. As other sectors reduce their emissions, overcoming these obstacles will become increasingly important to sustaining rates of decarbonisation.

Efficiency policies are effective at avoiding growth in energy consumption without impinging on the use of energy services. In the case of buildings and industry, energy efficiency measures are a key factor in reducing GHG emissions in both sectors by around one-fifth by 2030. Strong implementation of the Energy Efficiency Directive (EED), and the extension and tightening of eco-design and labelling requirements, accelerate the uptake of more efficient heating equipment and appliances in the buildings sector. Meanwhile, implementation of the Energy Performance of Buildings Directive and actions to overcome market barriers support more rapid refurbishment of the building stock, leading to a 16% reduction in space heating energy needs per square metre for households and a 25% improvement in commercial buildings per unit of value added (Figure 2.10). The phase-out of halogen light bulbs and the adoption of LEDs results in a reduction of more than 40% in electricity consumption for lighting per square metre in households. In industry, the EED leads to actions to encourage the diffusion of best available technologies, supported by energy audits and the implementation of energy management systems. As a consequence, newly installed electric motor systems for pumps, fans, compressed air and material handling are, on average, 30% more efficient in 2030 than current ones.

Figure 2.10 ▹ European Union energy intensity levels in domestic and commercial buildings in the INDC Scenario



Notes: kWh/m² = kilowatt hours per metre squared. GDP is expressed in purchasing power parity (PPP) terms.

Investment

In the INDC Scenario, EU investments in energy efficiency grow to reach similar levels to those in energy supply by 2030. Energy supply investments remain relatively constant at around $145 billion per year, focusing on renewables (and their integration) and natural gas. Nearly $70 billion per year is invested in power generation, of which 70% is in renewables – the largest recipient being wind (collectively, the EU is the world leader in wind power investment to 2030), followed by solar PV. Relatively smooth trends for renewables investment at the EU-level mask volatility at the country-level, where there may be more notable peaks and troughs in activity. While the desired capacity can still be delivered, such volatility may prejudice long-term industry development. The European

Union is also projected to invest over $30 billion per year in upgrading and expanding electricity transmission and distribution networks. Outside the power sector, the EU invests $25 billion per year in fossil-fuel supply (mainly conventional oil and gas), and nearly $20 billion in the midstream and downstream sectors (gas transport taking the largest single share). Investment in end-use efficiency nearly triples to $150 billion in 2030, with improvements in transport efficiency accounting for more than half of the total. Buildings are the next largest recipient: space heating is a major focus, as well as appliances, lighting and cooling.

China

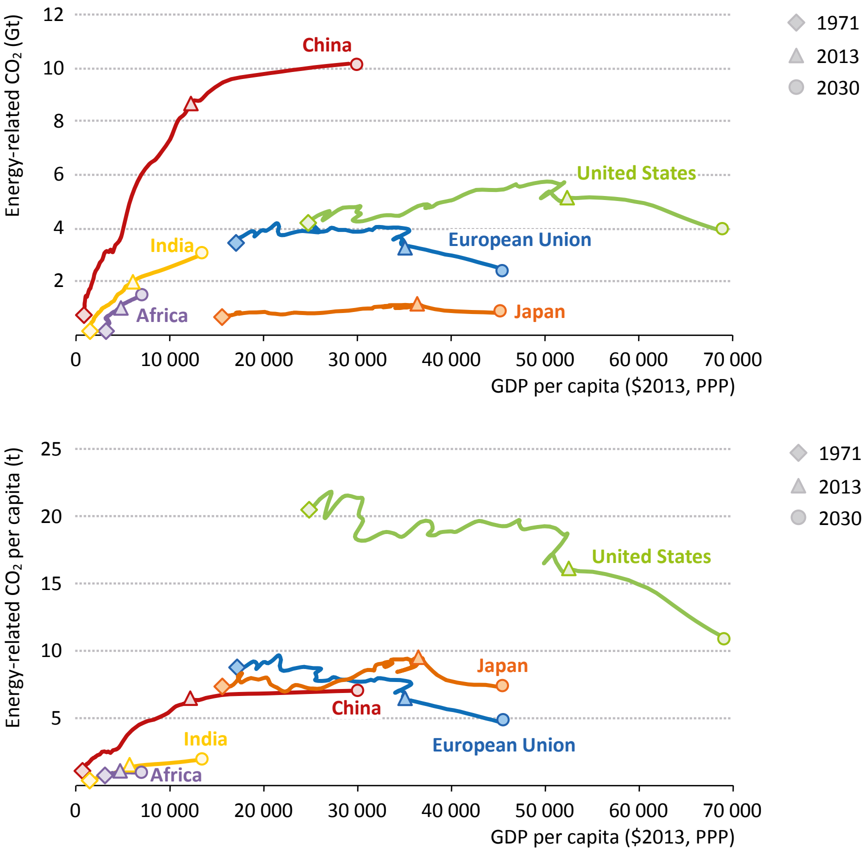
China's rapid economic growth has brought huge benefits to the country and the world, not the least of which has been the provision of electricity to around half a billion new customers in the last few decades and a rapid increase in average incomes. But these advances have also relied heavily on the consumption of coal, a choice driven by economic and energy security factors but which has seen China's GHG emissions escalate rapidly as a consequence. China's ongoing economic and social development will demand the continued expansion of the energy sector, but policy and other drivers will encourage a transition to a more efficient, low-carbon system.

While China has yet to formally submit its INDC, an important development in this regard is its stated intention to achieve a peak in its CO_2 emissions around 2030 (and to make best efforts to peak earlier) and to increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030. These goals were declared as part of the US-China Joint Announcement on Climate Change and Clean Energy Cooperation in November 2014, the stated intention of which was to clarify intended respective post-2020 actions on climate change. China already has a range of complementary energy and climate policies, such as targets to reduce the carbon intensity of the economy (40% to 45% decline by 2020, relative to 2005), reduce reliance on coal in the economy (limit the share of coal to less than 62% of total primary energy demand in 2020), introduce more stringent fuel-economy standards in transport, reduce the CO_2 intensity of industry by half by 2020 and to have a nationwide emissions trading scheme by 2020. While action has been taken to implement some of these policies, others still require implementing action and the effects may take some time to show up across the economy.

Given the pace at which China's energy sector emissions have grown, achieving a peak in emissions by 2030 will require a significant change in direction (Figure 2.11). In the INDC Scenario, China's energy-related emissions growth already show major signs of deceleration by the early-2020s and is at a near-halt by the mid-2020s, before finally reaching a plateau around 2030. Some of this change will result from restructuring the Chinese economy away from rapid investment-led growth towards consumption-led growth (at lower rates); but effective policy intervention across a range of sectors will also be required if the steep emissions growth observed in recent decades is to be succeeded by a similarly sharp slowdown in the years to come.

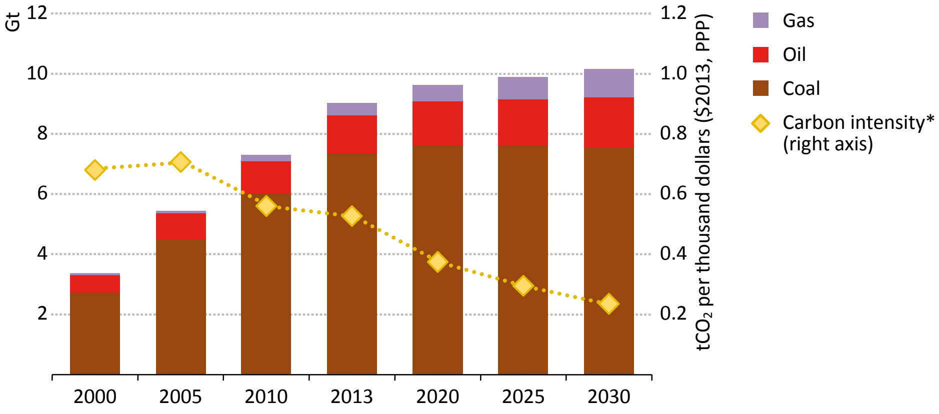
The relationship between economic development and emissions growth in China weakens notably, with China moving from emitting 8.7 Gt of CO_2, with GDP per capita of $12 000 in 2013, to an emissions peak at around 10.1 Gt, with GDP per capita around $30 000 in 2030. The peak in emissions comes at a lower level of GDP per capita than in the United States but at a similar level to Japan and the European Union. Despite this, China's total energy-related CO_2 emissions are projected to be around two-and-a-half times the level of the second-largest emitter in 2030 (the United States). Achieving a peak in energy-related emissions will be a major milestone for China, but the sheer scale of its total emissions in the global picture highlights the importance of then moving on to a declining path.

Figure 2.11 ▷ **Total and per-capita energy-related CO_2 emissions and GDP per capita by region in the INDC Scenario**



China is, and is projected to remain, the world's largest consumer and producer of coal through to 2030 in the INDC Scenario. The country's energy-related emissions are dominated by coal (more than 80% of the total) and this picture changes only gradually (Figure 2.12). In the INDC Scenario, China's coal demand growth slows to very low levels in the 2020s, but shows no notable sign of decline by 2030 (as projected under a path consistent with the 2 °C climate goal). China's oil demand grows by 44% to 14.6 mb/d in 2030, overtaking the United States as the world's largest oil consumer around this time. Despite this, per-capita oil consumption in China remains relatively low – standing at 87% of the world average in 2030 – and the share of oil in total energy-related emissions remains around one-sixth. In line with government policy, natural gas use increases rapidly in China, particularly in power generation, industry and buildings, helping to mitigate emissions growth where it acts as a substitute for higher-carbon fuels.

Figure 2.12 ▷ **China energy-related CO_2 emissions by fuel and carbon intensity of the economy in the INDC Scenario**



* Calculated as energy-related CO_2 emissions per thousand dollars of GDP in purchasing power parity terms.

Power sector

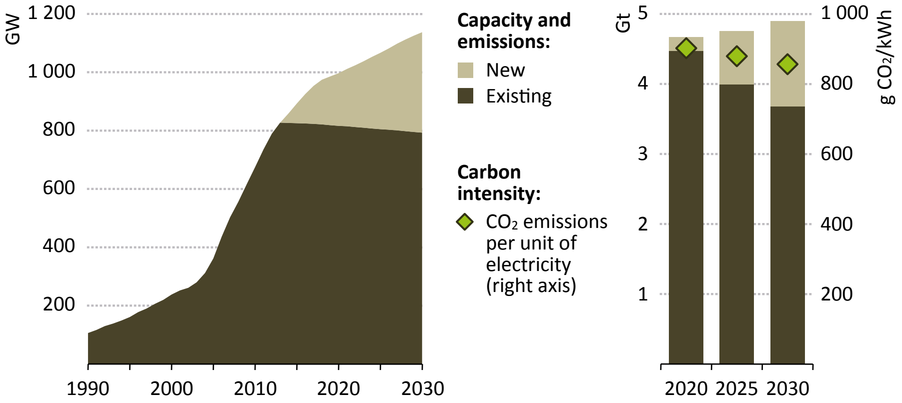
In the INDC Scenario, China's electricity demand is projected to increase by 75% by 2030, and is twice the level of demand in the second-largest global electricity market (the United States) at that time. The scale and age of China's existing coal-fired power generation capacity highlights the risk of high carbon lock-in to its energy supply infrastructure, a potentially significant factor in determining the pace at which it retreats from its emissions peak. Much of China's coal-fired power capacity has been constructed since 2000, meaning that it is technically capable of continuing to operate for decades to come. But it is also true to say that China has taken steps to invest in developing and constructing highly efficient coal-fired power plants and to retire some of its most inefficient existing coal-fired capacity.

In the INDC Scenario, around 95% of China's existing coal capacity is projected to still be in operation in 2030, and 345 GW of net new capacity is installed by that year (Figure 2.13). Overall, China's share of the world's coal-fired power plant fleet increases to half by 2030, and it accounts for 4.9 Gt of CO_2 emissions, of which three-quarters is from existing plants.

The projected level of energy sector CO_2 emissions inevitably means that China's decisions (for example, on the retirement, mothballing, life extension and retrofitting of CCS to existing coal-fired power plants) will be a major determinant on the international drive to achieve the 2 °C commitment, even if the decisions are driven by domestic priorities (such as tackling local air pollution).

China accounts for 65% of global growth in nuclear capacity in the INDC Scenario, and overtakes the United States as the largest holder of nuclear power generation capacity around 2030. Renewables grow rapidly in China through to 2030, led primarily by hydropower, wind and solar in the power sector. Power generation capacity from wind increases by 220 GW by 2030 and from solar PV by 155 GW, a major expansion over existing levels for both technologies. The traditional use of biomass in the residential sector (principally as fuel for cooking) declines by around 2% per year to 2030, but remains significant. In the INDC Scenario, the share of non-fossil fuels in total primary energy demand increases from 10% in 2013 to around 20% in 2030.[7]

Figure 2.13 ▹ China coal-fired electricity generation capacity, related emissions and carbon intensity in the INDC Scenario



Notes: CO_2 emissions per unit of electricity produced depend on the efficiency of existing and new power plants operational in the system. Statistical differences on coal use for existing power plants, in some cases due to reported or assumed calorific values, may lead to differences in the implied efficiency of the existing coal-fired power plant fleet.

End-use sectors

In the INDC Scenario, energy demand in China's end-use sectors increases by less than 2% per year, on average, to 2030, while the economy grows at nearly 6% per year. Industry (a large coal consumer) sees emissions decline from around 2020, led by a gradual decline

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[7] The non-fossil fuel share is calculated according to the methodology of the Chinese National Bureau of Statistics. This differs from the IEA's calculation in so far as 1) statistical differences and the traditional use of biomass are excluded; 2) the calorific value for coal is lower; and, 3) the partial substitution method (coal equivalent method) is used to calculate the primary energy equivalent for renewables, while the IEA uses the physical energy content method.

in iron and steel and cement production, reflecting the structural shifts in the economy. In transport, car ownership almost quadruples by 2030, implying consistently world-leading levels of car sales over the period. Fuel-efficiency standards for new vehicles continue to improve and are close to those of Korea in 2025, while old vehicles are removed by compulsory scrappage schemes in some parts of the country, helping to suppress oil demand growth. The stock of alternative vehicles grows, but the market penetration rate remains low. Overall, growth in transport GHG emissions slows over time, dropping from around 4.5% per year to 2020 to 2.2% per year from 2020 to 2030. Growth in electricity and natural gas use in buildings helps to reduce the consumption of coal and bioenergy, bringing ancillary benefits in terms of local air pollution and public health. By 2030, CO_2 emissions per square metre of residential floor space decline by nearly 30%.

Investment

The growth of China's energy sector is expected to slow in line with economic and population trends, but total investment in energy supply is still projected to average $265 billion per year from 2015 to 2030. Investment in power generation capacity accounts for around $90 billion per year, with around 60% of this being for renewables capacity (mainly wind, solar and hydro), 19% for coal and 18% for nuclear. Investment in transmission and distribution accounts for around another $80 billion per year. Investment in end-use energy efficiency increases rapidly across all sectors. In transport, efficiency investment grows to more than double existing levels by 2030, driven by a huge increase in car sales, the efficiency of which improves over time. In buildings, investment more than quadruples, but from a low base, focusing on appliances and insulation.

India

There has been a huge expansion in the Indian energy sector in recent decades, as India has sought to power a rapidly growing economy.[8] The energy sector has brought electricity to hundreds of millions of people who were previously without electricity supply, but the task remains far from done, with about 300 million people still without access and many more living with poor quality supply. In some ways, this situation reflects a more general challenge to expand and improve India's underlying infrastructure. Fossil fuels – particularly coal – are playing a major role in powering India's economic development, making India the world's fourth-largest source of energy-related CO_2 emissions. India's large (and growing) population, its low (but increasing) levels of energy consumption per capita and the high level of projected economic growth are powerful trends that, in the absence of concerted action, will commit India to a high-carbon development path.

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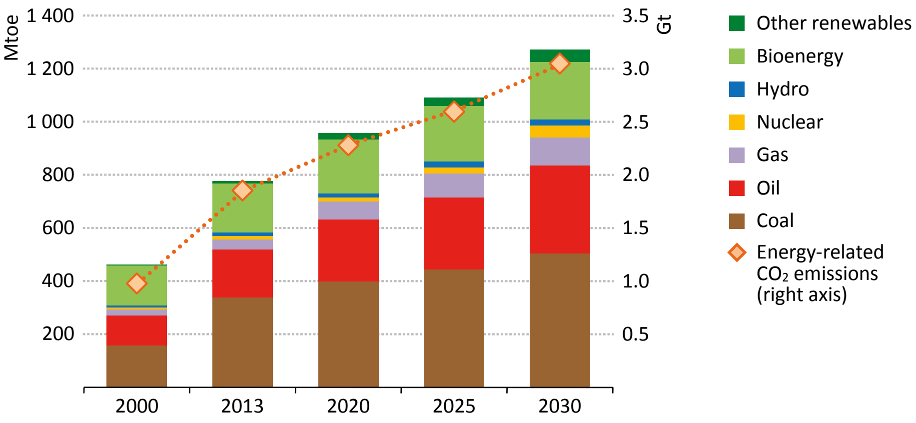
[8] See a special focus on India's energy outlook in the *World Energy Outlook-2015* to be published on 10 November 2015.

India has yet to submit its INDC, and so a full analysis of its intentions is not yet possible. However, it has indicated that the increased deployment of renewables and improvements in energy efficiency are important national energy priorities. In the case of renewables, the government announced in 2014 a target to have 175 GW of renewable-based power generation capacity by 2022 (excluding large hydropower), a major increase relative to today. Of this total, 100 GW is to be solar, 60 GW wind, 10 GW biomass-based power and 5 GW small hydropower projects. Whether explicitly referenced in India's INDC or not, such a target is likely to be an important enabler of its achievement. Other examples of policies shaping India's energy sector emissions outlook include a target to reduce carbon intensity (excluding agriculture) by 20% to 25% below 2005 levels by 2020 (as reflected in the Copenhagen Accord), actions taken in the last year to reform fossil-fuel subsidies (diesel subsidies have been abolished, but subsidies remain on liquefied petroleum gas (LPG) and kerosene) and increased taxation on domestic and imported coal (around $3.2 per tonne) – the revenue from which goes to finance renewable energy projects. There are also plans to expand the nuclear share of electricity generation from around 3% today to 5% in 2020, 12% in 2030 and 25% in 2050.

In the INDC Scenario, which reflects these policy intentions, the major push on renewables helps to diversify India's energy supply. However, at a time of high demand growth, this by no means eliminates fossil fuels from the energy mix. Coal still accounts for 40% of India's energy mix in 2022 (44% in 2013), and all fossil fuels together provide three-quarters of total energy demand (the traditional use of bioenergy being the next largest component) (Figure 2.14). In the INDC Scenario, India's energy-related CO_2 emissions are around 30% higher than 2013 by 2022, reaching 2.4 Gt, and go on to exceed 3 Gt in 2030. Emissions per capita also continue to grow through to 2030, but are still only around half of the global average at that time (at 2.1 tCO_2 per capita). Overall, there are few signs of a disconnect between India's energy demand growth and related emissions through to 2030.

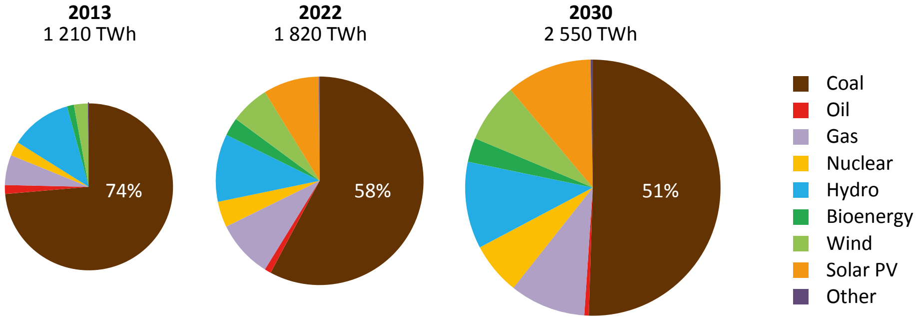
Figure 2.14 ▷ India primary energy demand by fuel type and related CO_2 emissions in the INDC Scenario



Power sector

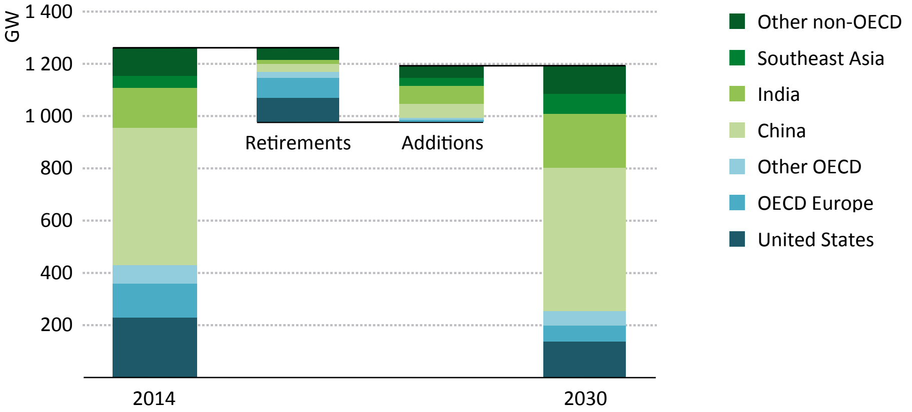
In the INDC Scenario, India's electricity consumption more than doubles to 2030, reaching around 2 000 TWh. Renewable-based power generation capacity more than triples to meet the stated government target of 175 GW by 2022 (Figure 2.15). However, meeting the 2022 target will be challenging. In particular, to meet India's solar target would imply average annual solar capacity additions of over 12 GW, a similar level has so far been observed only in one year in one country (China). This would mean mobilising large-scale capital investment, taking steps to ensure that projects are financially robust, that land is available and that regulatory approvals are granted rapidly. The power network will also need to be matched to the needs of this new (mainly variable) renewable-based supply. Even so, setting such a target provides an important signal of the direction in which the government intends that the energy sector should move. Even near-success in meeting the target will signal very significant change in the scale of India's renewable energy sector and the creation of the necessary regulatory and industrial infrastructure to deliver it.

Figure 2.15 ▷ India electricity generation by type in the INDC Scenario



However, as noted, even a rise of renewables sufficient to meet the stated target would not spell the end of coal-fired capacity, which grows by 70% by 2030 in the INDC Scenario. An important determinant of this projection is what happens beyond India's 2022 renewables target and, in the absence (at present) of a policy commitment for renewables in the longer term, the INDC projections see continued growth in demand for coal for electricity generation. The average efficiency of India's existing coal-fired capacity is relatively low due, among other things, to the use of poor quality coal. The absence of control technologies in many existing power plants leads to concerns about worsening air pollution (mainly sulphur dioxide, oxides of nitrogen and particulate matter), with negative consequences for health and economic development. Efforts to move to more efficient coal technologies are assumed in the INDC Scenario and have a positive impact, but a significant share of Indian coal-fired generating capacity in 2030 is still subcritical (Figure 2.16). A push towards higher efficiency coal technologies could be supported by actions to improve the quality of the coal used (such as coal washing).

Figure 2.16 ▷ Subcritical coal capacity and retirements/additions in the INDC Scenario by region



End-use sectors

In the INDC Scenario, India's rapidly growing economy and population drive end-use energy demand one-third higher by 2022. Around three-quarters of the growth in final energy consumption through to 2030 is met by fossil fuels, either directly or indirectly, through higher electricity demand. Oil consumption in end-use sectors grows by 1.4 mb/d by 2022 and then a further 1.6 mb/d to 2030. Net oil imports more than double by 2030 (to 6.2 mb/d) and the related import bill rises to around $270 billion. The projected growth in vehicle ownership drives oil demand growth, with average incomes in India reaching a level at which rapid increases are expected in car ownership. The implications of this for oil demand would be even higher, were it not for the planned introduction of a national fuel-economy standard of 4.8 litres per 100 kilometres (l/100 km) by 2021-2022. Due to the relatively small size of cars in India, average fuel efficiency is relatively high when compared with many other countries.

India's industrial sector is the largest end-use energy sector, despite making up a relatively small share of the overall economy. It is also relatively carbon intensive, primarily due to heavy reliance on fossil fuels (mainly coal) and the significant share of energy-intensive industries. Over time, grid-based electricity supply improves, allowing some industrial users to move away from having their own back-up capacity and some others to switch to using electricity for part or all of their energy needs. Overall, the carbon intensity of the industrial sector drops by 30% by 2030 in the INDC Scenario, but remains relatively high.

India's urban population grows by around 185 million through to 2030, putting pressure on cities to modernise and expand their energy supply infrastructure. Across the country, a strong continuing push is assumed to extend residential access to electricity and to move households away from the traditional use of bioenergy as a cooking fuel. A corollary benefit of both trends is that energy is used more efficiently, dampening the growth in consumption (final energy consumption grows by 3.2% per year, on average, from 2013 to 2030, while the economy grows by 6.5%). The Energy Conservation Building Code is assumed to become mandatory by 2017 and stricter efficiency standards to be announced for some appliances; but significant potential for further improvements remains.

Investment

In the INDC Scenario, investment in India's energy supply infrastructure averages around $85 billion per year to 2022 and increases to nearly $120 billion in 2030. Perhaps unsurprisingly, the power sector accounts for around 70% of total energy supply investment over the projection period and, in line with the expected focus on expanding renewables, investment in solar and wind collectively more than doubles to reach $28 billion in 2022. Overall, India's future power sector investment moves towards a less carbon-intensive path than in the past (with hydro, nuclear and natural gas also seeing increases over time) but investment in coal does not cease and could grow if strong policy signals for low-carbon energy supply were to fade after 2022. Investment in power transmission and distribution infrastructure averages $28 billion a year to 2030 and is a high priority both to permit fuller use of existing power generation capacity and to meet the needs of new plants coming on stream. Investment in energy efficiency is more than two-and-a-half times current levels by 2030. Two-thirds of efficiency-related investments are directed towards the transport sector, particularly cars, where efficiency improves by around 25% to 2030.

Russia

Russia's INDC proposes that it should limit its GHG emissions in 2030 to 70% to 75% of the level in 1990 taking maximum possible account of the absorptive capacity of forests, which play an important role in Russia's overall emissions.[9] The Russian INDC also cites legally binding instruments that already exist to limit GHG emissions to no more than 75% of 1990 levels by 2020.

In the INDC Scenario, Russia's energy-related CO_2 emissions decline slightly from 2013 to 2030, with primary energy demand growing by only 0.1% per year, on average. Coal demand reaches a peak around 2025 and demand for oil well before 2020. The carbon intensity of Russia's economy declines through to 2030, though it remains high relative to that of many other countries (Figure 2.17), due to the continuing high share of fossil fuels in the energy mix (led by natural gas), the inefficient use of energy in some sectors and some non-energy factors, such as the climatic conditions. The efficiency of Russia's thermal electricity generation is projected to increase significantly to 2030 and the share of nuclear in the electricity mix increases, both factors helping to suppress growth in power sector emissions. Efficiency measures in end-use sectors help to limit the increase in final energy consumption to 9% by 2030. Such measures include the phase-out of outdated production processes and mandatory energy audits in energy-intensive industries, the tightening of building codes, voluntary labelling programmes for electric appliances and incentives to promote the purchase of hybrid and small cars.

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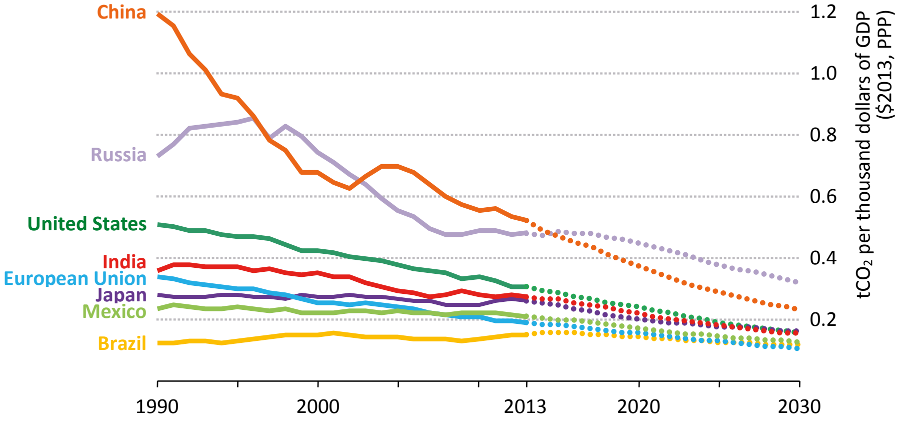
[9] LULUCF are currently estimated to absorb 540 Mt CO_2 every year (UNFCCC, 2015).

Beyond energy-related CO_2 emissions, Russia is one of the world's major oil and gas producers and its methane emissions from the oil and gas sector were around 350 Mt CO_2-eq in 2013. While the majority of these emissions come from oil and gas production, a significant share also comes from Russia's extensive pipeline network. In the INDC Scenario, methane emissions from oil and gas production decline by around 15% between 2013 and 2030, to stand at 180 Mt CO_2-eq.

Figure 2.17 ▷ Carbon intensity of the economy by selected region in the INDC Scenario



Mexico

Mexico has already established a comprehensive National Climate Change Strategy encompassing both climate change mitigation and an assessment of its own vulnerability to climate change. It has also adopted a General Law on Climate Change that established institutions and instruments to reduce GHG and particle emissions, as well as to increase the adaptive capacity of the country. In its INDC, Mexico puts forward an unconditional 25% reduction in 2030 in its emissions of greenhouse gases and short-lived climate pollutants, relative to a reference scenario.[10] This translates into a GHG emission target of 759 Mt CO_2-eq in 2030, a level slightly lower than today. The energy sector accounts for the majority of Mexico's GHG emissions, with the next largest source being methane emissions from waste disposal in landfills. While Mexico has stated that it aims to cut emissions from deforestation to zero by 2030 and tackle its relatively large methane emissions through improvements to the waste management infrastructure, the energy sector is central to future mitigation efforts.

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[10] Mexico has also expressed a conditional target of a 40% reduction below the reference scenario if, among other things, an international carbon price and carbon border adjustments are put in place. This conditional commitment has not been incorporated in the INDC Scenario.

In the INDC Scenario, Mexico's energy-related CO_2 emissions increase by 9% to reach 475 Mt in 2030, while its economy is expected to almost double in size and its population to increase by around one-fifth over the same time period. Currently, CO_2 emissions from the energy sector in Mexico are dominated by transport and power generation, which each account for about one-third of the total. Although the number of cars on Mexico's roads increases by around 60% by 2030, and the number of trucks more than doubles, transport-related GHG emissions are projected to increase by only around 15%. Existing emissions standards are assumed to be tightened and sales of hybrid vehicles increase in the INDC Scenario, both helping to improve average fuel economy. Electricity demand increases by around 50% by 2030, as a result of higher industrial activity, more appliance purchases for households (more and larger refrigerators, washing machines and air conditioners). Despite the significant increase in electricity demand, CO_2 emissions from power generation decrease slightly to 2030, as natural gas- and renewable-based generation grows and oil-fired generation is drastically reduced. In line with the goals of the National Climate Change Strategy, the share of electricity generation from low-carbon sources increases to nearly 40%, with wind and hydropower being the largest sources, followed by geothermal, nuclear and solar PV.

In the INDC Scenario, methane emissions from the upstream oil and gas sector (which are included in Mexico's INDC) peak around 2020 and then decline gradually to reach 15 Mt CO_2-eq in 2030, even though oil and gas production both increase over the same period. While not analysed here, Mexico's INDC is notable for the positive inclusion of an adaptation element.

Selected other countries and regions[11]

Decisions on the future energy mix, in particular the strategy envisaged for nuclear power, is expected to weigh heavily on the content of Japan's INDC, when it is announced. The Strategic Energy Plan published in 2014 provides for nuclear power to remain an important source of baseload electricity, but the process of regulatory approval is far from complete and, as of mid-May 2015, none of the existing fleet of nuclear reactors supplied electricity to the grid. The inactivity of the nuclear fleet has boosted Japan's consumption of fossil fuels and stepped up its reliance on energy imports. Japan has plans to increase to 20% the proportion of electricity generated by renewables by 2030 and there are some indications that this target may be revised upwards.

Japan's energy-related CO_2 emissions are around 25% lower than 2013 levels by 2030 in the INDC Scenario, reaching 0.9 Gt (Table 2.2). In parallel, per-capita emissions decline from the relatively high level of 9.5 tonnes per year to around 7.3 tonnes in 2030 (but still around 75% higher than the world average). Japan's economy grows by 17% over the same period. It is assumed that most idled nuclear power plants steadily return to service, after receiving

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[11] For countries and regions analysed in this section that have not either submitted an INDC by 14 May 2015 (all except Gabon in Africa) or signalled the expected content of their INDC, the policy assumptions are consistent with those in the *WEO-2014* New Policies Scenario. See Chapter 1 and Annex A for more on the definition of the INDC Scenario.

regulatory approval. In parallel, renewables – led by solar and, to a lesser extent, wind – continue to grow in the power mix. Policy actions (in the form of attractive feed-in tariffs) have, in recent years, stimulated a rush into providing new solar-based electricity, but this has prompted concerns on the part of the utilities (who also own the grid) regarding the reliability of this new supply and the stability of the grid. In an effort to attract viable projects, Japan recently revised the price level for the feed-in tariff, as well as construction and purchase rules, including setting new deadlines for grid connections. As nuclear generation resumes and renewables expand, Japan's use of fossil fuels in the power sector declines, their share going from around 85% of generation today to about 55% by 2030.

Japan's dearth of domestic fossil-fuel resources has underlain its long-standing focus on energy efficiency and relevant policy actions have put Japan among the world leaders. Japan's energy conservation law from the 1970s and its successful implementation via the Top Runner Program and mandatory energy management in industry and some commercial buildings have been important in securing energy efficiency gains across energy-consuming sectors. In the INDC Scenario, these standards are expected to tighten further over time and be extended to more product categories. In transport, energy efficiency efforts, together with policies to support alternative fuels, help push oil demand down by one-third by 2030. Actions across sectors that help to reduce Japan's fossil-fuel demand bring benefits not only in terms of emissions, but also in terms of energy security, reducing Japan's oil-import bills by more than one-fifth in 2030 with respect to 2013.

Energy-related CO_2 emissions in Southeast Asia increase by 60% from today's level to reach 2 Gt in 2030, with Indonesia (the largest regional economy) accounting for around 35% of the total. The emissions increase outpaces the growth for primary energy demand, reflecting the greater share of fossil fuels in the energy mix (Figure 2.18). The largest increase in emissions comes from the power sector as a result of the rapid growth in demand for electricity and coal becoming the dominant fuel in the region's electricity mix. The growing importance of coal is largely due to Indonesia's abundant and low-cost coal supply, contrasting with relatively expensive natural gas in most countries. Continuing industrialisation, particularly in the regions' three largest economies (Indonesia, Thailand and Malaysia) pushes industrial emissions up by more than 40% by 2030. An increase in personal mobility and domestic trade, and weaker fuel-efficiency standards than in many developed markets (or lack of standards), all help to push up emissions from personal and freight transport by nearly 45% by 2030.[12]

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[12] A *WEO Special Report* on the energy outlook for Southeast Asia will be published in October 2015.

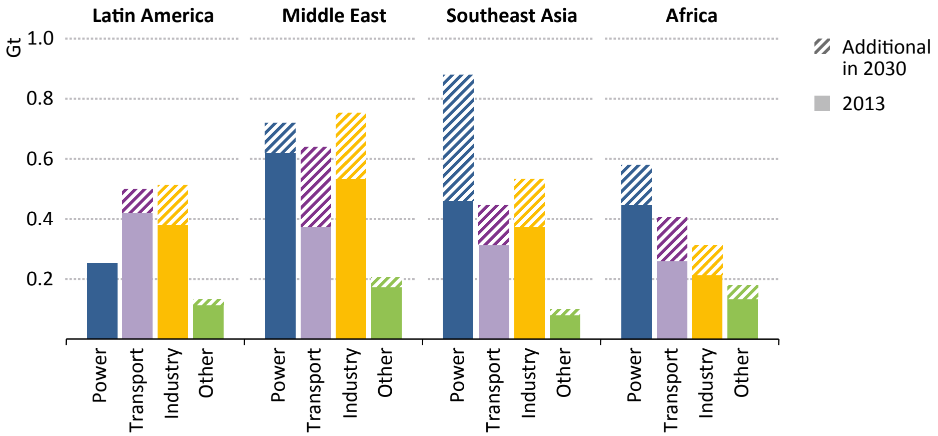
Table 2.2 ▷ Energy- and climate-related indicators by scenario

		INDC Scenario			450 Scenario		
	2013	2020	2025	2030	2020	2025	2030
Energy-related CO_2 emissions (Gt)							
World	32.2	33.9	34.3	34.8	32.4	29.6	25.6
United States	5.2	5.0	4.4	4.0	4.8	3.9	3.0
European Union	3.4	3.0	2.8	2.4	2.9	2.4	2.0
Japan	1.2	1.0	0.9	0.9	0.9	0.8	0.6
China	8.7	9.6	9.9	10.1	9.1	8.0	6.4
India	1.9	2.3	2.6	3.0	2.2	2.3	2.3
Energy intensity (toe/GDP in $2013 PPP)							
World	0.13	0.11	0.10	0.09	0.11	0.09	0.08
United States	0.13	0.11	0.09	0.08	0.11	0.09	0.08
European Union	0.09	0.08	0.07	0.06	0.08	0.07	0.06
Japan	0.10	0.09	0.08	0.08	0.09	0.08	0.07
China	0.18	0.14	0.11	0.09	0.13	0.10	0.08
India	0.11	0.09	0.07	0.06	0.09	0.07	0.06
Carbon intensity (tCO_2/toe)							
World	2.4	2.3	2.2	2.1	2.2	2.0	1.7
United States	2.4	2.2	2.1	1.9	2.2	1.9	1.5
European Union	2.1	1.9	1.8	1.7	1.9	1.7	1.4
Japan	2.7	2.3	2.2	2.1	2.2	2.0	1.7
China	2.8	2.7	2.6	2.5	2.6	2.3	1.8
India	2.4	2.4	2.4	2.4	2.4	2.2	2.0
Clean energy investment (billion $2013)							
World	470	797	950	1 093	985	1 474	1 900
United States	60	150	184	220	178	243	328
European Union	106	167	211	222	202	268	286
Japan	37	30	34	37	42	56	67
China	139	166	164	179	222	286	353
India	22	55	53	71	59	101	160
Fossil-fuel import bills (billion $2013)							
United States	278	121	152	130	127	134	113
European Union	555	474	550	552	454	467	395
Japan	259	186	203	203	172	171	147
China	304	390	539	643	372	463	484
India	135	188	268	343	179	230	255

Notes: Clean energy in this table includes energy efficiency, renewables, nuclear and CCS in the power and industry sectors. Energy efficiency investment is measured relative to a 2012 baseline efficiency level. PPP = purchasing power parity; tCO_2/toe = tonnes of carbon dioxide per tonne of oil equivalent.

Energy demand has grown strongly in the Middle East in recent years, but often with important distinctions between major energy exporters (such as Saudi Arabia, Qatar, Kuwait and others), and smaller energy exporters or importers in the region. In the INDC Scenario, energy-related CO_2 emissions rise in the Middle East by around 35%, from 1.7 Gt in 2013 to 2.3 Gt in 2030. Today, per-capita emissions are already 75% higher than the world average and they are projected to reach 8.2 tonnes per capita in 2030, double the world average at that time.

Figure 2.18 ▷ Energy-related CO_2 emissions by sector and selected region in the INDC Scenario



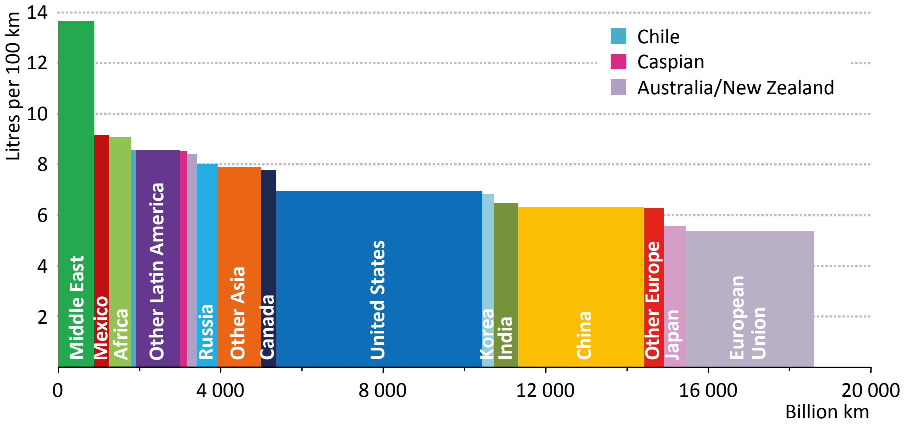
Notes: Industry includes emissions from non-energy use, refineries and fossil-fuel supply. "Other" includes buildings and agriculture. Electricity sector emissions in Latin America decline slightly from 2013 to 2030.

An important question for the emissions trajectory in the Middle East is whether policymakers can get spiralling energy demand growth under control. Emissions growth is high in industry, both due to low energy prices encouraging the growth of energy-intensive industries (foremost the petrochemical industry) and wasteful use of energy because of the extent of fossil-fuel subsidies. Although Saudi Arabia announced fuel-economy standards for imported vehicles in 2014, average fuel consumption per vehicle in the Middle East is projected to remain the highest in the world in 2025 (Figure 2.19). Energy demand growth in buildings is less than in other sectors, as several countries in the region introduce thermal insulation standards for new buildings and minimum energy performance standards for air conditioners (by far the largest source of electricity consumption). Despite electricity demand increasing by around 75% from 2013 to 2030, emissions increase by only around 15%, as the power sector shifts from inefficient oil-fired power plants to gas-fired power plants and low-carbon technologies. Some countries in the region have targets and policies in place to expand low-carbon sources in the power sector (such as Saudi Arabia, Kuwait, and Dubai), but progress has typically been limited so far.

In the INDC Scenario, methane emissions from upstream oil and gas activities in the Middle East are projected to increase from around 235 Mt CO_2-eq (around 25% of the global total) to 295 Mt CO_2-eq in 2030 (around 30% of the global total), linked to significant growth in both oil production (nearly 34 mb/d in 2030) and gas production (765 billion cubic metres in 2030). Efforts, such as those in southern Iraq and elsewhere, are underway to try and capture and utilise associated gas in power generation, petrochemicals and industry.

Greenhouse-gas emissions in Latin America have historically been dominated by land use, land-use change and forestry, and, not wholly unrelated to this, agriculture. Energy-related CO_2 emissions in Latin America are significantly lower than the global average, not only in terms of per-capita emissions, but also in terms of emissions per unit of economic output. The main reason is the dominance of low-carbon technologies in the electricity mix (particularly hydropower in Brazil), but also the high share of biofuels in the transport sector. The regions' energy sector is becoming a more significant source of emissions growth and will be important in determining whether Latin America can maintain its low-carbon profile as domestic energy demand increases rapidly. In the INDC Scenario, energy-related CO_2 emissions increase from 1.2 Gt in 2013 to 1.4 Gt in 2030, equivalent to an 18% increase. The emissions increase is largely driven by rising industrial activity, including in steel production and chemicals production, and by higher vehicle ownership. Emissions from electricity generation decrease by around 7% to 2030, as the power sector is able to meet additional demand for electricity through increased generation from hydropower, natural gas and wind. Since 2005, Brazil (the region's largest emitter) has embarked on a large-scale campaign to slow deforestation, with a particular focus on how to contain growth in energy-related emissions. In 2008, Brazil announced a National Energy Efficiency Plan and in 2013 introduced the Inovar-Auto programme to increase the efficiency of road vehicles; but these measures are not yet sufficient to tap into the large unrealised energy efficiency potential (IEA, 2013).

Figure 2.19 ▷ Average fuel-economy of passenger light-duty vehicles and vehicle kilometres travelled by region in the INDC Scenario, 2025



Africa currently accounts for a small share of global GHG emissions: in 2013, the entire continent accounted for just 3% of global energy-related CO_2 emissions, with South Africa accounting for more than one-third of the total.[13] Yet Africa is expected to suffer severely from the impacts of a changing climate. Gabon is the first African nation to submit its INDC, pledging to keep 2025 emissions at least 50% below a business-as-usual (or "uncontrolled development") level, primarily through land management, but also by reducing flaring

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[13] See *Africa Energy Outlook: World Energy Outlook Special Report* 2014. Download a free copy at *www.worldenergyoutlook.org/africa*.

from the oil and gas sector (see Chapter 3 for more on gas flaring reduction), boosting energy efficiency, increasing hydropower supply and setting up a domestic carbon offset market.

In the INDC Scenario, electricity consumption in Africa doubles from 2013 to 2030, as households purchase more electrical appliances as living standards increase. Around 500 million people are projected to gain access to electricity for the first time by 2030, and the regions' small industrial base expands significantly. Despite this, access to reliable, affordable modern energy remains a major challenge in many parts of the continent, stifling economic and social development. Africa starts to unlock its vast renewable energy resources, with half of the growth in power generation capacity coming from renewables. New hydropower capacity in the Democratic Republic of Congo, Ethiopia and Mozambique, among others, plays a major role in bringing down the region's average cost of power supply. Other renewables, led by solar technologies, make a growing contribution to supply, while geothermal is an important source of power in East Africa.

African energy-related CO_2 emissions are projected to increase by around 40% to 2030, with Nigeria, parts of North Africa, Angola, Mozambique and others contributing to this growth (but often starting from very low levels). Emissions in South Africa are projected to follow a "peak, plateau and decline" trajectory, as announced by the South African government in 2009. Specifically, emissions peak in the period from 2020 to 2025, plateau for a several years and then start to decline in the 2030s. Key drivers of this trend are improved energy efficiency in end-use sectors and the power sector becoming less dependent on coal, as it turns more towards renewables and nuclear.

A strategy to raise climate ambition

Five energy sector measures as a bridge to further action

Highlights

- The energy sector can achieve a peak in GHG emissions by around 2020, while maintaining the same level of economic growth and development. The IEA proposes a near-term strategy, building on available technology and five proven policy measures, which are developed and illustrated in a "Bridge Scenario". Adoption of these measures can lock-in the recently observed decoupling of emissions growth from economic growth, an important first step to move the energy world towards a path consistent with the achievement (through the adoption of further measures later) of the long-term commitment to a maximum temperature rise of 2 °C. A near-term peak in global emissions will send a powerful signal of the determination of governments to transform their energy economies.
- The proposed policy measures are:
  - ☐ Increasing energy efficiency in the industry, buildings and transport sectors.
  - ☐ Progressively reducing the use of the least-efficient coal-fired power plants and banning their construction.
  - ☐ Increasing investment in renewable energies to $400 billion in 2030.
  - ☐ Gradually phasing out subsidies to fossil-fuel consumption.
  - ☐ Reducing methane emissions from oil and gas production.
- The Bridge Scenario puts a brake on growth in oil and coal use within the next five years: oil demand rises to 95 mb/d by around 2020 and then plateaus, while coal demand peaks before 2020. The shift towards renewables increases their share in power generation to 37% in 2030, 6 percentage points above that in the INDC Scenario.
- China cuts energy-related GHG emissions by 1.3 Gt CO_2-eq in 2030, relative to the INDC Scenario, mainly through improved energy efficiency. The abatement in India (400 Mt CO_2-eq) and the European Union (210 Mt) is mostly driven by energy efficiency as well, while in the United States (360 Mt), renewables contribute about one-third of the savings. In the Middle East (550 Mt) and Africa (260 Mt), reducing methane releases and fossil-fuel subsidies reform are central to emissions savings. In Southeast Asia, all five measures contribute to total savings of 300 Mt CO_2-eq.
- At $26 trillion, energy supply investments in the Bridge Scenario up to 2030 are $1.6 trillion *lower* than in the INDC Scenario. Higher renewables investments are more than offset by lower investment in fossil fuels. Average annual energy efficiency investment rises to $650 billion, almost one-third over the INDC Scenario, but household expenditure on energy generally falls. Globally, 1.7 billion people gain access to electricity for the first time by 2030 and 1.6 billion people gain access to their first clean cookstoves.

Introduction

Background

Analysis in Chapter 2 of the Intended Nationally Determined Contributions (INDCs) and their implications for the future conveys mixed messages. Existing national commitments and nations' engagement in this process are clear signals of collective seriousness of purpose in acting to contribute to international climate objectives. The results, as exposed in Chapter 2, lift expectations for the future. But the extent of the changes envisaged is not enough.

More can be done. But can it be reconciled with other government priorities, such as economic growth and energy security and affordability? And in what timescale?

This chapter, the "Bridge Scenario", suggests how the results of the INDC Scenario could be enhanced by a series of immediately practicable steps. Taking as an absolute constraint that the package of additional measures must not prejudice the levels of development and economic growth underlying the INDC Scenario, the Bridge Scenario sets out a series of steps which could be taken in the short term and what they could achieve. It is not a judgement on the limits of what it is politically possible to achieve, nor does it attempt to plot a path to the ultimate climate goal (see Chapter 4). But it suggests a practicable course of short-term action, drawing only on known technologies and policy measures which are tried and tested, which can lift the path of international achievement significantly higher towards the ultimate objective.

One highly significant feature of the results achieved in the Bridge Scenario is that the level of total global energy-related greenhouse-gas (GHG) emissions ceases to rise after 2020.[1] Such a peak is an essential feature of a successful path to a long-term temperature rise not exceeding an average of 2 degrees Celsius (°C). Commitment to such a peak, emerging from COP21, would send a profound signal to the energy and finance communities that governments are collectively determined that the energy sector shall change to the extent necessary to deliver the internationally agreed climate goals. Conveying that message wins half the battle. For countries which have already submitted their INDCs, the Bridge Scenario identifies productive opportunities to overachieve them. For countries which have not yet brought forward their INDCs, the scenario offers a selection of policies which would enhance current intentions.

Near-term opportunities for raising climate ambition

Previous analysis conducted for *Redrawing the Energy-Climate Map: World Energy Outlook Special Report* showed that the adoption of four readily available and proven measures could alone halt emissions growth by 2020, without harm to economic growth in any of the regions or individual countries considered separately in the World Energy

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[1] To allow comparison with INDCs by different countries, results in this chapter are presented for 2030, given that the focus of INDCs is the timeframe between 2025 and 2030.

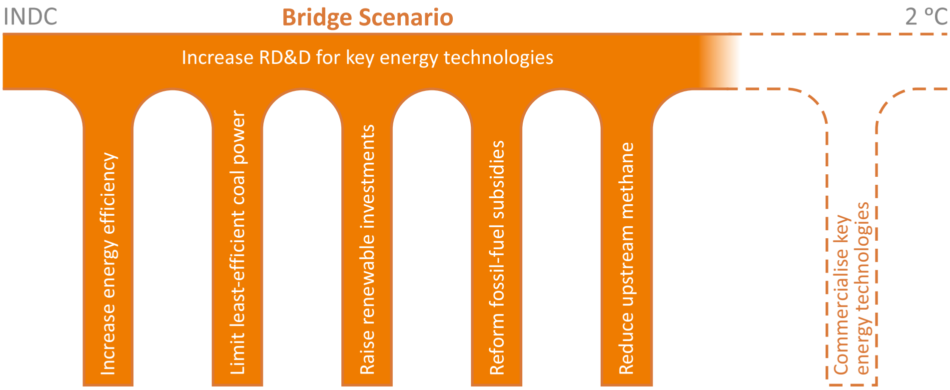
Model (IEA, 2013a).[2] These measures were endorsed by the ministers of all IEA member governments at their Ministerial meeting in November 2013[3] and many countries have been actively promoting their adoption since then (Box 3.1).

Taking recent policy progress into account, these proposed measures now constitute the core of the Bridge Scenario (Figure 3.1). They are complemented by a suggested increase in renewable energy investments, given significant cost reductions achieved in individual renewable energy technologies over recent years. The proposed measures are:

- Increasing energy efficiency in the industry, buildings and transport sectors.
- Progressively reducing the use of the least-efficient coal-fired power generating plants and banning the construction of new ones.
- Increasing investment in renewable energies in the power sector from $270 billion in 2014 to $400 billion in 2030.
- Gradually phasing out fossil-fuel subsidies to most end-users by 2030.
- Reducing methane emissions in upstream oil and gas production.

The measures in the Bridge Scenario are essential elements in an energy sector transition compatible with the 2 °C goal. In order to ensure that key technologies, such as carbon capture and storage (CCS) or electric vehicles are commercially available at the required scale by the early 2020s, a further push on research, development and deployment (RD&D) for key technologies will be essential. How this effort ties in with the long-term transition to 2 °C is the subject of Chapter 4.

Figure 3.1 ▷ On the road to 2 °C: policy pillars of the Bridge Scenario



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2. The analytical framework is the World Energy Model comprising of 25 regions. Within these regions, 12 countries are considered individually. The ENV-Linkages model has the same regional coverage. For further details, see *www.worldenergyoutlook.org/weomodel/* and (Chateau, Dellink and Lanzi, 2014).

3. The Ministerial statement is available at: *www.iea.org/newsroomandevents/ieaministerialmeeting2013/ministerialclimatestatement.pdf*.

The Bridge Scenario assessment of the policy measures which might be applied in each country was pursued in two steps. First, based on an in-depth analysis of existing policy frameworks in place in each country and their implications for the energy sector, as outlined in the INDC Scenario, additional policy opportunities were identified for each country or region individually. Second, the impacts on regional energy consumption and GHG emissions of pursuing such additional policy opportunities were analysed using the IEA's World Energy Model (WEM), and their impact on economic growth at a country or regional level was analysed using the ENV-Linkages model of the Organisation for Economic Co-operation and Development (OECD). If the package of measures identified for each individual country or region in step one was found, as a whole, to reduce economic growth in the period to 2030, or to negatively affect other energy policy considerations (such as by reducing the level of access to modern energy services in developing countries), then the level of application of the policies with the most severe negative impact was reduced or – where applicable – the measure was abandoned. Inversely, if the package of measures was found to increase economic growth, then the level of ambition was raised further.

Box 3.1 ▷ Tracking progress since "*Redrawing the Energy-Climate Map*"

The Bridge Scenario builds on previous analysis conducted for *Redrawing the Energy-Climate Map: World Energy Outlook Special Report* (IEA, 2013a), which proposed four measures that each country can do individually to stop global emissions growth by 2020.[4] These measures have been promoted by many governments since the launch of the report in June 2013. Some recent progress includes:

Energy efficiency: The United States has announced standards for electric motors, walk-in coolers and freezers, strengthened Energy Star appliance standards for residential refrigerators and freezers, and announced the extension of heavy-duty vehicle standards beyond 2018. Vehicle fuel-economy standards for passenger vehicles have been introduced in India, Mexico and Saudi Arabia, while the European Union and China have extended minimum energy performance standards for certain categories of appliances. Countries from Southeast Asia launched the ASEAN-SHINE programme in late-2013 to harmonise efficiency standards for air-conditioners. On a broader level, the G20 released an Energy Efficiency Action Plan at the end of 2014 to strengthen voluntary energy efficiency collaboration.

Reducing inefficient coal use in power generation: In 2014, China published the Action Plan for Transformation and Upgrading of Coal Power Energy Conservation and Emission Reduction (2014-2020). It establishes the target of phasing out 10 gigawatts (GW) of small thermal power plants by 2020. The United States put forth the Clean Power Plan in June 2014 (to be finalised in 2015), with the objective of cutting carbon dioxide (CO_2) emissions from power plants. In May 2015, the European Union agreed on a plan to introduce a Market Stability Reserve in 2019 that could withdraw allowances in times of surplus and thus strengthen the carbon price signal.

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[4] The report was aimed at providing input into the work-stream 2 of the UNFCCC Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP).

Fossil-fuel subsidy reform: Several countries have announced reforms to fossil-fuel consumption subsidies over the past two years. While 14% of global CO_2 emissions came from subsidised fossil-fuel use in 2012, this share dropped to 13% by the end of 2014, following the most recent reforms of diesel subsidies in India and gasoline subsidies in Indonesia. The latter reforms reduce the volume of subsidised oil products by around 2 million barrels per day (mb/d), comparable to the oil demand of Korea.

Reducing upstream methane emissions: The United States is in the process of adopting additional regulations to give effect to the announced intention to cut methane emissions from the oil and gas sector by 40% to 45% in 2025, relative to 2012. If adopted, the regulations currently envisaged would apply to an amount equivalent to 16% of projected global oil and gas production in 2025. Several companies (including BG Group, Eni, PEMEX, PTT, Southwestern Energy, Statoil and Total), together representing 8% of global oil and gas production, have agreed voluntarily to reduce emissions under the Climate and Clean Air Coalition's Oil & Gas Methane Partnership. Gabon and Mexico have made reducing methane emissions from oil and gas production part of their INDC for COP21.

Increasing energy efficiency has been a central feature of policy in many countries in recent years. Measures already implemented have reduced energy demand and curbed GHG emissions growth, as highlighted in Chapter 1. But despite these gains, the existing policy frameworks fail to harness the full economic energy efficiency potential. The Bridge Scenario suggests the pursuit of **targeted, practical measures to improve energy efficiency in the industry, buildings and transport sectors**. The focus is on improving the efficiency of new products by increasing existing minimum energy performance standards (MEPS) and introducing new ones, effectively banning the sale of the least-efficient technologies. Further options are available, ranging from the retrofit of buildings to transforming industrial production processes more efficient measures in transport. The proposed measures are usefully complemented by supporting measures to overcome possible barriers to their deployment, such as labelling and raising awareness.[5]

The power sector is central to climate abatement in the energy sector. Although already the focus of much policy attention, previous analysis in the *World Energy Outlook* (*WEO)* showed that the sector has the potential to reduce emissions by a further 25% by 2040, yielding half the saving in overall CO_2 emissions required to achieve the 2 °C target (IEA, 2014a). The Bridge Scenario proposes two main measures for the power sector: first, a **gradual reduction in the use of the least-efficient coal-fired power plants and a ban on the construction of new ones**. Coal is the backbone of power generation in many countries and has been responsible for more than 40% of global energy-related CO_2 emissions growth since 2000. Half of total CO_2 emissions from the power sector today (6 gigatonnes [Gt]) come from inefficient (typically subcritical) coal power plants. We do not project a complete phase out of coal in the near term, in order to safeguard the reliability of future electricity supply, thus

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[5] For a discussion of such supporting measures, see IEA, 2012.

balancing environmental needs with considerations of energy security and (in some regions) providing electricity access to those currently deprived. This policy helps both to curb GHG emissions growth and to make room for the faster expansion of low-carbon technologies.

The second means of reducing GHG emissions in the power sector adopted in the Bridge Scenario is an **increase in renewable energy investment to $400 billion by 2030**. We estimate that, in 2014, about $270 billion was invested in renewable energy development in the power sector, often supported by various forms of intervention around the world.[6] As a result, renewables – especially wind and solar photovoltaic (PV) – are becoming increasingly competitive in the marketplace. For solar PV, average investment costs – a longstanding obstacle to further commercialisation – fell by a factor of more than four over the past few years in China, and by a factor of two on average in the OECD (IEA, 2014b). Further market uptake beyond the levels achieved in the INDC Scenario will require complementary regulatory attention designed to ensure system reliability, but not necessarily a need for publicly financing renewables investment. Rather, there is a need to create the conditions which will redirect investment in energy supply to maximise investment in low-carbon technologies, such as renewables, by providing the appropriate signals to all stakeholders involved.

Phasing out subsidies to fossil fuels reduces wasteful energy use by sending more accurate price signals, while also improving the case for investing in energy efficiency and competing non-fossil energy supply technologies. Subsidies that support the consumption of fossil fuels are typically intended to make energy more accessible for the poor, but they are often an inefficient means of doing so and other forms of support would cost much less. The IEA estimates that only 8% of the money spent on fossil-fuel consumption subsidies reaches the poorest 20% of the population (IEA, 2011). In the Bridge Scenario, we assume a complete phase-out of fossil-fuel consumption subsidies by 2030, except in a few countries in the Middle East, where reforms progress at a slightly slower pace. No assumptions are made about reforms to fossil-fuel production subsidies (e.g. trade instruments, tax breaks, risk transfers, etc.) largely due to the complexity and uncertainty associated with their relationship on energy demand and supply trends. Even though the vast bulk of the savings in energy use and associated GHG emissions from subsidy reform would arise from the removal of consumption subsidies, systematic review of the efficiency and effectiveness of fossil-fuel production subsidies could produce dividends.

In the Bridge Scenario, we also assume that policies are adopted **to reduce releases of methane to the atmosphere in upstream oil and gas production**. Methane is a powerful greenhouse gas that has a stronger effect than CO_2 in trapping solar radiation in the atmosphere (although it also has a much shorter lifetime in the atmosphere).[7] Reducing

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[6] Investment made over the construction period is allocated to the year a completed project begins operation, which may result in differences from other published estimates.

[7] The various ways to compare the effects of methane versus CO_2 on global warming are discussed in the section on minimising methane releases that follows. The data for CO_2 equivalency provided are on the basis of methane's global warming potential over 100 years.

methane emissions is particularly valuable because of its high short-term global warming potential. We estimate that the energy sector currently emits around 100 million tonnes (Mt) of methane (CH_4) per year (or 3.0 Gt of carbon-dioxide equivalent [CO_2-eq]), with the bulk of emissions arising from oil and gas operations (an estimated 56 Mt CH_4, or 1.7 Gt CO_2-eq), of which close to 60% (32 Mt, or 965 Mt CO_2-eq) as a result of upstream oil and gas activities. When producing oil and gas, a certain amount of methane (whether from associated gas in oil production or from natural gas production) escapes into the atmosphere. These releases can be intentional (i.e. a feature of current industry practice or equipment operation), or inadvertent, for example because of ageing infrastructure. They can also occur as a result of incomplete combustion during flaring activities, both during short-term flaring for safety reasons or during flaring in locations where infrastructure to make use of the gas is lacking. There are policies to address different aspects of methane emissions in some countries, for example in Norway and Russia, although implementation is sometimes delayed. In the United States, the White House has recently requested the US Environmental Protection Agency (EPA) to propose additional rules to reduce methane releases. In general terms, there remains a deficit in awareness and enforcement. Successful policy intervention will need to start by raising awareness of the problem and taking steps to measure its extent.

Box 3.2 ▷ The role of nuclear energy in the Bridge Scenario

In many countries, nuclear energy is an important part of the electricity mix. In 2013, the world's 392 GW of installed nuclear capacity accounted for 11% of electricity production, mostly in OECD countries. Use of nuclear energy has avoided the release of 56 Gt of CO_2 since 1971, equivalent to almost two years of global emissions at current rates (IEA, 2014a). Further deployment of nuclear energy is stated government policy in a number of countries, and 74 GW of capacity was under construction by end-2014 (of which almost 40% in China). In the INDC Scenario, nuclear generation rises by more than 60% over today's level in 2030, with much of the growth occurring in markets in which electricity is supplied at regulated prices, utilities have state backing or governments act to facilitate private investment.

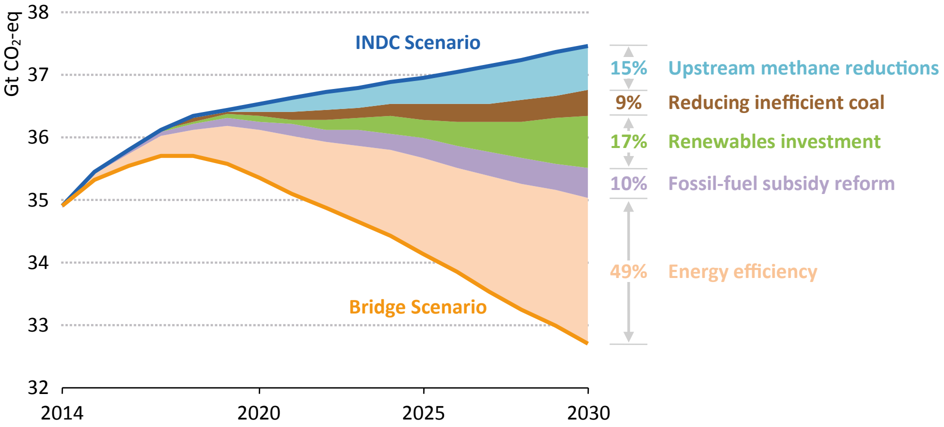
Encouragement of new nuclear power plant construction is not one of the specific policies in the Bridge Scenario, particularly because of the long-lead times involved relative to the near-term focus of the scenario. Nuclear energy nevertheless plays an important role in curbing GHG emissions growth in the Bridge Scenario. Nuclear capacity reaches 540 GW in 2030, driven by the same level of government support as in the INDC Scenario. The share of nuclear energy in power generation increases to 13% in 2030, two percentage points over today's level and one percentage point more than in the INDC Scenario, due to the lower electricity demand as a result of energy efficiency measures.

Emissions trends in the Bridge Scenario

Global emissions abatement

Effective implementation of the proposed measures in the Bridge Scenario would have profound implications for global GHG emissions.[8] Emissions would be 2.8 Gt (or 8%) lower than in the INDC Scenario by 2025 and 4.8 Gt (or 13%) lower by 2030, meaning that energy-related GHG emissions would peak and then begin to decline by around 2020 (Figure 3.2). Their adoption is insufficient alone to put the world on track for reaching the 2 °C target (the long-term global mean temperature would rise by 2.8 °C if no additional mitigation measures were taken later), but they would put the world on track for further emissions reductions. They would also lock-in recent trends that decouple economic growth from emissions growth in some regions and broaden that de-linking (Figure 3.3).

Figure 3.2 ▹ Global energy-related GHG emissions reduction by policy measure in the Bridge Scenario relative to the INDC Scenario



The largest contribution to global GHG abatement comes from energy efficiency, which is responsible for 49% of the savings in 2030 (including direct savings from reduced fossil-fuel demand and indirect savings as a result of lower electricity demand thereby reducing emissions from the power generation).[9] The power sector is the second-largest contributor to global GHG savings, at 26% in 2030. While limitations on the use of the least-efficient coal power plants are effective in curbing global GHG emissions until 2020

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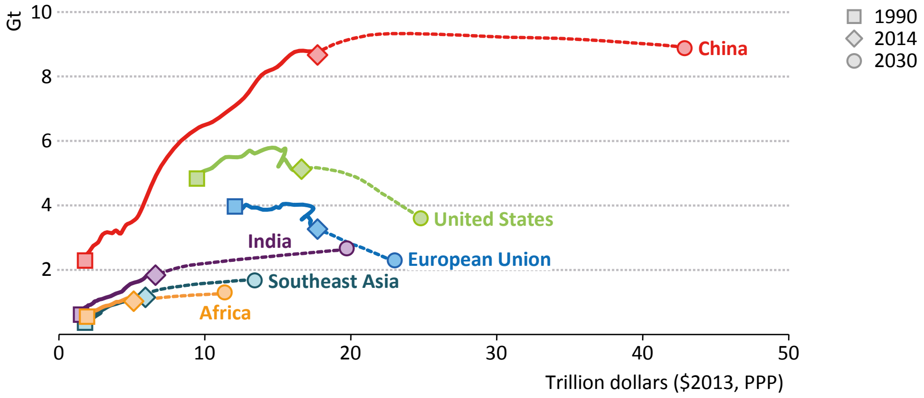
8. Tables containing detailed projection results for the Bridge Scenario by region, fuel and sector are available in Annex B.

9. The results take into account direct rebound effects as modelled in the IEA's World Energy Model. Direct rebound effects are those in which energy efficiency increases the energy service gained from each unit of final energy, reducing the price of the service and eventually leading to higher consumption. Policies to increase end-user prices are one way to reduce such rebound effects, but are not considered in the Bridge Scenario (except for fossil-fuel subsidy reform). The level of the rebound effect is very controversial; a review of 500 studies suggests though that direct rebound effects are likely to be over 10% and could be considerably higher (IPCC, 2014).

and achieve around half of total power sector savings, an increasingly larger part of the additional GHG savings after 2020 come from increased investment in renewable energies (providing two-thirds of power sector savings by 2030, or 17% of total GHG savings). Minimising methane emissions from upstream oil and gas operations is effective in both the short and longer term, contributing 11% of global GHG savings relative to the INDC Scenario in 2020 and 15% in 2030. The gradual phase-out of fossil-fuel consumption subsidies is an effective measure both to moderate demand growth and to support the implementation of energy efficiency policies. It contributes 10% of global GHG savings by 2030.

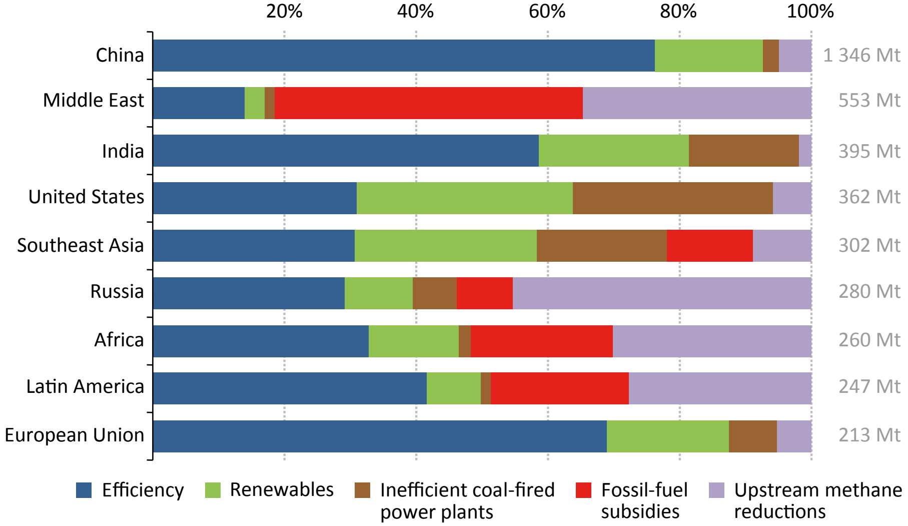
Figure 3.3 ▷ Energy-related CO_2 emission levels and GDP by selected region in the Bridge Scenario



Note: PPP = purchasing power parity.

Implementation of the Bridge Scenario measures is effective in all regions, although to different degrees depending on variables such as the respective size of the economy, characteristics of the energy sector and the existing policy framework. For example, the more ambitious the policy package put forward through existing regulations and the INDCs, the lower the level of additional emissions savings achieved in the Bridge Scenario (Figure 3.4). In the *United States*, for example, the INDC targets a reduction of all GHG emissions of 26% to 28% (relative to 2005 levels) by 2025. In the INDC Scenario, the United States achieves a reduction of energy-related GHG emissions of 1.9 Gt CO_2-eq by 2030, relative to 2005. The additional measures in the Bridge Scenario could save another 360 Mt CO_2-eq in 2030, helping to move to the upper-end of the US climate pledge, without negative impacts on economic growth. The *European Union*, which already has a comprehensive energy policy framework that would allow reducing GHG emissions by at least 40% in 2030, relative to 1990 levels, under the existing INDC, reduces total emissions in the Bridge Scenario by another 4 percentage points (or 210 Mt CO_2-eq).

Figure 3.4 ▷ Energy-related GHG emissions reduction in CO_2-eq terms by policy measure and region in the Bridge Scenario relative to the INDC Scenario, 2030



Notes: The relative shares of emissions savings by policy measure have been calculated using a Logarithmic Mean Divisia Index I (LMDI I) decomposition technique. In regions where fossil-fuel subsidies hinder energy efficiency investments today, the existing subsidy level in each sector was used to quantify the impact of fossil-fuel subsidy reform on emissions savings.

Although the strong growth in energy demand in *China* over the past decade has locked-in a relatively carbon-intensive energy infrastructure, an earlier peak in CO_2 emissions (including process emissions) can be achieved than in the INDC Scenario: in the Bridge Scenario, it is achieved in the early 2020s, as China's carbon intensity (i.e. the amount of CO_2 emitted per unit of gross domestic product [GDP]) drops by 5.4% per year between 2013 and 2030, compared with 4.7% in the INDC Scenario. The share of non-fossil fuels in primary energy demand rises to 23%[10] by 2030, three percentage points above the target in the INDC Scenario. In *India*, planned energy sector policies have a focus on large-scale solar PV deployment. Making more use of the energy efficiency potential across all sectors could help to cost-effectively reach India's energy sector targets and support a total reduction of GHG emissions by 400 Mt CO_2-eq (or 11%) in 2030, relative to the INDC Scenario.

As in the case of China and India, most other countries had not submitted their INDCs for COP21 by 14 May 2015, but their existing and planned policies give a good indication of the likely level of ambition of their targets. In *Japan*, for example, the existing and announced

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[10] Value is calculated using the coal-equivalent approach in Chinese statistics, which is likely to be the basis of the Chinese INDC. Using IEA definitions, the share of non-fossil fuels is 20% in 2030 in the Bridge Scenario.

energy sector policies suggest that there is scope to reduce GHG emissions by a further 160 Mt CO_2-eq in 2030 (or 17%) through the adoption of the policy measures in the Bridge Scenario (mainly through additional energy efficiency gains). In *Southeast Asia*, a broad portfolio of options is available to curb collective emissions growth by 300 Mt CO_2-eq in 2030, relative to the INDC Scenario, with increasing use of renewables, reduced coal use in power generation and energy efficiency improvements. About one-third of the savings is achievable in Indonesia alone. In *Latin America*, the measures in the Bridge Scenario save 250 Mt CO_2-eq by 2030, relative to the INDC Scenario, mainly from energy efficiency and reductions in methane emissions (of the latter, about 40% is in Brazil). The *Middle East* can save an additional 550 Mt CO_2-eq of GHG emissions by 2030, relative to the INDC Scenario, through the adoption of the measures in the Bridge Scenario. Fossil-fuel subsidy reform and energy efficiency policies combined achieve 60% of the additional emissions savings in 2030; minimising methane emissions from upstream oil and gas production contributes much of the remainder. Emissions continue to rise in *Africa* in the Bridge Scenario, given the low level of emissions per capita today, but at a slower pace than in the INDC Scenario (at the same level of economic growth). Africa's share in total abatement in the Bridge Scenario is only 5% in 2030 (260 Mt CO_2-eq). It stems from four main pillars: energy efficiency, reducing methane emissions (of which around two-thirds in sub-Saharan Africa), fossil-fuel subsidy reform and renewables. Further savings from additional renewables investments are limited by the already strong level of deployment in the INDC Scenario.

Trends by policy measure

Energy efficiency

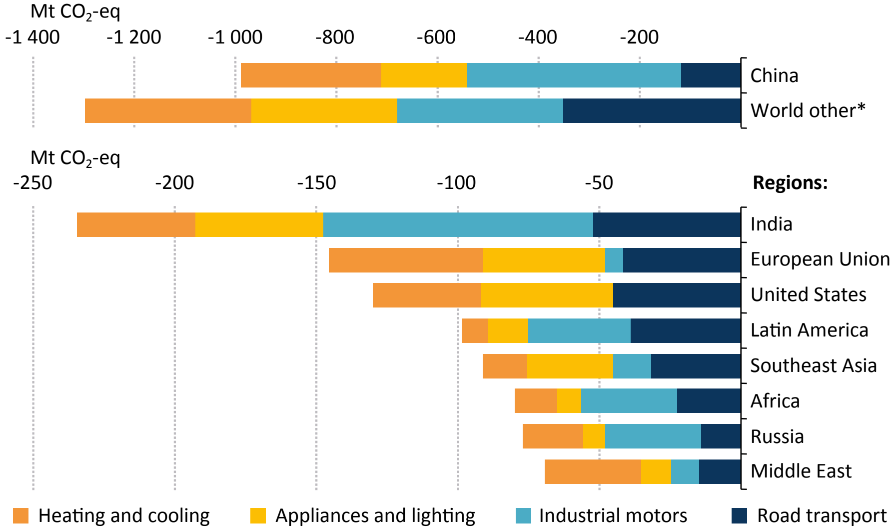
The adoption of energy efficiency measures offers a wide range of benefits, well beyond their contribution to climate policies. These benefits include increases in disposable income and improved industrial productivity (with positive effects for economic growth), improved local air quality (with associated health benefits) and poverty alleviation (IEA, 2014c). All of the measures adopted in the Bridge Scenario have already proven to reduce average energy use for the same energy service. They can all be adopted immediately and do not involve overcoming obstinate deployment hurdles (such as those associated with split incentives as a result of ownership, i.e. the landlord/tenant issue, or demand substantial effort in terms of consumer education). The proposed energy efficiency measures in the Bridge Scenario include:

- **Industry sector:** minimum energy performance standards (MEPS) are introduced for electric motor systems (including for the electric motors, gears, transmission systems and motor-driven equipment) and the adoption of variable speed drives is made mandatory (where applicable). Incentives are introduced for heat pumps that provide low-temperature heat, and mandatory audit programmes raise awareness, particularly in industries where the largest potential remains, including food, textile, paper and chemicals.

- **Buildings sector:** MEPS support a phase-out of the least-efficient categories of selected refrigeration and cleaning appliances[11] by 2030. A phase-out of the least-efficient category of televisions and computers is accomplished by 2030. A ban on incandescent light bulbs in residential and commercial buildings is introduced by 2020 and on halogen light bulbs by 2030. For heating and cooling, MEPS are set for new equipment, and technology changes made (e.g. expanded use of heat recovery). For new buildings, an increase in insulation levels is applied as a step towards near-zero-energy buildings.
- **Transport sector:** Fuel-economy standards are imposed in every country for new light-duty vehicle sales, so that the global average fuel consumption for these new vehicles is reduced to around 4 litres per 100 km in 2030, i.e. a reduction of 50% relative to 2005.[12] For new freight trucks, standards are adopted to achieve a 30% reduction in average vehicle fuel consumption per truck relative to today.

In the Bridge Scenario, energy efficiency is the largest contributor to additional GHG emissions savings, with savings of around 2.3 Gt CO_2-eq relative to the INDC Scenario in 2030, or 49% of the total. Early adoption of energy efficiency policies is important, because savings increase over time as they take effect and the proportion of more efficient technologies in the stock rises, in particular in road vehicles and electric motors in industry, where the average lifetime is typically in the range of 10 to 15 years.

Figure 3.5 ▹ Energy-related GHG emissions reduction by energy efficiency measure and region in the Bridge Scenario relative to the INDC Scenario, 2030



* World other represents all countries except for China.

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[11] Cleaning appliances include washing machines, dryers and dishwashers.

[12] The proposed level is consistent with the targets of the Global Fuel Economy Initiative (GFEI), for details see *www.fiafoundation.org/our-work/global-fuel-economy-initiative*.

The value of particular measures in different regions naturally varies with local circumstances (Figure 3.5). *China* accounts for more than 40% of the additional global emissions savings from energy efficiency policies in the Bridge Scenario, around 1.0 Gt CO_2-eq. Strengthening MEPS for electric motors systems in the industry sector contributes a particularly large component to the savings in China (Table 3.1), as its industry sector is responsible for around two-thirds of total electricity demand, of which an estimated 60% to 70% is for motors. The buildings sector saves 450 Mt CO_2-eq of GHG emissions by 2030 relative to the INDC Scenario, although improving energy efficiency in buildings is already a policy priority in China: main measures in place include efficiency labels for some appliances (the China Energy Label), a phase-out of incandescent light bulbs by end-2016 and a 50% target for energy-efficient buildings in new construction under the National Climate Change Plan (2014-2020). Increasing fuel-economy standards of road vehicles is particularly effective after 2020 in China. The standard already set for passenger vehicles in 2020, of 5 litres/100km, is strengthened, reducing GHG emissions by 115 Mt CO_2-eq in 2030, relative to the INDC Scenario, and helping to cut road transport fuel use by almost 10%. New policies are also adopted for road freight vehicles (Table 3.2).

Table 3.1 ▷ Minimum energy performance standards for electric motors in industry by selected region in the Bridge Scenario

	United States	European Union	China	India	Southeast Asia	South Africa	Middle East
2013	IE3 (from 2016)	IE3 or IE2 +VSD*	IE2	IE2	n/a	n/a	n/a
2030	IE4+VSD	IE4+VSD	IE4+VSD	IE4+VSD	IE4+VSD	IE4+VSD	IE4+VSD

Notes: IE1, IE2, IE3 and IE4 represent the efficiency levels standard, high, premium and super premium, respectively, as defined by the International Electrotechnical Commission. For a motor with an output of 10 kilowatts, IE1 represents an efficiency of 87%, IE2: 89%, IE3: 91% and IE4: 93%. * VSD = variable speed drive, i.e. equipment used to control the speed of machinery. Where process conditions require adjustment of flow from a pump or fan, VSD may save energy.

India saves 230 Mt CO_2-eq by increasing energy efficiency in the Bridge Scenario, relative to the INDC Scenario. As in China, the industry sector is the largest electricity-consuming sector in the economy today (more than 40%). MEPS for electric motors already exist in India, but further increasing the efficiency of electric motor systems drives a reduction of electricity demand by 12% (or around 100 terawatt-hours [TWh]) in 2030 and saves 95 Mt CO_2-eq of GHG emissions, relative to the INDC Scenario. Energy demand is expected to rise considerably in India's buildings sector, as a large part of the population at present lacks access to modern energy services. Only 4 out of 13 available labels for appliances are mandatory in India today, so MEPS to increase energy efficiency in buildings help reduce emissions growth (saving 85 Mt CO_2-eq of GHG emissions by 2030) while also improving the effectiveness of strategies to improve energy access. The road transport sector contributes emissions savings of more than 50 Mt CO_2-eq in 2030 relative to the

INDC Scenario, as the recently adopted fuel-economy standards for passenger vehicles of 4.8 litres/100km in 2021/2022 are further tightened and extended to 2030 and standards for freight trucks are introduced. As in other developing countries, programmes to improve the condition of road infrastructure can help reap the full benefit of efficient final fuel use.

The *United States* has adopted a raft of energy efficiency policies over the past few years but, given today's level of energy consumption per capita, further improvements are possible without significant changes to current lifestyles. The pursuit of energy efficiency measures in the Bridge Scenario achieves additional savings of 120 Mt CO_2-eq in 2030, relative to the INDC Scenario. The principal contribution to the savings comes from the buildings sector, where emissions are reduced by an additional 90 Mt CO_2-eq in 2030. The transport sector saves another 45 Mt CO_2-eq of GHG emissions in 2030, mainly through further improving and extending to 2030 the fuel efficiency standard for trucks.

Table 3.2 ▷ Performance levels for selected new products in the residential and transport sectors in the Bridge Scenario, 2030

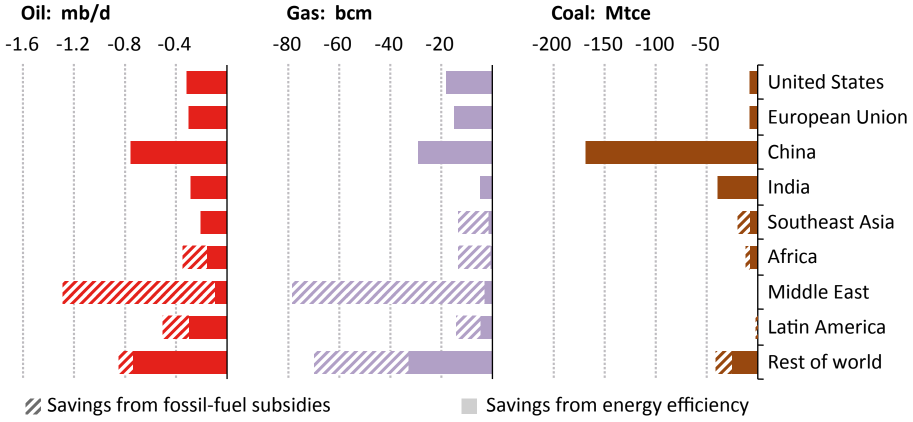
		Refrigerators	Cleaning equipment	Lighting	Heating and cooling	Passenger vehicles	Heavy trucks
		(kWh/appliance)	(kWh/appliance)	(kWh/m²)	(2013=100)	(l/100km)	(l/100km)
United States	2013	720	375	9	100	6.8	46
	2030	485 (Energy Star)	265 (Energy Star)	5 (Energy Star)	32	3.9	32
European Union	2013	305	255	4	100	5.3	30
	2030	220 (A++)	235 (A)	2 (A)	29	3.4	21
China	2013	375	135	6	100	7.3	38
	2030	365 (Grade 3)	170 (Grade 3)	6 -	49	4.4	27
India	2013	365	135	5	100	6.1	40
	2030	335 (3 Star)	170 (3 Star)	5 -	73	4.1	28
Southeast Asia	2013	480	435	3	100	6.9	44
	2030	395	485	3	100	4.6	31
South Africa	2013	350	295	4	100	6.6	38
	2030	180 (A)	275 (C)	4 -	85	4.0	27

Notes: Cleaning equipment refers to washing machines, dryers and dishwashers. For appliances, the average consumption in 2030 can be higher than today if the size of the equipment rises with higher income per capita. For labels, values in parentheses represent the level of the least-demanding label in 2030. In the United States, labels have no range. The voluntary label "Energy Star" represents an increase of efficiency of 10% to 30%, relative to the current level of energy efficiency standards, and is considered as mandatory by 2030 in the Bridge Scenario. For passenger vehicles, the values represent test cycle fuel consumption of new sales; for heavy trucks (above 16 tonnes), they are estimated on-road fuel consumption of new vehicles.

The *European Union* has been similarly active in improving energy efficiency over recent years, including through the Energy Efficiency Directive and through vehicle fuel-economy standards. Residential electricity demand has barely changed over the past decade (as a result, for example, of improving the efficiency of appliances and heating equipment) and oil demand for road transport has been on a steadily declining trend since 2007. But scope for further improvements exists and its exploitation results in a total saving of close to 150 Mt CO_2-eq from energy efficiency by 2030, relative to the INDC Scenario. Further tightening fuel-economy standards for passenger vehicles to 85 grammes CO_2 per kilometre (km) in 2030 (from 95 g CO_2/km in 2020) and adopting standards for freight trucks (a strategy to reduce emissions from freight is currently under development) contributes 40 Mt CO_2-eq of additional GHG emissions savings. For other sectors, the 2030 framework for climate and energy policies foresees a review by 2020 to assess the possibility of raising the level of energy efficiency ambition beyond current targets. In the Bridge Scenario, greater energy efficiency in the buildings sector saves an additional 100 Mt CO_2-eq in 2030, relative to the INDC Scenario.

Potential GHG emissions savings in other countries are necessarily smaller in absolute terms than those from the above regions, given their relative size, even though the degree of ambition of existing and planned policies (as considered in the INDC Scenario) is generally lower. But, on aggregate, savings in the Bridge Scenario from other countries do make a significant difference. For example, recent *WEO* analysis shows that around three-quarters of the economic efficiency potential of *Southeast Asia* remains untapped until 2035 under existing and planned policies (IEA, 2013b). The adoption of more stringent energy efficiency requirements in the region could save 90 Mt CO_2-eq emissions by 2030 (of which almost 40% is in Indonesia), relative to the INDC Scenario. The co-benefits for energy security are significant (Figure 3.6): oil demand is down by 0.2 mb/d in 2030 relative to the INDC Scenario and electricity demand growth is moderated to 3.5% per year, compared with 4.1% in the INDC Scenario.

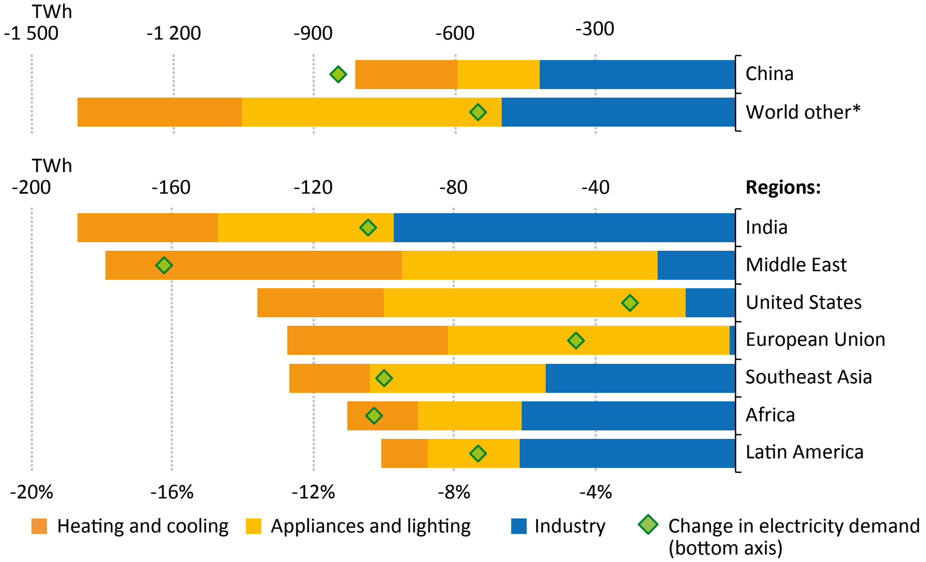
Figure 3.6 ▷ Fossil-fuel savings from energy efficiency and fossil-fuel subsidy reform in the Bridge Scenario relative to the INDC Scenario, 2030



Notes: mb/d = million barrels per day; bcm = billion cubic metres; Mtce = million tonnes of coal equivalent.

In the *Middle East*, addressing energy efficiency is complex, as fossil-fuel subsidies weaken the end-user incentive to economise. In the Gulf region, mandatory building codes are in place in all countries, but they generally lack enforcement. The overall potential for energy savings in new buildings has been estimated to be larger than 60%, while retrofit pilot efforts have revealed potential to increase energy efficiency by 25%. Almost 20% of electricity demand in the buildings sector in the Middle East comes from the need for cooling, but MEPS for air-conditioning are not widespread; their adoption reduces electricity demand growth in the Bridge Scenario (Figure 3.7). In the transport sector, Saudi Arabia has adopted fuel-economy standards for passenger vehicles, but their impact on fuel savings is likely to be obstructed by low fuel prices. The energy efficiency measures taken in the region in the Bridge Scenario, in combination with fossil-fuel subsidy reform, reduce GHG emissions by around 330 Mt CO_2-eq in 2030, relative to the INDC Scenario. One co-benefit for the region is increased availability of fossil fuels for export.

Figure 3.7 ▷ **Electricity demand reduction by sector and region in the Bridge Scenario relative to the INDC Scenario, 2030**



* World other represents all countries except for China. Note: TWh = terawatt-hour.

As in India, the case for improving energy efficiency in *Africa* is closely linked to providing energy access to those currently without supply: today, more than 620 million people lack access to electricity, and nearly 730 million rely on the traditional use of biomass for cooking purposes. The potential to improve energy efficiency on the continent is vast; at the basic needs level, biomass cookstoves often have very low conversion rates (10% to 15%), and improving their efficiency can reduce indoor air pollution and certain GHG emissions. In some cases, even a switch to modern fuels, such as liquefied petroleum gas (LPG), might reduce GHG emissions (Spotlight). Vehicles across Africa are often second-hand and one highly productive measure is to impose restrictions on vehicles above a certain age (as has been done in Angola, Botswana and Kenya, for example). MEPS for household appliances can help moderate the pace of capacity build-up required in the power sector to meet growing demand. Allowing for accompanying measures taken in the Bridge Scenario to ensure no worsening in energy access relative to the INDC Scenario, energy efficiency in the Bridge Scenario saves around 80 Mt CO_2-eq of emissions in Africa in 2030 relative to the INDC Scenario.

Power sector: reducing inefficient coal use and additional investment in renewables

Two-thirds of global power generation today comes from fossil fuels, making the sector responsible for more than 40% of global energy sector-related CO_2 emissions. This scale of emissions, combined with the availability of low-carbon alternatives, makes the power sector central to any mitigation strategy. The required transformation can materialise only if the right signals to investors are in place. An analysis of power sector investments over the past decade, undertaken for the IEA's *World Energy Investment Outlook* (IEA, 2014d), shows that a transition has begun, around 60% of total power plant investments since 2000 have been made in low-carbon technologies, in particular hydro, wind and solar PV. But the process needs to go much further: every year that passes locks in further fossil-fuel generation and consequent emissions growth from the power sector.

Energy efficiency policies curb electricity demand while safeguarding essential supply; their adoption is a key enabler to power sector decarbonisation. In the Bridge Scenario, the other two pillars are:

- Progressively reducing the use of the least-efficient coal-fired power generating plants and banning the construction of new ones.
- A further increase in investment in renewable energy technologies from $270 billion in 2014 to $400 billion in 2030.

In some cases, these policies will need to be complemented by other power sector reforms to facilitate the transition and maintain system reliability (the considerations differ by country). This mainly involves ensuring adequate capacity in the system and strengthening and expanding grid interconnections to enable full use of the flexibility of the power plant fleet. At very high levels of renewables penetration, necessary additional measures might extent to energy storage, use of smart grid technologies and demand response measures (Chapter 4); but in the Bridge Scenario, the integration challenge is not exacerbated in any region, compared with the INDC Scenario. In regions where access to electricity is inadequate today, as in India or Africa, the Bridge Scenario reaches the same level of electricity access in 2030 as in the INDC Scenario.

Box 3.3 ▷ Protecting fossil-fuel assets through CCS

The policy framework in the Bridge Scenario includes a reduction in the use of the least-efficient coal-fired power plants. But the adoption of this policy does not mean that investment even in efficient coal power plants is without risk. Any strategy to realise the long-term 2 °C target will require a level of decarbonisation of the energy sector that cannot be achieved even with the most efficient coal power plants, as they are constituted today. In the very long term, gas-fired power generation will also be incompatible unless measures are taken to abate their CO_2 emissions. Investors in new fossil-fuel power plants, especially coal-fired power plants, need to ensure not only the high efficiency of the plants, but also that they are, where possible, suitable for later modification to incorporate carbon capture and storage (CCS), i.e. that they are "CCS-ready" to ensure that the capital invested in these assets is not wiped out as climate targets are strengthened. Action can be taken at the time of design and construction to improve the technical and economic feasibility of retrofitting CCS, notably:

- Ensuring sufficient space available on-site for the installation of additional CO_2 capture equipment.
- Locating the plant in reasonable proximity to an existing possible CO_2 storage site, or one that is likely to become available by the time of retrofit.
- Verifying that local water will continue to be available in sufficient quantities for the needs of the plant, as CCS increases water requirements.

The gradual reduction in the use of the least-efficient coal-fired power plants has three key stages:[13] first, a ban on the construction of new inefficient coal-fired power plants (typically conventional subcritical power plants)[14]; second, a gradual reduction in the level of operation of the least-efficient plants that are currently under construction (i.e. 83 GW of capacity, but ensuring that they can still recover the investment costs); and, third, the retirement or idling of all ageing inefficient coal-fired power plants that have already repaid their investment costs, to the full extent possible without affecting power system reliability.

Relevant measures are already in use in many countries. They include CO_2 pricing (such as through an emissions trading scheme, as in the European Union and in selected pilot regions in China, or carbon taxes, as in the Nordic countries); the imposition of power production limits for each generator; the allocation of generation quotas favouring operation of low-emission plants; renewing (or failing to renew) operational licenses or altering the dispatch schedule in favour of more efficient plants; and the adoption of standards on the energy efficiency of coal power plants, on their average level of CO_2 emissions per kilowatt-hour (kWh) or on the average level of air pollution.

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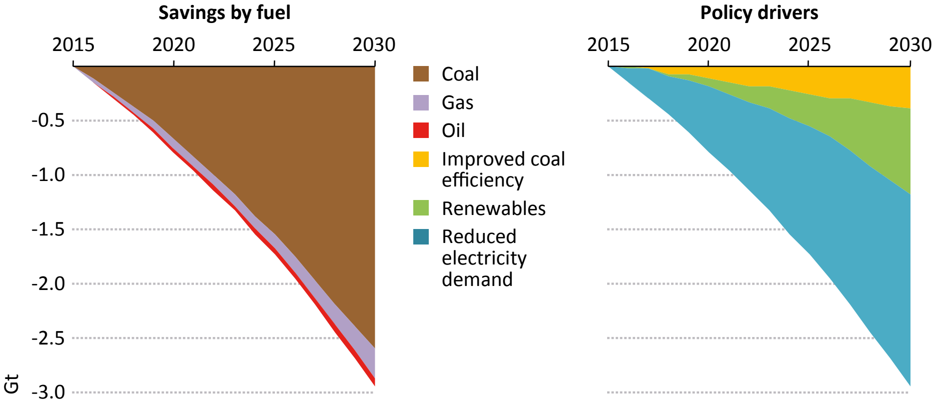
[13] See also (IEA, 2014e).

[14] Small power systems may not be able to deploy large, more efficient coal-fired power plants such as supercritical or ultra-supercritical technologies. In such cases, it will be important to deploy the most efficient feasible technology, which may be subcritical.

Further increasing investment in renewable energy technologies in the power sector, to $400 billion per year by 2030, as assumed in the Bridge Scenario, is a substantial increase over the $270 billion invested in 2014 and the $285 billion in the INDC Scenario in 2030. The majority of this additional investment goes to variable renewables, particularly for wind power and solar PV.[15] Scaling up renewables investment to this extent is not thought to be constrained by limits on the availability of finance, provided appropriate signs are given to investors and markets. These include CO_2 pricing, which improves the competitiveness of renewables versus fossil-fuel power plants; clear and stable financial support measures from governments (such as feed-in tariffs, feed-in premiums or tax credits); auctions for long-term power purchase agreements; or defined requirements for the contribution from renewables, either in terms of capacity (as in China or India) or generation (as in the European Union and parts of the United States). All these measures help lower investor risk, in turn lowering the cost of capital for renewables investments. In some high-risk environments, such as in some developing countries, framework conditions will need to go further, including more political stability, effective regulatory systems and greater market transparency. Where possible, preference should be given to measures that foster competition and innovation (e.g. transparent auctioning systems), in order to support renewables deployment at minimal cost.

Figure 3.8 ▷ Global energy-related CO_2 emissions savings from the power sector in the Bridge Scenario relative to the INDC Scenario



Note: Besides reducing CO_2 emissions from power generation, the suggested policies indirectly reduce methane emissions from coal mining, contributing 1.0 Gt CO_2-eq to cumulative savings from the reduced use of coal.

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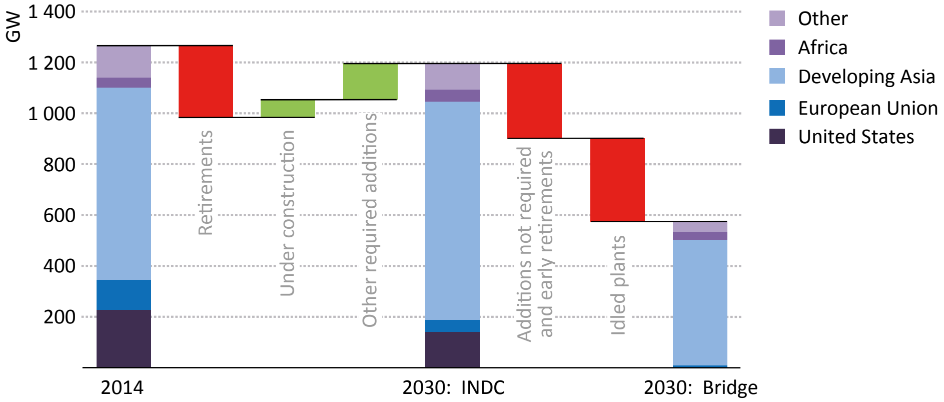
[15] Variable renewables are renewable energy technologies with output that depends on variable renewable energy inputs, such as solar irradiation and wind, and which do not incorporate energy storage technologies.

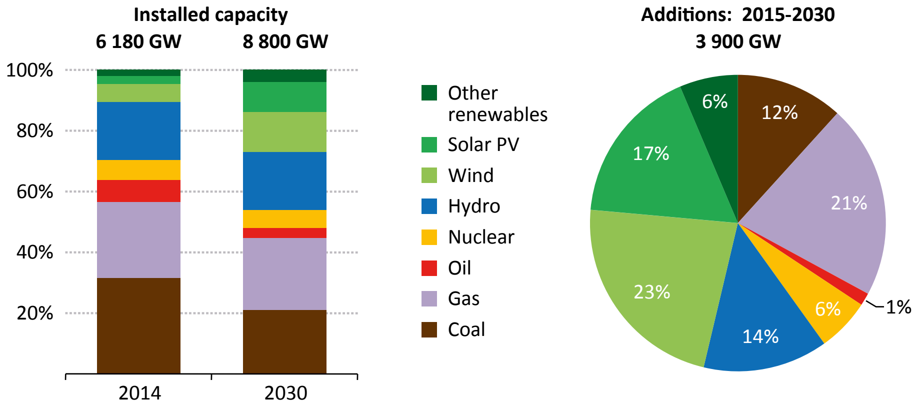
Relative to the INDC Scenario, the cumulative emissions reductions from coal-fired power plants in the Bridge Scenario account for around 90% of power sector reductions to 2030 (Figure 3.8), the amount of CO_2 emissions from inefficient coal power plants dropping from 6 Gt today (around 50% of total power sector emissions) to 1.4 Gt in 2030 (around 15%). The installed capacity and the use of subcritical power plants changes significantly: the operational subcritical coal capacity is around half that of today (compared to only a marginal reduction in the INDC Scenario), with some 620 GW either idled or not built at all (Figure 3.9). Around 60% of the capacity reduction takes place in developing Asia, where reliance on electricity generation from subcritical coal-fired power stations is almost halved in 2030, compared with the INDC Scenario. A further 30% of the capacity reduction takes place in the United States and the European Union, where the role of subcritical generation almost disappears by 2030.

Figure 3.9 ▻ **Changes in capacity of subcritical coal in the Bridge and INDC Scenarios**



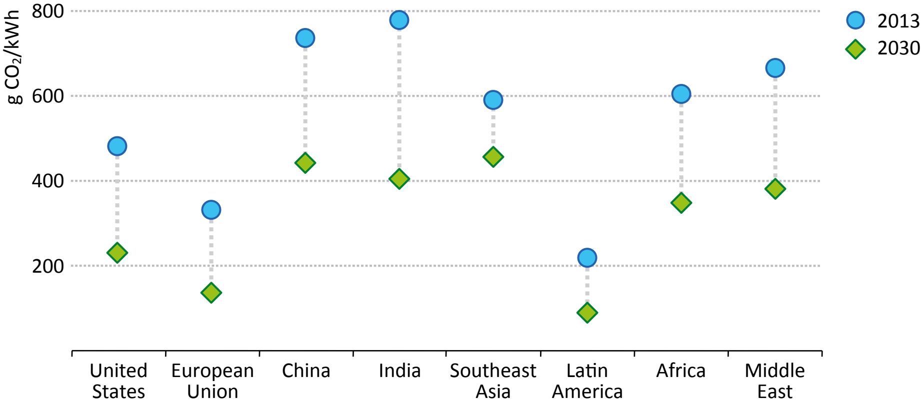
In the Bridge Scenario, the increase in renewables investment is particularly effective after 2020. While total capacity of renewable energy technologies in the Bridge Scenario is only marginally higher than in the INDC Scenario in 2020, it is 285 GW, or 8%, higher in 2030, reaching around 4 000 GW (Figure 3.10). In 2030, around 70% of total capacity additions in the power sector are from renewable energies in the Bridge Scenario, 14 percentage points above the level achieved in the INDC Scenario in 2030, and up from around 45% in 2014. The increase in investment in renewable energy technologies in the power sector in the Bridge Scenario varies by region, depending on the prevailing power mix, the level of climate ambition in the INDC Scenario and the regional cost of renewables deployment. In some regions, investment in certain renewable energy technologies is lower than today, even if capacity additions are higher, as technology costs gradually decline. But the renewables investment of around $400 billion in 2030 in the Bridge Scenario is an increase of $110 billion (or almost 40%) over that in the INDC Scenario. The strongest increases occur in China ($27 billion more than in the INDC Scenario), the United States ($15 billion), Southeast Asia ($13 billion) and India ($12 billion).

Figure 3.10 ▷ World power generation capacity mix and capacity additions in the Bridge Scenario



The power sector policies of the Bridge Scenario achieve remarkable reductions in average emissions from the power sector in all countries and regions (Figure 3.11). Today, the power sector emits around 530 grammes of carbon dioxide per kilowatt-hour (g CO_2/kWh) on a global level. This is reduced to 430 g CO_2/kWh in the Bridge Scenario in 2020 and around 300 g CO_2/kWh in 2030.

Figure 3.11 ▷ Average CO_2 emissions per kWh by selected region in the Bridge Scenario



In many countries, the measures adopted in the Bridge Scenario simply increase the effectiveness of policies that are already in place today (as in the European Union), under development, or further extend their application to 2030. In the *United States*, for example, the Clean Power Plan significantly constrains the use of coal-fired power plants in the INDC Scenario, but spurring additional investment in renewables means that less reliance is put on emissions reductions from coal-to-gas switching, making the compliance pathway more compatible with long-term decarbonisation goals. *China*, over the course of the 11th Five-Year Plan, closed 77 GW of small inefficient coal power plants and then targeted another 20 GW during the 12th Five-Year Plan (to 2015), of which 10 GW is known to have been closed to date. The primary goal of these measures was to combat air pollution, but together with the stated intention to enhance the emissions trading scheme to a national level (it currently operates in seven provinces), they could also contribute towards achieving the targets of the Bridge Scenario.

The challenge for *India* is different to that which is facing many other countries. India's power sector relies on fossil fuels, mostly coal, for more than 80% of electricity generation, and a significant part of the population has no access to electricity today. In the Bridge Scenario, an additional 400 million people obtain access to electricity by 2030. Chronic issues persist over high transmission and distribution losses and problems with financing power sector investment in an environment in which revenues from power generation are insufficient to provide an adequate return on investment (IEA, 2014d). In the Bridge Scenario, solar PV provides most of the variable renewables capacity in 2030, at 135 GW, followed by 110 GW of wind power, extending stated power sector targets (Chapter 2). Compared to the INDC Scenario, the capacity of the least-efficient coal power plants operating in 2030 is reduced by almost 160 GW, due to lower electricity demand. Increased use of flexible capacity, such as hydropower, helps to accommodate variable renewables generation.

The two power sector policies proposed in the Bridge Scenario are particularly effective in regions with high shares of coal in power generation. *Southeast Asia*, for example, has cumulative coal-fired capacity additions of around 80 GW by 2030 in the INDC Scenario. In the Bridge Scenario, the average amount of subcritical coal installed per year is reduced by 1.5 GW relative to the INDC Scenario, while the share of renewables in total electricity generation increases 8 percentage points, to 26%, by 2030. As a result, the power sector in Southeast Asia saves 230 Mt CO_2-eq of GHG emissions by 2030, relative to the INDC Scenario. In the *Middle East*, where oil is frequently used for power generation, partly as a result of the phase-out of fossil-fuel subsidies, renewable generating capacity additions rise to 8 GW per year in 2030 (40% over what is achieved in the INDC Scenario), reducing emissions from the power sector by 140 Mt CO_2-eq in 2030, relative to the INDC Scenario. In *Africa* and *Latin America*, average annual installations of renewables for power generation to 2030 reach 7 GW (about 15% above what is achieved in the INDC Scenario) and 8 GW (around 10%), respectively. Achievement beyond this is limited by the already ambitious plans considered in the INDC Scenario.

SPOTLIGHT

How increased electricity access and decarbonisation work together

The IEA has been providing in-depth analysis on energy access for more than a decade and consistently highlights that achieving universal access adds less than 1% to overall energy demand and energy-related CO_2 emissions by 2030 when compared to planned policies (IEA, 2013c). The threat to global warming from achieving greater access to energy for the under-privileged is negligible.

There are even examples that suggest a positive impact on climate mitigation. One relates to the use of kerosene lamps or candles for lighting, which is prevalent among most of the 1.3 billion people without access to electricity today. In this case, providing access to electricity has multiple benefits: most importantly, access to cleaner lighting solutions, such as electricity or solar torches, would reduce adverse health impacts from indoor air pollution, reduce the incidence of fires and represent an important income benefit for households. From a climate mitigation perspective, a kerosene lamp emits between 3 and almost 40 times more CO_2 emissions than a grid-connected compact fluorescent lamp (depending on the power mix). As a result, providing electricity access to replace kerosene lamps could save an estimated 35 Mt CO_2 per year.[16] Additional climate mitigation potential lies in the fact that around 8% of the kerosene used in a simple lamp is converted into pure black carbon, which can trigger regional climate forcing (CCAC, 2014; Lam N., 2012).

A second example relates to clean cooking solutions. Today 2.7 billion people rely on the combustion of solid fuels for cooking purposes. A shift towards modern fuels such as LPG is essential to prevent associated health problems and reduce premature deaths; but there is also a potential co-benefit for reducing GHG emissions. Even though biomass is considered a renewable source (if sustainably harvested), its use may emit more GHG emissions than LPG stoves. There is much uncertainty around GHG emissions of traditional cookstoves using solid biomass, since their efficiency is widely variable; but the efficiency is typically low and the combustion process incomplete. Further uncertainty is associated with the methane emissions of traditional cookstoves. The IPCC reports emission factors ranging from 4 to 38 kilotonnes (kt) of CH_4 per million tonnes of oil equivalent (Mtoe), with the default value at 12.5 kt CH_4/Mtoe. Experimental studies with traditional and improved stoves conducted mainly in Asia found an even higher range, from 10 to 78 kt CH_4/Mtoe. The threshold for greater emissions of GHG from the traditional use of biomass for cooking than from the use of LPG lies at emissions from the traditional stove of 15 kt CH_4/Mtoe (Figure 3.12). Failure to re-plant biomass crops in many developing countries shifts the GHG advantage further towards the use of modern fuels, such as LPG.

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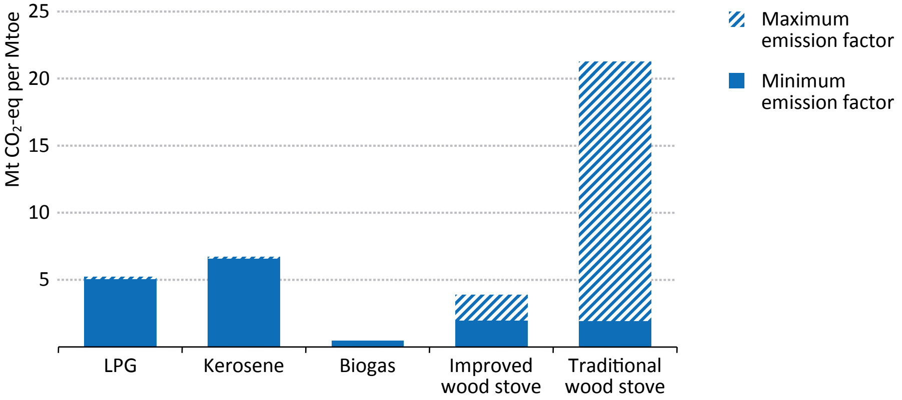
[16] These estimates do not take into account oil lamps used in small businesses.

Figure 3.12 ▷ Ranges of GHG emissions from different combinations of cookstoves and fuels



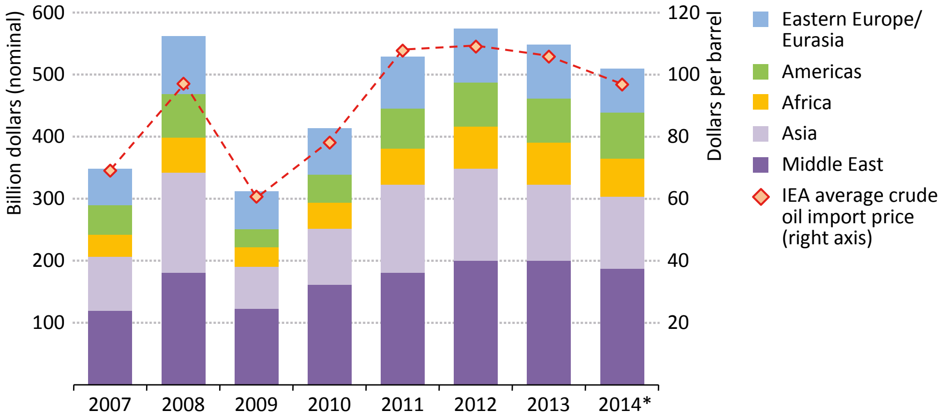
Notes: Mtoe represents the useful energy, i.e. the delivered energy to the cookstove (taking into account the efficiency of the cookstove). GHG emissions take into account CO_2 emissions for LPG and kerosene, and methane and nitrous oxide for all fuels.

Reform of fossil-fuel consumption subsidies

Fossil fuels receive many types of subsidy, provided through both direct and indirect channels. Some are designed to confer benefits to consumers, others to producers. Although some fossil-fuel subsidies have well-intentioned objectives (such as holding down the cost of energy to poor households for social reasons), they have, in practice, usually proved to be unsuccessful or inefficient and often have profound and adverse impacts. One of their most harmful effects is that they damage the competitiveness of low-carbon technologies. This hinders investment in renewables, enhancing reliance on fossil fuels. They can also undermine the financial attractiveness of investment in more energy-efficient equipment, appliances and practices, thereby encouraging excessive energy use. Where energy suppliers suffer financial losses because of under-pricing, subsidies can create a vicious cycle of under-investment, poor maintenance and under-supply.

Despite their economic, social and environmental costs, subsidies to fossil fuels are stubbornly persistent. Based on preliminary data, subsidies that artificially lowered the end-user prices of fossil fuels in 2014 totalled $510 billion (Figure 3.13). Currently, around 13% of global energy-related CO_2 emissions are from fuels that are subsidised to a greater or lesser extent. This equates to an average incentive to emit CO_2 of $115 per tonne. A total of 40 countries have been identified as subsidising fossil-fuel consumption, with oil and gas exporters in the Middle East and North Africa accounting for almost half of the worldwide spending. Globally, the value of fossil-fuel consumption subsidies amounts to around four-times the value of subsidies to renewable energy. In addition, the OECD estimates that other types of subsidies in its member countries fluctuated between $55 billion and $90 billion per year between 2005 and 2011, with preferential tax treatment supporting fossil-fuel production making up around two-thirds of the total.

Figure 3.13 ▷ **Economic value of global fossil-fuel consumption subsidies by region**



*Estimate using preliminary data for 2014.

Momentum for reform of subsidy programmes has been building for several years now, with good prospects that this will continue (Table 3.3). Recognition of the case for reform can, in large part, be attributed to the extended period of persistently high energy prices until mid-2014, which pushed the cost of subsidies to crippling levels in some countries, particularly those with fast-growing energy demand. It can also be attributed to the initiatives of groups such as the G20, Asia-Pacific Economic Cooperation (APEC), the Friends of Fossil Fuel Subsidy Reform (a group of non-G20 countries that support the reform of inefficient fossil-fuel subsidies) and the Global Subsidies Initiative. Some loans by international lending agencies and the International Monetary Fund for energy projects now have conditions attached relating to subsidy reform. Moves have been made in developing countries to reduce consumption subsidies and in developed countries to reduce producer subsidies for investment in fossil-fuel extraction.

Somewhat paradoxically, given what is said above about the motivational force of high oil prices, the plunge in oil prices since mid-2014 could add further momentum to the phase-out of consumer subsidies, by making withdrawal of subsidies less politically controversial. Indeed several countries, including India, Indonesia and Malaysia, have already seized the opportunity. On one hand, by reducing the cost of subsidising energy consumption, lower international prices may be said to reduce the budgetary urgency for governments to take action. But they also present a unique opportunity to abolish subsidies – or increase energy taxes – without having a major upward impact on prices – or inflation – and provoking public outcry. However, the durability of such reforms will be tested if and when international prices again move higher. Observance of a few guidelines can increase the likelihood of long-term success (Box 3.4).

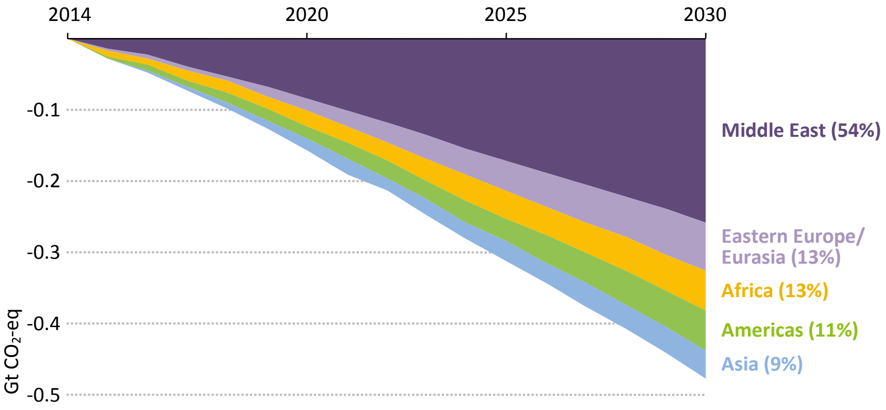
The bulk of subsidies are now concentrated in the major oil and gas exporting counties. The opportunity cost to them of pricing domestic energy below market levels has declined; but export revenues have also shrunk, making budgetary pressures more acute and so increasing pressure to rein in expenditure wherever possible. The task of persuading the public in energy exporting countries that fossil fuels should be sold at their opportunity cost is a tough one – all the more so when the spoils from exploiting resources are not otherwise shared by the population at large. Nonetheless, a number of key fossil-fuel exporters are implementing reforms or are reported to be considering them, including Iran, Kuwait and Venezuela.

Table 3.3 ▷ Selected recent fossil-fuel subsidy reforms

Country	Main fuels subsidised	Recent developments
China	LPG, natural gas, electricity	In February 2015, the National Development and Reform Commission announced plans to group existing and new industrial gas consumers under a single pricing mechanism.
India	Kerosene, LPG, natural gas, electricity	Stopped subsidising diesel in October 2014, following similar reforms to gasoline in 2010. In January 2015, a cash transfer scheme was introduced for residential LPG consumers with the key objective of stopping the diversion of subsidised cylinders to commercial use.
Indonesia	Diesel, electricity	At the end of 2014, subsidies to gasoline (88 RON) abolished and the diesel subsidy capped at IDR 1 000 ($0.08) per litre.
Iran	Gasoline, diesel, kerosene, LPG, natural gas, electricity	The parliament approved a 5% increase in gasoline prices for fiscal year 2015-2016. The revised price of regular gasoline will be IRR 7 350 ($0.27) per litre.
Kuwait	Gasoline, diesel, kerosene, LPG, natural gas, electricity	In January 2015, prices of diesel increased from KWD 0.055 to 0.170 ($0.59) per litre. At the end of January 2015, prices of diesel and kerosene were cut back to KWD 0.110 following political pressure. Plans to remove subsidies on gasoline and electricity have been postponed.
Malaysia	LPG, natural gas, electricity	In December 2014, subsidies for gasoline (RON95) and diesel were abolished, with prices for both now set monthly to track international levels. In January 2014, electricity tariffs were increased by 15% on average to MYR 0.38 ($0.12) per kWh. Fuel cost pass-through, based on international gas price movements, was resumed in the same month. In May 2014, natural gas prices were increased by up to 26% for certain users.
Morocco	LPG	Ended gasoline and fuel oil subsidies at the beginning of 2014 and diesel subsidies in January 2015.
Oman	Gasoline, natural gas	In May 2014, plans were announced to gradually reduce fuel subsidies, especially for gasoline. In January 2015, gas prices for industrial consumers were raised by 100% to OMR 0.041 per cubic metre ($3.01 per million British thermal units). A 3% annual rise is to be introduced for industries.
Thailand	LPG, natural gas, electricity	In October 2014, the price of compressed natural gas for vehicles was increased by THB 1 ($0.03) per kilogramme. In December 2014, subsidies for LPG were ended.

In the Bridge Scenario, fossil-fuel consumption subsidies are completely phased out in net importing countries within the next ten years. In net exporting countries, they are phased out by 2030, with the exception of countries in the Middle East where reforms progress at a slightly slower pace (the average subsidisation rate is reduced to around 20% by 2030, compared with around 75% today). We have adopted this differentiated approach, rather than a uniform approach across all countries, in recognition of the fact that reforms are likely to be more difficult to achieve in countries where cheap energy is often considered a means of sharing the nation's natural resource wealth. The assumed pace of reform may be considered ambitious. However, if fully effected, energy prices in countries that currently subsidise consumption would still remain relatively low as there is no assumption that new excise taxes will be introduced. For example, under these assumptions, average gasoline prices in the Middle East would be almost 65% cheaper than in OECD Europe in 2030.

Figure 3.14 ▷ Global GHG emissions savings from fossil-fuel subsidy reform in the Bridge Scenario relative to the INDC Scenario



Note: Percentage shows the region's share in cumulative global emissions savings from fossil-fuel subsidy reform.

In the Bridge Scenario, subsidy reform reduces GHG emissions by around 160 Mt CO_2-eq in 2020, relative to the INDC Scenario. This represents 13% of the total savings between the two scenarios (Figure 3.14). Savings increase to about 480 Mt CO_2-eq in 2030 (10% of the total), as rising international prices provide consumers with growing incentive to change their behaviour and purchase more energy-efficient equipment and renewables producers with improved competitive prospects. While the contribution of subsidy reform to abatement may seem modest at the global level, in some regions it is a major factor. Savings are greatest in the countries of the Middle East, where subsidy reform accounts for almost 50% of total abatement in 2030, relative to the INDC Scenario. It accounts for 35%

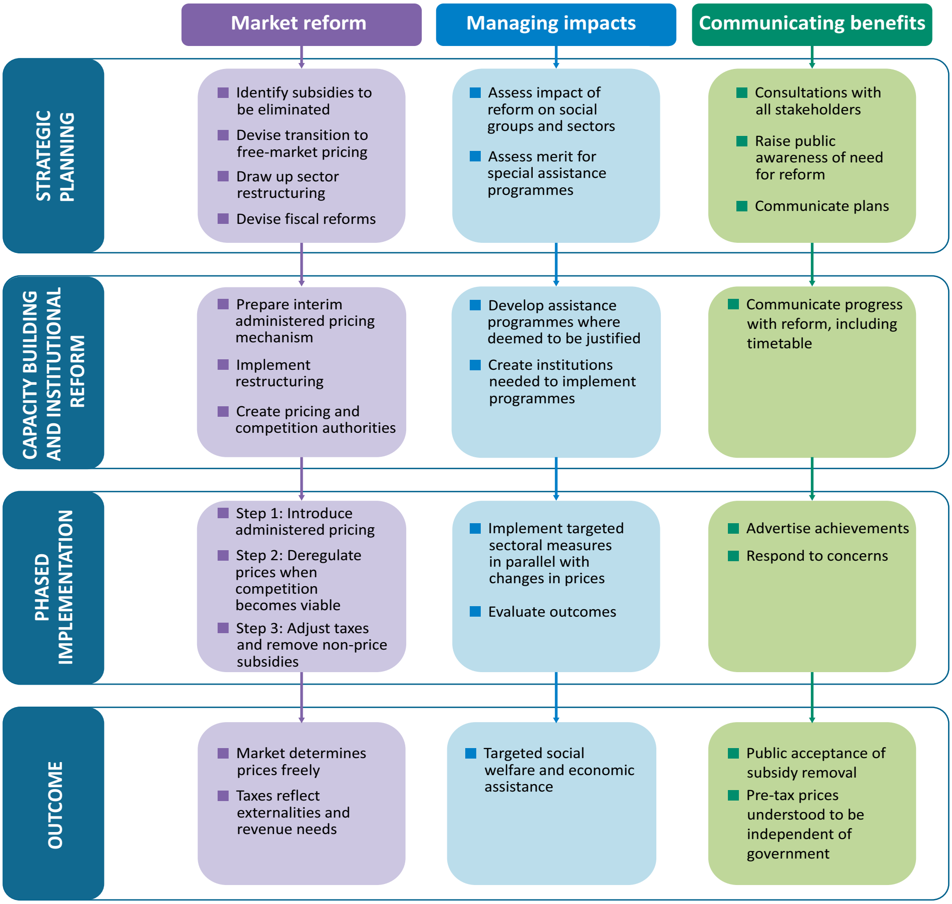
of the total abatement in the Caspian region, around 20% in both Africa and Latin America and 13% in Southeast Asia. There is an important relationship between the fiscal and climate benefits from subsidy reform: reforms could lead to even greater abatement than indicated here if some of the financial savings are directed into programmes to improve energy efficiency, deploy renewables and expand public transport.

Box 3.4 ▻ Common elements to successful subsidy reform

National circumstances and changing market conditions mean that there is no single path to follow when reforming fossil-fuel subsidies. However, past experience has shown that the prospects for success can be enhanced by adherence to some simple guidelines (Figure 3.15):

- **Get the prices right –** One of the basic pillars of successful subsidy reform is to ensure that prices reflect the full economic cost of the energy that is being supplied. Prices before tax should be set with reference to international market prices and be adjusted as necessary to reflect inflation and currency volatility. This process is more complicated with electricity than, say, oil products: it is necessary to ensure that tariffs are sufficient to cover not only the costs of the fuel inputs but also of transmission and distribution, while also giving utilities a return on their capital. Public authorities need to ensure that pricing systems are transparent, well-monitored and enforced. Government controls on pricing may be warranted in certain situations, for example, to ensure that the poorest households have access to clean cooking fuels and electricity, but other forms of social support are often more efficient.
- **Implement reforms in steps –** Subsidy reforms should typically be introduced in small steps; to do otherwise risks abrupt and large price rises that may crystallise strong opposition. As a country makes the transition away from subsidies, it is advisable to introduce a formula-based pricing system that ensures retail prices track international benchmarks. To de-politicise the process, an independent body should be set-up to oversee energy pricing, helping consumers understand and accept the reasons for price changes.
- **Manage the effects –** Subsidy reform can have undesirable consequences for some groups, and social reforms may need to be implemented in parallel to protect vulnerable groups, such as the poorest households. For example, conditional cash transfers to those with the lowest income may be required; but the effectiveness of such measures must be regularly monitored and evaluated.
- **Consult and communicate at all stages –** A comprehensive communication strategy is essential to convince citizens of the need for reform and the justice of its implementation. Such a strategy must speak to all energy users, but especially those most affected by the reforms. Public inquiries, speeches, debates, workshops and printed material can all contribute.

Figure 3.15 ▷ Critical steps of a process to reform fossil-fuel subsidies



Sources: IEA based on Beaton, et al. (2013); IEA, OPEC, OECD and World Bank (2010).

Minimising methane releases from upstream oil and gas operations

Methane is a powerful contributor to global warming, many times more potent than CO_2.[17] It remains in the atmosphere for a shorter period of time, compared with CO_2, but these characteristics, taken together, mean that reducing methane emissions has the potential to yield a relatively rapid climate response. This is no substitute for long-term measures to cut CO_2 emissions, but the potential to slow the near-term rate of warming means that action to minimise methane emissions plays an important role in our Bridge Scenario.

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[17] There are different ways to evaluate the effects of methane on global warming. This section uses a value of 30 for the global warming potential (GWP) of fossil-fuel methane, relative to CO_2, averaged over 100 years (meaning that volumes of methane are multiplied by 30 to give equivalent volumes of CO_2). The GWP in the shorter term is higher: over 20 years, fossil-fuel methane is estimated to be 85 times more effective at trapping heat than CO_2 (IPCC, 2013).

Box 3.5 ▻ Addressing methane emissions from downstream operations

Methane releases to the atmosphere occur both during the production of oil and gas and during their transmission and distribution, in particular in the case of natural gas. We estimate that downstream releases amounted to around 24 Mt in 2013 (710 Mt CO_2-eq), or 42% of methane emissions from the oil and gas sectors. Methane leakages from natural gas pipelines are largest in the United States, Russia, the Middle East and China (which are the countries with the largest pipeline networks), particularly where the pipelines are old or poorly maintained. The main causes of leakage are the high permeability of some pipeline materials (the oldest pipelines are more than 100 years old and made of cast iron), maintenance activities and incidents due to corrosion, damage or equipment failure.

The replacement of ageing infrastructure can make a major difference to the incidence of leaks, but is a challenging and expensive task. Significant improvements can be made by using materials with lower permeability (such as polyethylene) wherever possible and optimising the network to reduce the number of joints (i.e. the area most vulnerable to leakage). Emissions during maintenance are often unavoidable, but can be mitigated through the flaring of the leaked methane. Reducing the incidence of leakage is a continuous challenge, involving regular monitoring and efficient and prompt responses. The benefits have been documented in a study in 2015, sponsored by the US Environmental Defense Fund and various downstream operators, which included bottom-up measurement of thirteen urban US distribution systems (Lamb et al., 2015). The study produced estimates for downstream emissions from 36% to 70% lower than data from the 2011 EPA inventory, with the decrease attributed to better maintenance activities and improved infrastructure components.

Preventing methane leakage is in the first place a matter of safety, as the accumulation of gas leaked from pipelines can lead to explosions and is therefore particularly dangerous in urban distribution networks. Regulation to ensure proper maintenance of pipelines for safety reasons can have important co-benefits for the climate (measuring the gas amounts between inlet and outlet stations can help identify major leaks, if the relevant metering stations are in place). But beyond the assumption of regular maintenance schedules, no major pipeline rehabilitation is included in the Bridge Scenario, since this can easily take between 10 to 15 years to implement, involving major investment and large construction works.

It is estimated that 550 Mt of methane is released into the atmosphere every year, of which 350 Mt come from anthropogenic sources, amounting to 10.5 Gt CO_2-eq. The contribution of the energy sector to these emissions is highly uncertain, as measured data are very limited. We have further deepened our analysis of methane emissions for this special report, and estimate that annual energy-related methane emissions were around 100 Mt (3.0 Gt CO_2-eq) in 2013, of which about 56 Mt came from the oil and gas sectors, 31 Mt from coal mining activities and 15 Mt from other sources (mostly the burning of biomass).[18] These estimates are based primarily on standardised emissions factors for different energy sector activities; the emissions factors are derived from studies made by the EPA[19] and the Intergovernmental Panel on Climate Change IPCC (IPCC, 2006). Using the EPA emissions factors for the United States as a guide, the estimated levels of methane emitted to the atmosphere are equivalent (in energy terms) to up to 2% of total oil and gas production. New studies, mostly US based, are ongoing to obtain better bottom-up and top-down measurements of amounts leaked by source, but much greater efforts are required globally in order to define more accurately the magnitude of the problem and the investment required to address it effectively.

Of the estimated 56 Mt (1.7 Gt CO_2-eq) of methane emissions from the oil and gas sectors today, upstream operations account for around 30% and 27% respectively. These upstream releases represent the "low-hanging fruit" for reducing methane releases (and are therefore the focus for action in the Bridge Scenario), as both the sources of these emissions and the technologies and operational procedures to address them are relatively well-known. Tackling the share of downstream emissions, those estimated to come from transmission and distribution networks, is enticing from a climate mitigation perspective, but the timelines involved and efforts required are daunting (Box 3.5).

In the Bridge Scenario, methane emissions from upstream oil and gas operations are reduced by 5 Mt of CH_4 (0.1 Gt CO_2-eq, or 14%) in 2020, and 24 Mt (0.7 Gt CO_2-eq, or 73%) in 2030, relative to the INDC Scenario. Our previous assessment of the scope for reducing emissions by 2020 has been revised downwards, given the absence of new policy initiatives outside the United States and the current focus on cost-cutting in the oil and gas industry. Unsurprisingly, the largest savings can be achieved in places with large oil and gas production activities such as the Middle East (190 Mt CO_2-eq savings in 2030), Russia (130 Mt CO_2-eq) and Africa (80 Mt CO_2-eq) and Latin America (70 Mt CO_2-eq). In the case of Africa, the opportunities for reducing methane emissions from upstream oil and gas production are largely concentrated in Nigeria, Algeria and Angola, where the lack of infrastructure and incentives to market associated gas continues to be a major cause of gas flaring. Globally, the reduction of methane emissions from upstream oil and gas operations in the Bridge Scenario requires a cumulative investment of $31 billion until 2030. For countries with large mitigation potential and inadequate or weakly enforced regulation in place, this represents a very cost-effective way to raise climate ambition, potentially drawing on the international community to finance the required investment.

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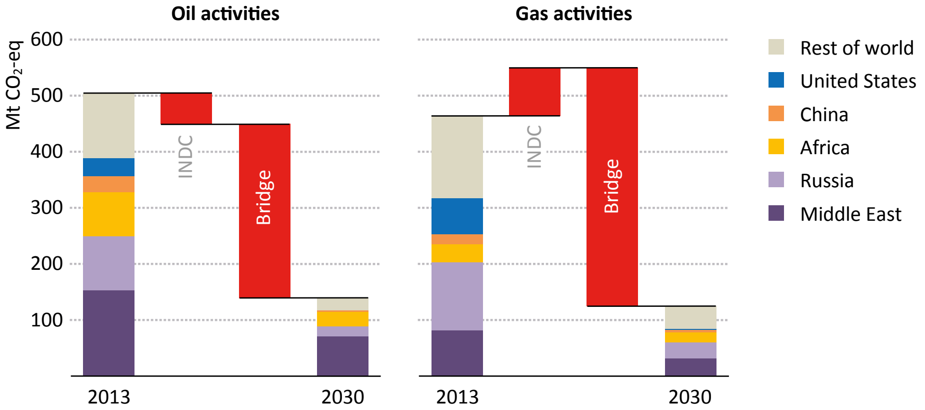
[18] Other sources derive different estimates for global methane emissions. The Emissions Database for Global Atmospheric Research (EDGAR) and the EPA estimate that energy-related methane emissions (including the coal, oil and gas sectors) were 129 Mt in 2010, while the UNFCCC reports these emissions to be 38 Mt for Annex I countries in the same year. Such variations stem both from differences in the emissions factors used for each activity, as well as differences in the data for activity levels.

[19] Our new global estimate takes into account EPA's latest available data for US methane emissions, which have been revised down in the context of a review process and recent measurements (US EPA, 2015).

Figure 3.16 ▷ Methane emissions from upstream oil and gas operations by selected region in the Bridge Scenario



Two factors account for most of the upstream methane savings in the Bridge Scenario. In the first case, the pursuit of energy efficiency measures across all end-use sectors reduces demand for oil and gas and thereby the amount of methane leaked during oil and gas operations (i.e. a reduction in activity levels). The second reason is a series of measures directly designed to reduce the emissions associated with upstream activity, all based on known technologies and operational best practices:

- Enhanced efforts to reduce flaring of natural gas, not only a wasteful and unproductive use of gas, but also a practice that, as with many end-uses, results in methane releases because of incomplete burning (especially in windy conditions).
- Increased inspection and repairs to reduce involuntary or "fugitive" emissions from leaky valves, seals or pipes.
- Application of best practice to reduce the venting that occurs as part of normal operations: there are relatively low-cost measures available to achieve this, such as minimising emissions during work-overs and reducing the frequency of start-ups and blow-downs.
- A focus on reducing emissions during well completion operations: this is a particular concern in the case of unconventional gas, because of the large amount of methane that can be released to the atmosphere during the flowback phase after hydraulic fracturing. Best practice is to use a so-called "green completion" to recover hydrocarbons, including methane, from the flowback fluid (instead of allowing them to be vented or flared. The methane can then be marketed, offsetting the additional cost).
- More complex reductions, involving modifications such as the installation of pressurised storage tanks with vapour recovery units: these take time and larger investment, and so have a strong impact on emissions reduction only towards 2030.

In all cases, collaborative efforts between industry, policymakers and research institutes – including concentrated efforts to gain better data through measurement and monitoring – are essential to deliver tangible and cost-effective results. Good examples of industry and government collaboration and exchange of best practice and technical solutions exist in the US EPA Natural Gas Star Program and the United Nations Environment Program/Climate and Clean Air Coalition Oil and Gas Methane Partnership. Yet more could be achieved if systematic, statistically significant measurements relative to the size and type of gas and oil infrastructure were collected and analysed.

From a policy perspective, measurements that are statistically representative for a given sector and country are an essential step towards sound policy formulation. The United States National Oceanic and Atmospheric Administration's (NOAA) airborne measurement initiative is an important example of an effort to identify emission differences at geological basin level. Further bottom-up data are required to identify major emission sources and opportunities for mitigation (some of which can turn into profitable investments, as product loss is minimised, in particular in the upstream sector). Baseline analysis can prepare the way for an implementation plan that is well-targeted and that takes into account factors such as the availability of infrastructure and proximity of gas markets, as well as covering issues of compliance and enforcement. Policymakers and industry will need to agree on a timeline of implementation, given that the solutions will range from easy and cheap to difficult and expensive.

Wider implications of the Bridge Scenario

Economic benefits

In the Bridge Scenario, global GDP grows on average by 3.8% per year from 2013 to 2030, with growth at 2.1% per year in OECD countries and 4.9% per year outside the OECD. This growth rate is the same as that in the INDC Scenario, which means that the policy package adopted in the Bridge Scenario does not affect global or regional prospects for economic growth and development.[20] This should not imply that the adoption of every single policy is neutral with regards to economic growth; rather, the combination of measures as a whole is tailored to regional characteristics with a view to ensuring the same level of development of the countries or regions which are separately analysed (Figure 3.17).

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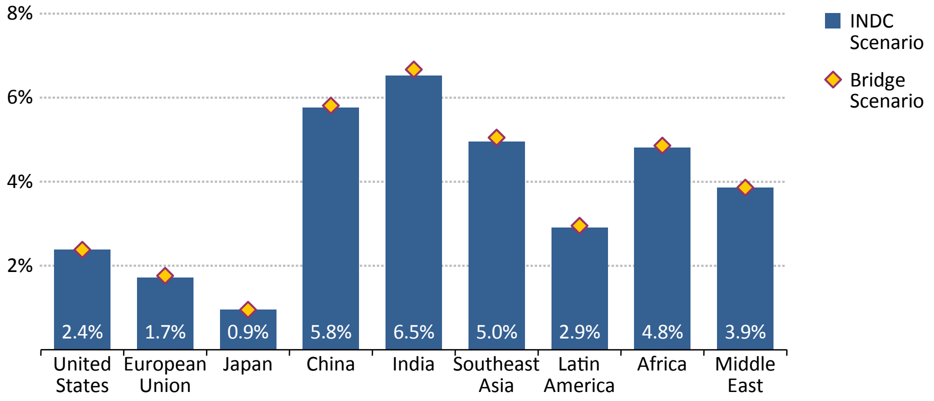
[20] The IEA's World Energy Model (WEM) was coupled with the OECD's ENV-Linkages model to determine the level of policy ambition that complies with GDP-neutrality relative to the INDC Scenario in any region or country considered individually in WEM. The analysis of GDP-neutrality does not extend to certain co-benefits such as those arising from reducing local air pollution or avoiding climate change, which have the potential to further boost economic growth.

Figure 3.17 ▷ **Average annual GDP growth by scenario by selected region, 2013-2030**

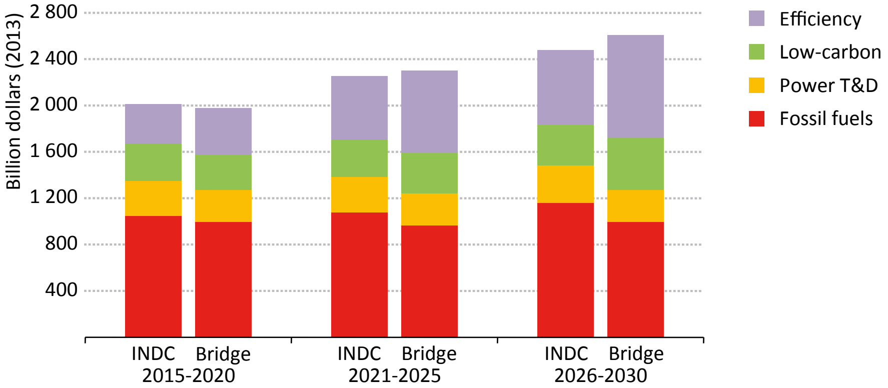


Source: OECD ENV-Linkages model. Growth rates are calculated on a PPP-basis.

Within the total package of policy measures adopted in the Bridge Scenario, there are some which will have a positive effect on economic growth, while others will reduce the value added from individual sectors, due to the additional costs that sector will bear. The latter is particularly true for energy sectors that are concerned with supply and transformation. The power sector incurs additional costs to compensate for the reduced availability of inefficient coal-fired power plants and to increase investments in renewable forms of energy. Total investment in transmission and distribution (T&D) grids is reduced, as electricity demand (and therefore generation) is lower than in the INDC Scenario, although this effect is partially offset by increased investment to integrate variable renewables. In the Bridge Scenario, cumulative power sector investments to 2030 are $360 billion lower than in the INDC Scenario. In oil and gas production, reduction of upstream methane emissions involves additional cost, estimated at $31 billion to 2030, but overall investment in fossil-fuel extraction and distribution is reduced by $1.2 trillion, compared with the INDC Scenario, due to lower fossil-fuel demand (Figure 3.18).

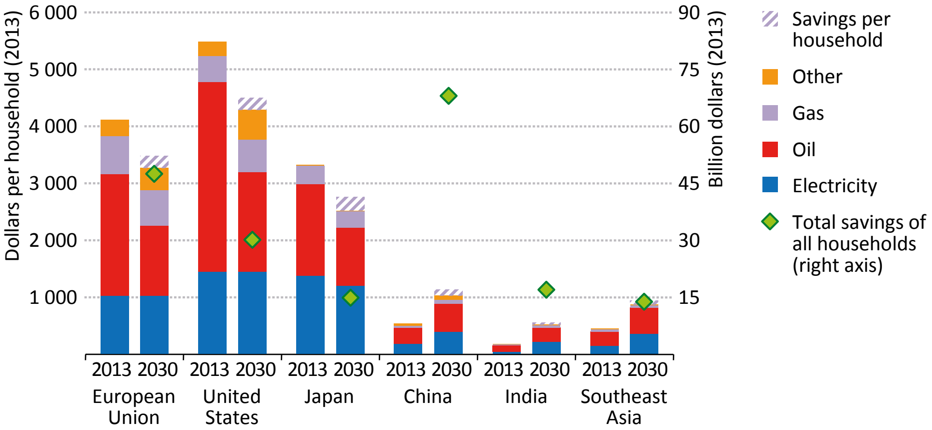
The investment required to exploit the economic potential for energy efficiency in the industry, buildings and transport sectors is higher in the Bridge Scenario relative to the INDC Scenario. The increase of energy efficiency investment limits the ability of households (which are responsible for a large part of the investment made) and firms to invest in other activities. But the reduction of fuel bills outweighs the additional investment needs in both sectors, freeing up additional resources to such an extent that, overall, action on energy efficiency boosts economic growth. Increasing the energy efficiency of appliances and lighting, for example, helps to reduce household electricity bills in 2030 in the Bridge Scenario by 6% on a global average.

Figure 3.18 ▻ Global average annual investment in the energy sector by type and scenario



Household consumption, in general, is a particularly important driver of economic growth. The share of disposable income that is allocated to energy expenditures varies by country, depending, for example, on the level of taxation and extent of domestic energy resources. Oil consumption (e.g. for mobility purposes) usually accounts for a large share of household energy expenditure. While the recent sharp drop in international oil prices may temporarily relieve household budgets, our view on the longer term outlook for oil price developments remains generally unchanged and suggests a significant increase over today's level. Increasing energy efficiency can help insulate households against such price increases – in the Bridge Scenario, households in developed countries see a reduction of their average annual energy expenditures in 2030, relative to today (Figure 3.19). In developing countries, energy expenditures are rising due to increasing energy demand; but, in the Bridge Scenario, the rise until 2030 is generally lower than in the INDC Scenario, due to improved energy efficiency.

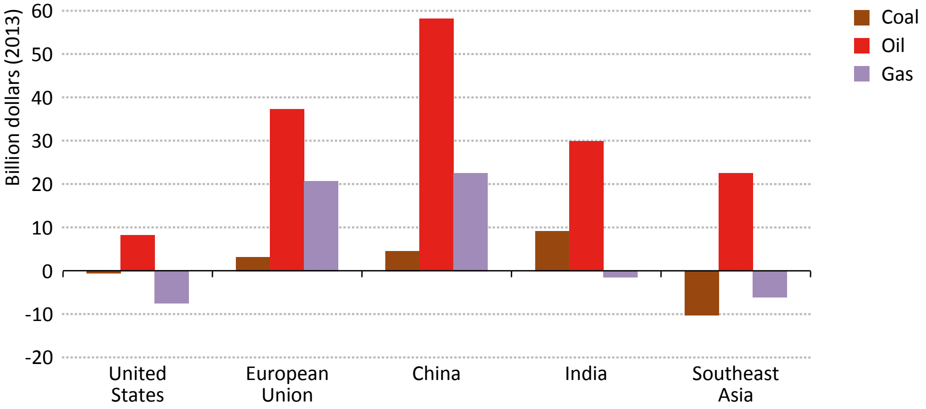
Figure 3.19 ▻ Household energy expenditures by fuel and region in the Bridge Scenario and savings relative to the INDC Scenario



Energy security

The dependence of countries on fossil-fuel imports is one indicator of energy security. In 2013, the European Union spent around $555 billion on the import of fossil fuels, followed by China ($304 billion), the United States ($278 billion), Japan ($259 billion) and India ($135 billion). In the INDC Scenario, existing and proposed policies successfully reduce, or at least stabilise, at current levels the import bills in most industrialised countries by 2030. But in all developing countries the strong rise in energy demand means that those relying on the import of fossil fuels become increasingly exposed to global price developments (the fossil-fuel import bills of China and India more than double in the INDC Scenario). In the Bridge Scenario, the total spending on fossil-fuel imports in importing regions by 2030 is generally lower than in the INDC Scenario (Figure 3.20). In exporting regions, the lower demand for fossil fuels in the Bridge Scenario generally results in a reduction in export markets and a loss in revenues compared with what they would achieve under existing and planned policies in the INDC Scenario. The impacts vary by country and region. In Southeast Asia, for example, the loss in earnings from a shrinking export market for coal is fully offset by savings in the oil import bill. For other regions, such as the Middle East, oil export revenues in the Bridge Scenario keep rising, by almost $160 billion in 2030, relative to 2013, and a 1.3 mb/d decline in oil demand in 2030, relative to the INDC Scenario, frees up additional resources for export.

Figure 3.20 ▹ Change in fossil-fuel trade bills by selected region in the Bridge Scenario relative to the INDC Scenario, 2030



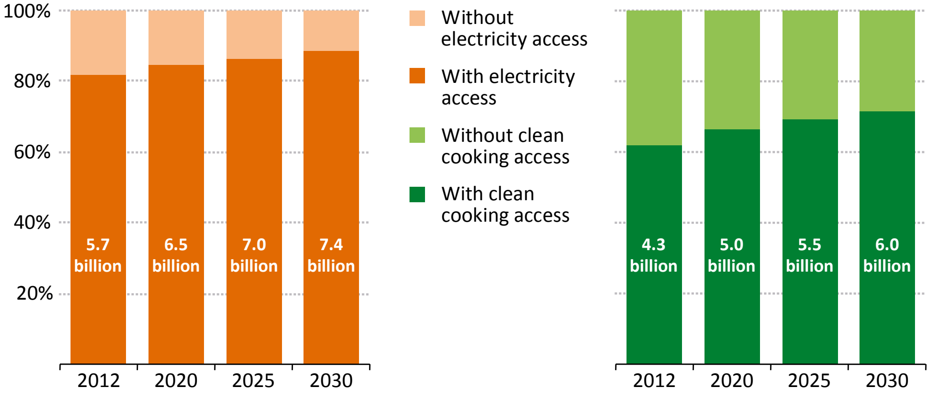
Note: Positive values are net savings in fossil-fuel trade bills, relative to the INDC Scenario.

Energy access

Secure access to modern energy has underpinned the development and prosperity gains of every advanced economy to date. Expanding access to modern energy services, including electricity and modern cooking facilities, is an important objective for many developing countries. Aligning these priorities with decarbonisation goals is a crucial challenge.

In 2012, nearly 1.3 billion people had no access to electricity and 2.7 billion people relied on the traditional use of biomass for cooking. The majority of people without access to modern energy live in sub-Saharan Africa and developing Asia. In the Bridge Scenario, the number of people with access to electricity rises by 1.7 billion people until 2030, while access to clean cooking devices rises by 1.6 billion (Figure 3.21). These are important improvements, but they still leave almost 1 billion people without access to electricity in 2030 and 2.4 billion people without access to clean cooking, given the pace of growth of the world's population. The level of energy access reached in the Bridge Scenario is similar to that in the INDC Scenario.

Figure 3.21 ▷ Global population with and without access to electricity and clean cooking in the Bridge Scenario



In order to achieve a similar level of energy access as in the INDC Scenario, care in policy design is required to protect the poorest against possible adverse impacts from the proposed policies in the Bridge Scenario. For example, careful implementation of fossil-fuel subsidy reforms needs to protect the poorest by redirecting at least a proportion of savings to social programmes (Box 3.4). Under most existing forms of policy intervention, the benefits tend to accrue disproportionately to wealthier segments of society. One example of successful reform is the Kerosene to LPG Conversion Programme in Indonesia, designed to facilitate a switch to the use of LPG for cooking purposes, thereby improving access to modern energy and reducing the financial burden for the state associated with the subsidies to kerosene. A similar programme has reduced kerosene use in New Delhi and is currently being rolled out in several other Indian cities.

Energy efficiency policy also requires specific provision for the poorest. At a macro level, increasing energy efficiency reduces the need to build supply-side capacity in order to provide electricity access, usually allowing more people to be connected at the same level of investment. It can also reduce the adverse health effects of using kerosene lamps for lighting, or diesel generators for electricity during times of outage. At a micro level, improving energy efficiency may increase purchasing costs when the least-efficient appliances and light bulbs are banned. Where this is the case, careful design is required to ensure that additional market barriers do not preclude the poorest segments of society from being able to afford basic appliances. Measures to improve energy access may also, of course, increase overall efficiency, such as where inefficient cookstoves are replaced by more efficient ones.

Increasing investment for renewable energies generally has positive effects on increased electricity access, for as long as the investment is additional. Off-grid renewables solutions, such as solar home systems or small hydroelectric plants, can boost electricity access in regions with important renewables potential, such as sub-Saharan Africa or India. In cases where a large-scale push is being made to increase on-grid renewables, the integration costs of renewables could increase electricity tariffs and put affordability at risk. Lower tariffs for a basic level of consumption in the residential sector may be a satisfactory means to mitigate the problem (while simultaneously incentivising energy efficiency), but the system will need to be carefully monitored for unintended effects.

Achieving the transition

Long-term energy sector transformation

Highlights

- The long-term transition to an energy system consistent with the 2 °C climate goal, reflected in the 450 Scenario, entails fostering the development of new technologies alongside the measures in the Bridge Scenario in the short term. These developments make way for the widespread deployment of emerging technologies to 2040 and beyond, keeping emissions in line with international climate goals.
- Deploying low-carbon technologies that are mature and commercially available in most regions achieves close to 60% of the additional emissions reductions in the 450 Scenario relative to the Bridge Scenario. The remaining portion comes from the deployment of emerging technologies. Government action to bring forward the additional low-carbon technologies in the 450 Scenario rely on intensifying RD&D, supporting market development and providing enabling infrastructure.
- Variable renewables account for significant investment today and are one of the most strongly deployed low-carbon options in the 450 Scenario, saving 37 Gt CO_2 over the period to 2040. Integrating increasing levels of variable renewables eventually requires more flexibility in the power system to maintain reliability, including conventional power plants, energy storage and demand response. Speeding up progress for some technologies, such as batteries, could ease the transition.
- CCS technologies are vital to decarbonising the power supply and industry in the 450 Scenario, capturing 52 Gt CO_2 from 2015 to 2040, of which 5.1 Gt CO_2 is in 2040. The fuel consumption by CCS-equipped facilities creates revenues of $1.3 trillion for both coal and gas producers respectively from 2015 to 2040. Deploying CCS at scale drives down costs and improves its competitiveness as a CO_2 abatement option in the power sector. Knowledge of CO_2 storage opportunities is expanding, but national level attention is needed to support the widespread adoption of CCS.
- Today, transport-related emissions account for over 20% of global energy-related CO_2 emissions and are set to increase without the strong uptake of alternative fuel vehicles. In the 450 Scenario, the deployment of electric vehicles and use of advanced biofuels reduce oil consumption by 13.8 mboe/d in 2040 and reduce CO_2 emissions by 11.5 Gt from 2015 to 2040. The falling emissions intensity of grid electricity over time, which fuels electric vehicles, helps to lower transport-related emissions.
- The transition to a low-carbon economy depends upon overcoming current challenges and giving the right signals to innovators and financiers within an appropriate market structure. Government intervention is needed to create sustainable markets for low-carbon technologies, fill in RD&D funding gaps, create the enabling infrastructure and encourage international collaboration.

Introduction

The Bridge Scenario, presented in Chapter 2, shows how the level of ambition to reduce energy-related greenhouse-gas (GHG) emissions can be raised appreciably at no cost to global economic activity. Its outcome holds no suggestion that it represents some sort of limit to what is politically feasible, nor is it offered in any sense, as an alternative to the existing internationally adopted goal. On the contrary, the level of limitation of global energy-related CO_2 emissions is still far short of that goal. But it advances the level of achievement likely to be reflected in the Intended Nationally Determined Contributions (INDCs) to be submitted before the COP21 meeting in December 2015 in Paris, notably, bringing global energy-related emissions to a peak by around 2020. The 450 Scenario (the main features of which are discussed in Chapter 1), which is presented here, carries this process further by offering an energy pathway to 2040 compatible with a 50% probability to limit the average temperature rise to no more than 2 degrees Celsius (°C) (which entails limiting the concentration of greenhouse gases in the atmosphere to no more than 450 parts per million).

Achieving an energy system which is compatible with climate goals remains a daunting task. All the required tools are not yet to hand. But this chapter sets out a feasible path consistent with the 2 °C goal, building on the achievements of the Bridge Scenario and showing what steps are required. The world must manage the legacy of its existing energy system, while harnessing established low-carbon energy sources and accelerating the development and deployment of new technologies that have yet to be adopted at scale.

The analysis in this chapter is one of a number of possible pathways to 2 °C. One defining element of the 450 Scenario is the increasing presence and weight of carbon pricing around the world, supporting the expansion of all low-carbon technologies. It draws on the potential contributions of emerging technologies across the energy system, but does not rest on technological breakthroughs which are as yet only aspirations, nor is it offered as a definitive, optimal pathway. Instead, the 450 Scenario depicts a pathway to the 2 °C climate goal that can be achieved by fostering technologies that are close to becoming available at commercial scale. Consistent with established and recent policy trends, it also incorporates a host of regionally specific factors, including the extent of policy support for technologies, public acceptance of different technologies, technology supply chains, areas of research, development and demonstration (RD&D), consumer behaviour, energy market frameworks and resource endowments. The world invests around $1.7 trillion per year on average from 2015 to 2040 into its energy-supply infrastructure in the 450 Scenario. However, this is within 1% of the average energy-supply investment over the same period in the Bridge Scenario, as energy demand is moderated through energy efficiency efforts and emerging technologies reach maturity.

This chapter focuses on three essential requirements of a decarbonised world: widespread deployment of low-carbon technologies in the power sector, technological advances to sharply reduce the GHG emissions intensity of industrial energy use and achieving low-carbon road transport. The analysis highlights the urgent need to develop the technologies that help achieve a long-term decarbonisation path. In the absence of the full uptake of these technologies, other pathways would require more difficult changes in how energy is supplied and used, could reduce the quality of energy services and would incur higher costs. A more comprehensive discussion of emerging technologies and the innovation process are available in IEA's *Energy Technology Perspectives 2015* (IEA, 2015a).

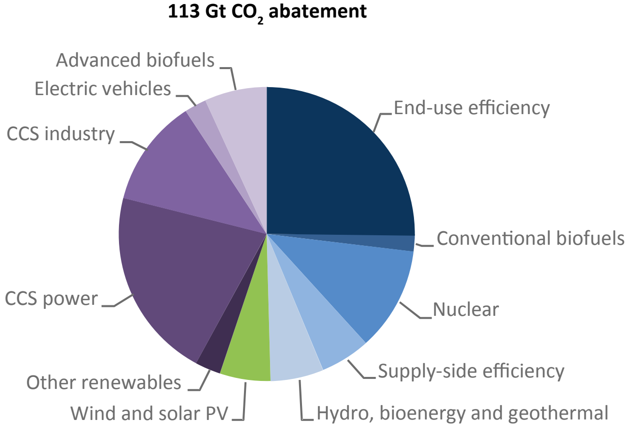
Technologies for transformation

The remaining global carbon budget is shrinking and the link between energy use and GHG emissions must be broken for the world to meet agreed upon long-term climate goals. While low-carbon technologies are being deployed in greater number already, the pace of transformation needs to be accelerated and must overcome formidable new challenges as they present themselves. This puts an important emphasis on bringing to maturity the most promising technologies in terms of emissions reductions in the future. Transformational change in the energy sector can be a very long process, reflecting the need to reconfigure both the supply infrastructure and end-use energy equipment, while conforming to consumer preferences. For example, it took 60 years to move from the first commercial production of oil to its capturing 10% of the primary energy mix and 50 years before the volume of liquefied natural gas (LNG) reached 30% of global gas trade. For emerging technologies, policies to create initial markets must run alongside research and development programmes, far ahead of the widespread deployment of the technologies, and draw on competitive market forces where possible, paving the way for exponential growth.

In the 450 Scenario, many separate efforts help to reduce energy-related CO_2 emissions by 113 gigatonnes (Gt) more than in the Bridge Scenario over the period 2015 to 2040 (Figure 4.1). Half of the additional emissions reductions come from decarbonisation efforts in power supply, followed by efforts in the industry sector (26% of total reductions), transport (16%) and buildings (6%). Stronger deployment of technologies that are familiar and available at commercial scale today delivers close to 60% of the emissions reductions of the 450 Scenario relative to the Bridge Scenario. Low-carbon power generation technologies that have long been employed, such as hydropower (the largest source of low-carbon generation today), nuclear power (the second-largest source), bioenergy and geothermal continue to play an important role to decarbonise the power sector. In the 450 Scenario, an additional 245 gigawatts (GW) of nuclear capacity is built compared with the Bridge Scenario (in countries where it is politically acceptable), leading nuclear power to make up 6% more of total power generation in 2040 and to account for 12.9 Gt CO_2 abatement from 2015 to 2040 (11% of the total additional reductions). Hydropower, bioenergy and geothermal, already strongly deployed in the Bridge Scenario, deliver an additional 6.6 Gt CO_2 abatement (6% of the total).

In transport, gains in fuel economy for internal combustion engines and the expansion of biofuels in regions where they have constituted a significant proportion of the fuel supply for years (Brazil, United States and European Union) and in newer markets (China, India and Southeast Asia), deliver an additional 15 Gt CO_2 abatement over the period to 2040. Energy efficiency is a central pillar of the Bridge Scenario, yet substantial potential is untapped. In the 450 Scenario, the majority of additional emissions reductions related to end-use efficiency stem from a broader set of efficiency measures in industry, expanding from a focus on electric motor systems to steam systems and the provision of process heat. Taken together, the 450 Scenario includes energy efficiency measures in industry, buildings, agriculture and other energy sectors that contribute 22 Gt of additional CO_2 abatement relative to the Bridge Scenario, one-fifth of the total additional emissions reductions.

Figure 4.1 ▷ Global cumulative CO_2 emissions reductions in the 450 Scenario relative to the Bridge Scenario by measure, 2015-2040



Notes: End-use efficiency includes the effect of reduced activity levels, process changes and fuel switching. Supply-side efficiency includes fuel switching by sector, such as coal-to-gas switching in power generation. Electric vehicles here take into account pure-electric and plug-in passenger and commercial light-duty vehicles.

Fostering the development and deployment of emerging technologies expands the number of low-carbon technologies available at scale on a commercial basis, providing more flexibility for national mitigation strategies and lowering the overall cost. In the 450 Scenario, about 40% of the cumulative emissions reductions over the Bridge Scenario are attributable to the widespread adoption of emerging technologies. Variable renewables, mainly wind power and solar photovoltaics (PV), account for about 6.3 Gt of additional CO_2 abatement beyond their central role in reducing emissions in the Bridge Scenario. While wind power and solar PV technologies are available today at commercial scale, they are grouped here with emerging technologies because further improvements are expected to drive down costs substantially and unlock more widespread deployment. Carbon capture and storage (CCS) becomes viable in the 450 Scenario and is widely deployed in the power and industry sectors, accounting for one-third of the additional CO_2 reductions needed to put the world on track to 2 °C. Alternative fuel vehicles contribute a smaller share of the total reductions, but are rapidly gaining market share by 2040 and point the way to deeper emissions reductions thereafter. Each of these three sets of technologies requires a carefully targeted approach to overcome the associated challenges if it is to contribute on the necessary scale to the realisation of the 450 Scenario pathway and even deeper decarbonisation of the energy system beyond 2040:

- **Variable renewables** – to accommodate high shares of variable renewables, the power system will have to be equipped with the flexibility needed to maintain the reliability of the electricity supply. In the 450 Scenario, variable renewables increase from 3% of global electricity generation today to more than 20% by 2040.
- **Carbon capture and storage** – wide deployment of CCS technologies in industry and in the power sector depends on substantial unit cost reductions and the identification of storage opportunities. In the 450 Scenario, rapid CCS expansion occurs after 2025, matching the pace of expansion of gas-fired capacity between 1990 and 2010.
- **Alternative fuel vehicles** – technical and consumer challenges have to be overcome in order to accelerate the transition to low-carbon forms of road transport, notably electric cars. In the 450 Scenario, sales of electric vehicles (EVs) take-off, exceeding 40% of total passenger car sales worldwide in 2040.

Though local circumstances vary, the remainder of this chapter gives general guidance on the requirements for success in these three areas.

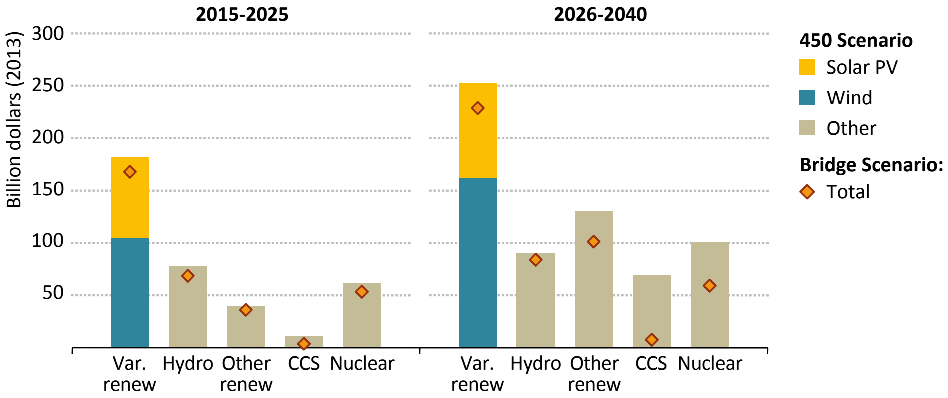
Variable renewables

Opportunity

Driven by widespread policy support and declining costs, annual global investment in renewables based power generation technologies already exceeds that in other types of power plants and these technologies will feature increasingly as an essential element in decarbonising the power sector. Annual investment in renewables reaches $400 billion in 2025 in the 450 Scenario, a level attained five years earlier than in the Bridge Scenario. Investment continues to increase after 2025, with average investment in renewables over 2026-2040 running at $470 billion per year. Total installed renewables-based capacity more than triples from today's level to reach 6 200 GW in 2040, almost 60% of total installed capacity at that time.

Installed capacity of variable renewables grows from about 450 GW today to 3 300 GW in 2040, representing more than 30% of total global installed capacity. Investment in variable renewables accounts for more than half of total annual renewables investment throughout the period 2015 to 2040 and far outpaces investment in other low-carbon technologies (Figure 4.2). The increased investment creates a positive cycle, driving down the capital costs of new projects, making them increasingly financially attractive and so expanding market opportunities, in turn leading back to higher investment and greater deployment. Together, variable renewables become a significant share of the power generation mix in many regions by 2040; they account for over 30% of total generation in Europe, more than 20% in the United States, Japan and India, and close to 15% in Latin America and Africa. The expansion of variable renewables saves about 37 Gt CO_2 from 2015 to 2040, compared with emissions if the rest of the power mix in each region were expanded proportionally to replace variable renewables. While investment in low-carbon power technologies is substantially higher in the 450 Scenario compared with the Bridge Scenario, it does not raise total investment to the same extent: cumulative investment in the power sector from 2015 to 2040, including power plants and supporting infrastructure (i.e. transmission and distribution), is only 13% higher overall, in part due to lower electricity demand achieved through end-user energy efficiency efforts.

Figure 4.2 ▷ Global average annual investment by low-carbon power generation technologies in the 450 and Bridge Scenarios



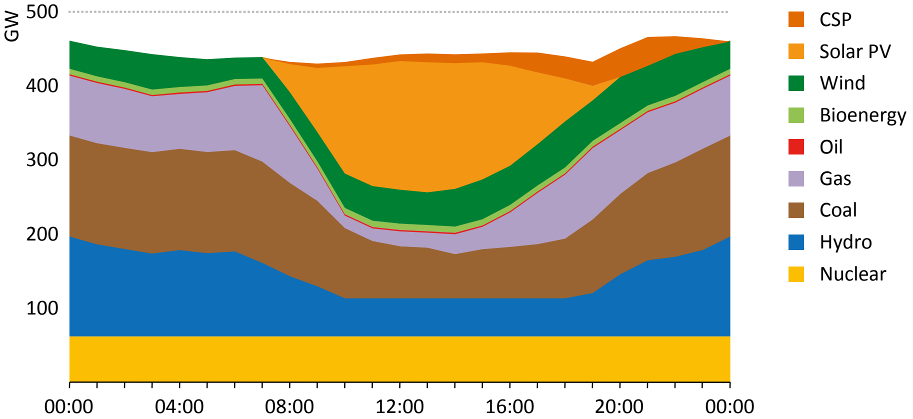
Note: Var. renew = variable renewables; other renew = other renewables.

Challenges

The reliability of power supply depends on the ability to match supply and demand in real time, a task which will become more difficult at high penetration levels of variable renewables. While variable renewables have been capturing large portions of recent investment in new power capacity, there is little experience as yet of integrating these technologies into power systems at medium penetration levels, let alone the higher levels reached by 2040 in the 450 Scenario. Even in the Bridge Scenario, where one of the five measures is enhanced investment in renewables, experience in handling high shares of variables renewables is limited to a few regions, mainly the European Union and India. While in the 450 Scenario, the deployment of variable renewables is widespread across all regions and is pushed to higher levels of penetration, meaning integration challenges will be faced in many more regions to some degree.

Integration challenges are related to the fact that output from a variable renewable energy technology at any point in time depends on the momentary availability of renewable energy sources (not including those which incorporate energy storage, such as concentrating solar power [CSP] with thermal storage). The degree of challenge depends on the additional variability introduced into the system as a result of the output from variable renewables and the flexibility of the rest of the power system (IEA, 2014a). In other words, the challenges are related to the extent that the variability of residual electricity demand (total electricity demand minus the output from variable renewables) exceeds that of total electricity demand and the ability of the rest of the system to handle the increased variability. Solar PV and wind power are the most variable and least predictable renewable energy sources on short timescales. Improvements in forecasting the output of wind and solar PV, along with technological advances, such as innovative wind turbine designs, are among the possible solutions. However, there will still be a need for the rest of the power system to be able to provide larger and more rapid increases and decreases in output in order to accommodate increasing amounts of variable renewables-based generation.

Figure 4.3 ▹ **Illustrative electricity load curve in India in the 450 Scenario, 2040**



Notes: The illustrative load curve is based on measured hourly load data in India in June 2012. Increasing demand for cooling or other evolving electricity demands could alter the pattern of electricity demand.

Consider an illustrative example of the hourly power supply on a sunny day in India in June (pre-monsoon season) 2040, based on the 450 Scenario, where nearly 190 GW of solar PV capacity represents close to 40% of peak demand (Figure 4.3).[1] The example balances supply and demand over the whole of India, assuming the complete integration of the regional power grids. The rapid expansion of solar PV output around mid-day has a large effect on the rest of the power system. In total, output from the rest of the power system must be reduced by about 40% in three hours; and, shortly thereafter, waning solar PV output means that the rest of the system needs to ramp up strongly (increasing output by some 100 GW in three hours). In the system illustrated, output from coal- and gas-fired power plants, hydropower and CSP can be adjusted to the extent and at the speed necessary to accommodate the variable solar PV output. However, the adjustments required of these power plants are much larger in order to accommodate the variable output of solar PV than they would be to match changes in electricity demand. On the one hand, transmission

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[1] *World Energy Outlook 2015*, to be released 10 November 2015, will contain a special focus on the energy outlook in India.

constraints that might be present in 2040 could make the situation more difficult, limiting the full use of the flexibility of the power plant fleet. On the other hand, other measures, such as energy storage, could alleviate some of the strain by shifting some demand to the hours when solar PV output is highest.

The integration of high levels of variable renewables into power systems may also require market framework reforms to guarantee a sufficient level of investment in the conventional power plants needed to keep the system in balance, together with other measures to shift demand when the sun is not shining or the wind is not blowing. Failing to address these needs in advance will negatively impact the reliability of the power system. For example, failing to expand grid interconnections can leave small regions with an imbalance of supply and demand which could have been accommodated over a larger region with sufficient interconnections. Difficulties of this sort, if not overcome, could stifle the support of further renewables deployment and put greater pressure on other low-carbon options, such as nuclear power and CCS.

Solutions

A range of solutions, both on the supply and demand sides, can help overcome the integration challenges facing variable renewables, each with different strengths and weaknesses (Table 4.1). Initially, there is unlikely to be a problem, but as variable renewables gain market share and increase the variability that the rest of the power system has to manage, some measures will be needed, such as ensuring that the grid infrastructure is sufficiently developed in order to balance the output from variable renewables over a large region. Expanding grid infrastructure also helps to take advantage of the flexibility of the rest of the power plant fleet. Eventually, at high levels of variable renewables, demand-side measures must also be part of the solution. Indeed, some demand-side measures are available at low cost and should be considered well before they are necessary to maintain reliability. While many measures exist today, not all have yet achieved the performance or cost level needed to make them attractive. Further technology development, through RD&D activities, is an essential element in facilitating the degree of decarbonisation of the power sector that is required to stay on the path to 2 °C beyond 2040.

On the supply side, fossil-fuelled generators and dispatchable renewables (such as reservoir hydropower, bioenergy-based power plants and CSP plants with thermal storage) can contribute to the flexibility of the power system. Nuclear power plants can also adjust their output in line with demand changes (as in France, though they are generally operated at a constant level of output). Another way to balance electricity supply and demand is by curtailing renewables output when it is disruptive to the system (typically when supply is high but demand is relatively low), but this reduces the amount of electricity generated and net project revenues (a disincentive to investment). Hydropower is one of the most flexible conventional technologies as it is able to rapidly ramp up to full capacity or down to zero output over the span of minutes. This characteristic means that countries with large amounts of hydropower, such as Brazil and Canada, potentially are well-positioned to integrate high levels of variable renewables without significant operational challenges.

Expanding grid interconnections and smart grid development are important supply-side measures that help to optimise grid operations by improving the use of the available supply and demand options. However, in and of themselves, grid infrastructure can integrate only low to moderate levels of variable renewables before other measures are required.

Table 4.1 ▻ Power system flexibility options and characteristics

Measure	Adjusts power supply	Adjusts power demand	Speed of power adjustment	Ability to integrate renewables*	Ability to improve power quality**	Affordability
Interconnections	✓		🟢	🟡	🟡	🟢
Conventional capacity						
• Hydropower	✓		🟢	🟡	🟢	🟢
• Coal-fired	✓		🟡	🔴	🟡	🟡
• Gas CCGT	✓		🟡	🟡	🟡	🟡
• Gas and oil GT	✓		🟢	🟡	🟢	🟡
Curtail renewables	✓		🟢	🟢	🟡	🟡
Smart grids	✓	✓	🟢	🟡	🟢	🟡
Energy storage						
• Pumped hydro	✓	✓	🟢	🟢	🟢	🟢
• Batteries	✓	✓	🟢	🟢	🟢	🔴
Demand response		✓	🟢	🟢	🟡	🟢

*Indicates the ability of a system with a high penetration of the measure to integrate high shares of variable renewables, for example, without additional measures conventional capacity (even hydropower) cannot accommodate very high levels of variable renewables. **Indicates the ability of a measure to provide ancillary services, such as frequency regulation.

Notes: 🟢 = high, 🟡 = moderate, 🔴 = low to none. CCGT = combined-cycle gas turbine; GT = gas turbine.

Energy storage technologies are able to adjust both the supply of electricity to the grid and demand for electricity from the grid, making it both a supply- and demand-side measure to some degree. Moreover, energy storage technologies may be deployed in large-scale projects by electricity suppliers or small-scale projects by households and other end-users. Energy storage technologies have impressive performance capabilities to address many needs related to the integration of variable renewables, but many are relatively expensive. Pumped hydropower is the exception, as its relatively low cost explains why it makes up almost all energy storage capacity connected to the grid today. Other grid-connected energy storage options collectively account for a very small share of total energy storage capacity and employ a wide array of technologies that could play an increasingly important role in power systems at higher penetration levels of variable renewables and as their costs improve (Box 4.1). For example, at low to medium levels of variable renewables, the main need is to counterbalance rising and falling output on a timescale of minutes. Despite recent declines in battery costs (see Alternative Fuel Vehicles below), gas-fired gas turbines (GTs) can, at present, meet this need for a fraction of the cost of batteries.

Box 4.1 ▻ Prospects for energy storage

Today, energy storage technologies account for about 145 GW of installed capacity worldwide (2% of global installed power generation capacity). Pumped storage hydropower accounts for nearly all of this capacity, supplemented by a mix of battery systems, compressed air energy storage, flywheels and hydrogen storage. Strong decarbonisation efforts in the power sector could push global storage installations to well over 400 GW by 2050 (IEA, 2014b). The value of storing electricity varies according to the circumstances. Beyond storing electricity when it is abundant and supplying it when it is scarce, electricity storage can offer a variety of services, including improving grid power quality, improving the quality of energy services in off-grid electrification, reducing investment needs in transmission infrastructure, providing independence from the power grid and enabling electrification of end-uses, e.g. transport.

Additional RD&D spending on storage can lead to cost reductions that, combined with ongoing cost reductions for variable renewables, could change the face of the power system. For example, batteries are an attractive RD&D target, as they offer modularity, controllability and responsiveness; but their energy density, charging times and overall costs need considerable improvement to unlock their full potential. Battery technology improvements would provide gains in applications beyond the power sector, particularly in transport. While electricity storage receives most attention and RD&D funding, other storage options, including thermal storage, should not be overlooked. In many cases, thermal storage is more economic than electricity storage and increases the efficiency of the energy system by using waste heat. Other technologies that consume electricity to produce a useful product that can be stored in large quantities, such as hydrogen or desalinated water, should also be given increased attention in RD&D efforts.

Regulatory frameworks need to be designed to leverage the value of adjusting electricity demand to ease the strain on the supply side. As an example of how this can be addressed, since 2007 the US Federal Energy Regulatory Commission (FERC) has issued several orders amending market rules in order to allow demand response and energy storage technologies to participate in established energy markets (e.g. for ancillary services) and to receive a higher level of remuneration for higher levels of performance (e.g. faster responding frequency regulation).[2]

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[2] For example, FERC Order 755 in 2011 and Order 784 in 2013 opened ancillary markets to energy storage and Order 1000 in 2011 requires the consideration of both transmission and transmission alternatives, which includes energy storage and demand response, during regional transmission planning processes.

Demand-side measures can ease the burden on supply-side measures at every stage of variable renewables penetration by improving the alignment of electricity demand with variable renewables output. At high levels of variable renewables penetration, demand-side measures become a key option to maintain power system reliability. In addition to energy storage technologies, demand response is widely available across regions and end-use sectors. Industry has the most accessible potential, followed by the services and the residential sectors. Programmes are in place in these three sectors in the United States, where 30 GW of demand-side resources were available in 2013 (SEDC, 2013), and in the European Union, while initial efforts have also been made in industry in China. Residential potential is the hardest to tap, facing co-ordination, predictability, verification and consumer behaviour challenges.

Power market frameworks will need to be modified to provide sufficient economic incentives to bring forth the needed supply- and demand-side measures to maintain the reliability of the power supply as large amounts of variable renewables are deployed. Numerous measures are possible. Capacity payments to reflect the ability to generate electricity at any time can provide an additional revenue stream to help maintain enough conventional capacity to ensure system adequacy. Care should be taken in the design of capacity mechanisms to be technology neutral, including between existing and new power plants. Measures that support the strengthening of regional grid interconnections, development of smart grid technologies, steps to encourage energy storage and support for demand-response programmes all have a part to play. In competitive wholesale electricity markets, allowing price spikes at times of scarcity and dips at times of abundance can increase revenues to generators and energy storage technologies, but public acceptance is likely to be a problem.

Carbon capture and storage

Opportunity

Carbon capture and storage, through a suite of technologies, separates and captures CO_2 from power and industrial sources, then transports the CO_2 to a suitable site for injection into deep underground formations for permanent storage. CCS makes possible the strong reduction of net CO_2 emissions from fossil-fuelled power plants and industrial processes, providing a protection strategy for power plants that would otherwise be decommissioned, mothballed or suffer reduced operations in a carbon-constrained world (IEA, 2013a; IEA, 2013b). As well as fossil fuels, CCS may also be used in combination with sustainable biomass, resulting in so-called "negative emissions".[3]

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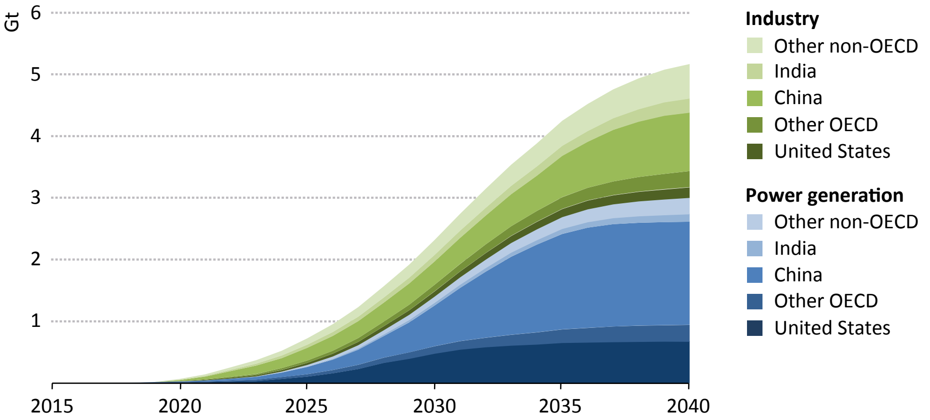
[3] Bioenergy with carbon capture and storage (BECCS) enables negative emissions because CO_2 sequestered during the growth of biomass is not released after the biomass is combusted or refined to produce biofuel. The CO_2 captured and stored underground outweighs the emissions related to producing the biomass, including those from land-use change and transformation into the final product. BECCS could be used in a wide range of applications, including power plants, combined heat and power plants, flue gas streams from the pulp and paper industry, fermentation in ethanol production and biogas refining processes.

In the 450 Scenario, CCS is increasingly adopted from around the mid-2020s, with deployment accelerating in the 2030s and capturing around 5.1 Gt of CO_2 emissions per year by 2040 (nearly triple India's energy sector emissions today) (Figure 4.4), close to 4.9 Gt higher than in the Bridge Scenario. Over the period 2015 to 2040, about 52 Gt of CO_2 emissions are captured. This involves a massive increase in CCS deployment over the 13 large-scale projects in operation today, which capture a total of about 27 Mt CO_2 per year (though only 5.6 Mt CO_2 at present is being stored with full monitoring and verification). To date, CCS investments have been made in sectors in which costs are relatively manageable (e.g. natural gas processing or refining) and where the captured CO_2 has a valuable application, such as for enhanced oil recovery. Widespread deployment will require moving well beyond these boundaries. Not all countries deploy CCS technologies in the 450 Scenario, but it is an important part of mitigation action in China and the United States, and to a lesser extent in India and the Middle East. Several other countries in Asia-Pacific, Europe and Latin America may also need to rely on CCS to achieve the required level of cuts in GHG emissions. Global investment to build CCS grows from a few billion dollars today to about $70 billion per year in the 2020s, on average, and to $110 billion per year in the 2030s. Investment in RD&D, mapping storage sites and other enabling factors needs to begin now. Of the cumulative investment in CCS to 2040, around 60% goes to the power sector and the remainder is made in industry.

Figure 4.4 ▷ CO_2 captured in the 450 Scenario by sector and region



Note: Industry includes the following sectors: steel, cement (energy- and process-related), chemicals and paper production; oil refining; coal-to-liquids, gas-to-liquids and natural gas processing.

In the 450 Scenario, installed capacity of power plants with CCS technologies begins to increase notably from the 2020s (averaging 20 GW per year) and growing rapidly in the 2030s (averaging over 50 GW per year). Global CCS capacity in the power sector reaches 740 GW in 2040, 20% of fossil-fuelled power generation capacity at that time. The global average CO_2 intensity of all power generation in the 450 Scenario falls to about 85 grammes per kilowatt-hour in 2040, less than one-tenth of the average level of an unabated coal-fired power plant today and one-fifth of the level of an unabated gas-fired power plant. Without CCS, neither coal nor gas-fired power plants could retain such a significant market share as they do in the 450 Scenario (gas-fired generation accounts for 16% of total generation in 2040 and coal-fired generation accounts for 12%). Given carbon pricing or other policy measures to incentivise low-carbon operations, equipping these plants with CCS can be a commercially sound investment, allowing them to operate for more hours. The retrofit of existing plants with CCS can provide plants with a new lease on life as low-carbon generators, which could be particularly important in countries like China that already have a large fleet of coal- and gas-fired power plants and where coal prices are anticipated to remain relatively low (Spotlight).

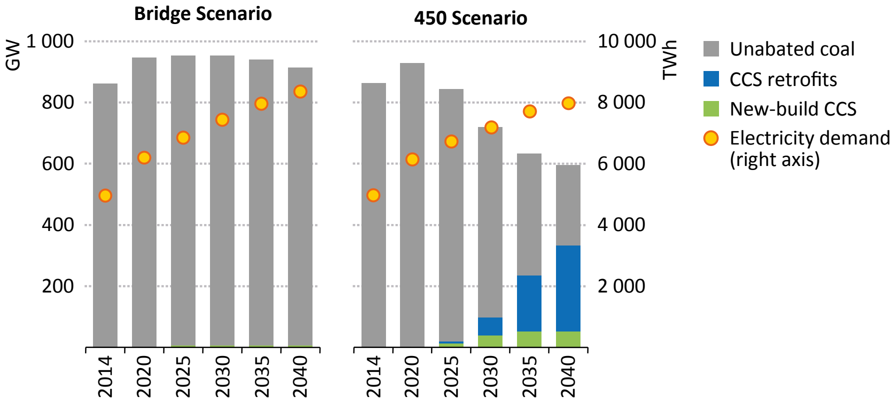
In industry, CO_2 capture increases to more than 2 Gt in 2040 in the 450 Scenario, playing an important role in putting the overall emissions from the sector on a declining path. Most of this CCS capacity is installed in non-OECD countries, led by China, India, Russia and the Middle East, with lesser amounts in OECD countries, led by the United States and Europe. Important industrial sectors, such as iron and steel, and cement, already see CCS as a serious abatement option if they are to achieve deep cuts in emissions. In large part, this is because the chemistry of their processes produces CO_2 that cannot be avoided without radically changing inputs and products, with major knock-on implications for their value chains. In the 450 Scenario, CO_2 capture is led by the cement sector (1.0 Gt CO_2 in 2040), iron and steel (nearly 500 Mt) and chemicals (about 300 Mt CO_2). To reach these levels of CO_2 capture means that around half of global cement and steel production capacity is equipped with CCS in 2040, along with a large share of chemicals production. In the case of chemicals, about 60% of the savings comes from ammonia and methanol production, which offer an attractive opportunity for early action due to the purity of the CO_2 in their flue gases, making its capture relatively inexpensive. Installing CCS would raise operating costs for power plants (by lowering efficiencies); but it also acts as a safeguard for assets in power generation and industry which could otherwise become stranded (see Chapter 3, Box 3.3), as well as preserving value for fossil-fuel producers. For example, over the period to 2040 in the 450 Scenario, facilities equipped with CCS in the power and industry sectors consume about 15 billion tonnes of coal equivalent that would be worth \$1.3 trillion and 4 000 billion cubic metres of natural gas worth about \$1.3 trillion at the prevailing fuel prices in the 450 Scenario. Countries and companies with revenue streams from the extraction and processing of fossil fuels thus have a clear interest in supporting the development and deployment of CCS.

SPOTLIGHT

China's coal-fired power fleet and CCS retrofits

China's power sector accounted for 4.5 Gt CO_2 in 2013, 14% of global energy-related CO_2 emissions. Combined with the expectation for continued economic and energy demand growth in China, reducing emissions from its power sector will be important to lowering global emissions. The installed capacity of coal-fired power plants in China was about 860 GW in 2014 (45% of global coal-fired capacity), all without CCS, and that figure is expected to rise through to 2020. In the 450 Scenario, coal-fired capacity in China falls by 30% percent by 2040 despite the widespread adoption of CCS (Figure 4.5). Along with about 50 GW of new builds with CCS, about 280 GW of coal-fired power plants are retrofitted with CCS by 2040 in the 450 Scenario. Without these retrofits, which can be a relatively low-cost CO_2 abatement option in the power sector, many more large power plants would face closure before the end of their technical lifetime.

Figure 4.5 ▹ **China installed coal-fired power generation capacity in the Bridge and 450 Scenarios**



Note: TWh = terawatt-hour.

While it is technically feasible to add post-combustion CO_2 capture to almost any plant, the economic decision to retrofit will be more attractive for larger plants that have higher efficiencies and flue gas desulphurisation, and have yet to reach the end of their technical lifetime. Nearly half of China's existing fleet is likely to meet these criteria in 2025 and, as such, could be excellent candidates for the addition of CCS. Available space onsite for the capture equipment and good access to facilities for CO_2 transport and storage will also be critical factors for CCS retrofits. Up to three-quarters of China's existing coal-fired power plants are within 250 km of potential storage sites, one indicator that significant retrofit potential exists. For new plants, it is important to ensure that they are located and built making provision for future CCS installation, reserving the required space onsite and situated, where possible, in proximity to CO_2 storage sites. A first step is to incentivise public or private organisations to explore CO_2 storage capacity and bring CO_2 storage services to the market.

Challenges

The two main challenges to widespread deployment of CCS technologies in the power sector are the need to bring down the costs to a level that sustains competition with other low-carbon technologies and to establish plant sites where CO_2 storage is available and economic. In addition, as with any new technology, it will be important to win public acceptance by addressing any concerns that may arise. Stakeholder engagement and broad access to balanced information on all aspects of the technology can help mitigate risks of delays and unnecessary hurdles. The commercial-scale CCS projects underway today are providing information about the costs (though they are still first-of-a-kind costs). In 2014, the first commercial-scale CCS power plant came online in Canada (SaskPower Boundary Dam Unit 3), after the retrofitting of an existing coal-fired facility at a cost of around $6 000 per kilowatt (kW) for the CO_2 capture equipment. The developer has estimated that the next project could be completed at a cost 30% lower. The Kemper County project in the United States (scheduled to begin operating in 2016) is the first new-build power plant with CO_2 capture (and also one of a handful of integrated coal gasification combined-cycle [IGCC] power plants in the world). The project has experienced considerable cost overruns, largely related to the IGCC technology, that put the latest cost estimates at around $9 500/kW, including all construction costs. At these initial levels of cost, government support will be necessary to create more market opportunities, thereby generating the additional experience needed to bring down costs. Applying a learning rate of 11% (per doubling of capacity) to the cost of CO_2 capture, in line with learning rates experienced for other power plant emissions control technologies (e.g. flue gas desulphurisation and selective catalytic reduction systems) (Rubin et al., 2004), the strong deployment of CCS in the 450 Scenario drives down the total capital cost of a new coal-fired power plant with CCS from an estimated $6 000/kW in 2020 to $4 300/kW in 2030 and $4 000/kW in 2040.

What such costs mean for the competitiveness of CCS against other low-carbon technologies depends on local circumstances. For example, consider the US power sector, where hydropower and nuclear power have long been the largest low-carbon sources of power generation and both sources will continue to expand over time in the 450 Scenario. However, a range of other considerations, not least of which are public acceptance and physical resource limitations,[4] indicate the need for the strong deployment of other low-carbon power generation technologies. Four additional utility-scale options to reduce CO_2 emissions related to the power supply are potentially widely available:

- Coal-to-gas switching, replacing coal-fired generation with gas-fired generation based on the existing fleet of power plants.
- New onshore wind projects.
- New utility-scale solar PV installations.
- New coal- or gas-fired power plants equipped with CCS or retrofitting existing coal- and gas-fired power plants with CCS.

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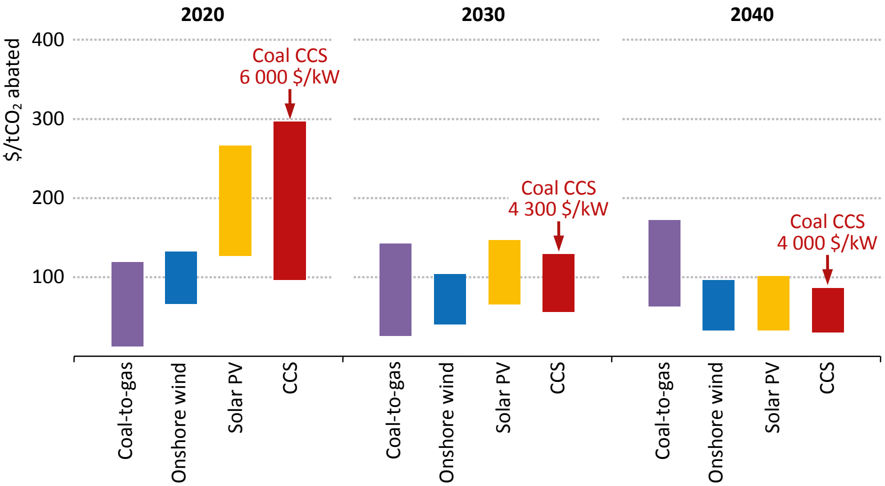
4. Additional hydropower potential has been identified at existing dam sites (Hadjerioua et al., 2012) and for new run-of-river projects (Kao et al., 2014), though environmental and political concerns have so far limited their development.

Building a new gas-fired combined-cycle gas turbine (CCGT) plant is taken as the standard of comparison, since such plants are widely available and generally, at present, the preferred option for new capacity. Based on the additional costs and resulting CO_2 emissions reductions for each option, CCS is not generally a competitive abatement option in the near term when compared with coal-to-gas switching or with building wind power projects (Figure 4.6). Nevertheless, continued development of CCS is critical for the longer term, as it expands the range of low-cost, low-carbon technologies available in the power sector, also adding to the set of low-carbon options with controllable output that will be needed in some regions to integrate increasing contributions from variable renewables (see previous section). With the deployment of about 200 GW of CCS (including both gas- and coal-fired power plants) in the United States by 2040 (and about 740 GW worldwide), it becomes a competitive abatement option with wind power and solar PV over time, and is more attractive than the dwindling opportunities for coal-to-gas switching, due to rising gas prices and the fact that little unabated coal-fired generation remains.

Figure 4.6 ▷ **Costs to reduce CO_2 emissions relative to gas CCGTs in the United States by selected technologies in the 450 Scenario**



Notes: coal-to-gas compares the operating costs of existing gas CCGTs with existing coal-fired power plants. Onshore wind, solar PV (utility-scale) and CCS compare the range of projected levelised costs of each technology with the levelised cost of a new gas CCGT, not including carbon costs. The range for solar PV in 2020 also includes comparison with the levelised cost of a new gas GT, as its output largely coincides with peak hours of demand. CCS includes the range of abatement costs for new builds and retrofits of both coal- and gas-fired power plants. The levelised costs of utility-scale solar PV are projected to fall from $105-140 per megawatt-hour (MWh) in 2020 to $80-105 per MWh in 2030 and $70-95 per MWh in 2040.

In China, the CO_2 abatement options in the power sector also include hydropower, which offers the lowest-cost emissions reductions. Beyond hydropower and nuclear power, the four main abatement options in the power sector are the same as those in the United States, though higher gas prices in China make coal-to-gas switching far less attractive and change the basis of comparison to high-efficiency coal-fired plants (the most widely available and deployed technology). In 2020, onshore wind offers the lowest abatement costs after hydropower, at less than \$20 per tonne of CO_2 (tCO_2) abated, followed by utility-scale solar PV (generally less than \$50/tCO_2), while the cost of abatement for CCS is in the range of \$50-100 per tCO_2. Coal-to-gas switching is an expensive way to reduce emissions in China, with an estimated abatement cost of \$120/tCO_2 or higher throughout the period to 2040. Investment in RD&D and learning through deployment reduce the costs of abatement through CCS to \$10-70 per tCO_2 in 2040, still generally higher than the estimated abatement cost for onshore wind power and solar PV projects.

Opportunities for the widespread use of CCS also depend on the proximity of suitable geological CO_2 storage sites. Large-scale CO_2 capture projects will not be financially attractive unless there is confidence that sufficient storage capacity is available and can be reached at reasonable cost – considering both the costs of CO_2 transport and storage. In terms of the science of CO_2 storage, the global knowledge base continues to grow, with results accumulating from both commercial projects storing a million tonnes per year in Norway, Canada and the United States, as well as smaller research projects. The risks of leakage and other sources of harm in both the short and long term are low where best practices are followed. However, whereas CO_2 capture technologies can be transferred relatively easily between countries, the subsurface knowledge needed to understand CO_2 storage potential is inherently local and can be developed only through exploration. Development of a CO_2 storage site can take close to a decade and can account for around half of total CO_2 storage costs, making early exploration and development a strategic investment to enable decarbonisation. But there is currently insufficient activity focused on converting storage resources to commercial capacity. The upfront cost and inherent risk of exploration, coupled with the other uncertainties currently surrounding the future of CCS and competition with the oil and gas sector for skills and capital, suggest governments will need to play a role in encouraging development of the CO_2 transport and storage businesses. The Crown Estate in the United Kingdom, Gassnova in Norway, and CarbonNet in Australia are rare examples of public bodies working towards development of commercial CO_2 storage assets. Such activities will need to be accelerated if the underpinning infrastructure for CCS is to be available on a timescale consistent with the 450 Scenario.

Even without government support to expand market opportunities for CCS, it is still likely to be deployed in certain applications in industry and the oil and gas sector. But the path to meet the 2 °C climate goal would be more difficult, limiting the range of low-carbon options. Renewables, including variable renewables, would need to make up some of the ground and pressure would grow for some countries to expand their nuclear power programmes. Without CCS, there would also be a higher risk of stranded assets, in a world already likely to be carrying higher costs to hold to a 2 °C pathway. In industry, there are currently no alternatives to reach the same level of emissions reductions, as maximum fuel switching and energy efficiency measures would only achieve a fraction of the CCS reductions. Ultimately, a lack of CCS would probably lead to other sectors having to carry more of the burden to make up for higher emissions from industry. While not as detrimental to the outlook for CCS technologies, failing systematically to increase local knowledge of CO_2 storage opportunities will slow the deployment of CCS, as individual developers have to identify suitable sites and incur the related costs.

Solutions

Nonetheless, CCS does become a widely competitive CO_2 abatement option by 2040 in the 450 Scenario, with the United States and China accounting for about 80% of the CCS installations in the power sector. This level of penetration can be brought forth by three types of actions:

- **Regulatory measures and targeted incentives to promote more large-scale projects.** As examples of what can be done, the Gorgon LNG project in Australia is authorised by a law that obliges it to incorporate CCS and the Decatur bioethanol plant in the United States is viable for CCS due to tax credits for CO_2 storage. However, in sectors where CCS represents a larger share of production costs, such as power generation or cement, policies guaranteeing a sustained reduction in both capital and operating costs may be needed to trigger investment in the near term. It will be essential for CCS projects to have access to climate funds, including those being developed within the UNFCCC, bilateral and other multilateral initiatives.
- **The continued pursuit of research and development to improve technologies and address challenges that arise during early commercialisation.** In this area, the emergence of pilot facilities that provide open access to developers to test and evaluate CO_2 capture technologies is encouraging, such as those in Canada, Norway, United Kingdom and United States.
- **Policies to encourage the early exploration for and development of CO_2 storage capacity.** Insufficient incentives exist today. All investment decisions for CCS depend on confidence that the CO_2 can be safely stored. While large-scale projects and RD&D will generate globally transferrable knowledge and safeguards, the development of CO_2 storage resources needs to be undertaken regionally and well in advance of deployment.

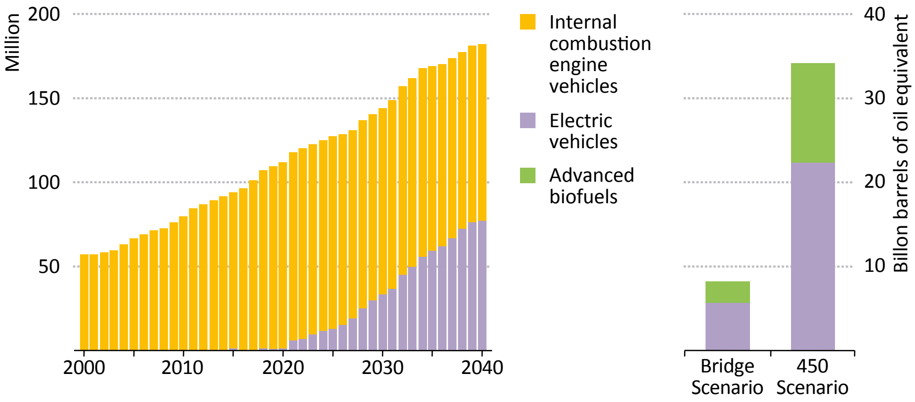
Alternative fuel vehicles

Opportunity

The transport sector is the second-largest emitter of CO_2 emissions after power generation. It accounts for more than one-fifth (7.3 Gt) of global energy-related CO_2 emissions today, a rise from 3.3 Gt/year in the 1970s. Road transport (passenger and freight) is the primary cause of the increase, accounting for over 80% of the growth, due to its heavy reliance on oil. Despite many attempts, dependence on oil as a transport fuel has not been overcome. Biofuels, in particular, have made some inroads, but still meet only 2% of road transport fuel demand today (mostly in Brazil, United States and European Union). Natural gas, as a road transport fuel, is important in some markets, such as Brazil, Pakistan and Iran, and has seen impressive growth in China and the United States over the last few years; but it remains a carbon-based fuel, which cannot deliver the long-term decarbonisation that is required in the transport sector. To date, sales of electric vehicles[5] represent well below 1% of global car sales, far below the volumes required in the 450 Scenario.

Growing demand for mobility, particularly from emerging markets, threatens to continue to push up transport oil demand, increasing the need for the development and deployment of alternative fuel vehicles in order to decouple mobility growth from emissions growth and put the world on track to meeting the 2 °C climate goal. In the 450 Scenario, electricity (through electric vehicles) and advanced biofuels[6] are the main alternative fuel options that deliver the deeper emissions reductions required from the transport sector. Together, they reduce oil consumption by 13.8 million barrels of oil equivalent per day in 2040 and energy-related CO_2 emissions by 11.5 Gt over the period 2015 to 2040, compared with the average fuel economy of the remaining vehicle fleet. Hydrogen (through hydrogen-powered fuel-cell vehicles) also plays a role, but to a much lesser extent.

Figure 4.7 ▷ Global light-duty vehicle sales by type in the 450 Scenario (left) **and global cumulative oil savings by scenario from electric vehicles and advanced biofuels, 2015-2040** (right)



Notes: Light-duty vehicles include passenger and commercial vehicles; internal combustion engine vehicles include hybrid, natural gas and flex-fuel vehicles; electric vehicles include pure-electric and plug-in hybrids.

The use of biofuels (primarily in road and aviation sectors) more than doubles in the 450 Scenario, relative to the Bridge Scenario. Their use, reaching 8.7 million barrels per day (mb/d) in 2040 in the 450 Scenario, displaces the need for refined petroleum

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[5] EVs here include plug-in hybrids and battery-electric vehicles.

[6] Advanced biofuels here refer to those produced from conversion technologies that are currently in the research and development, pilot or demonstration phase. This differs from the definition applied in the US Renewable Fuel Standard, which is based on a minimum 50% life-cycle greenhouse-gas reduction and therefore includes sugarcane ethanol.

products, namely gasoline, diesel and kerosene. Around 30% of the increase in biofuels use comes from the aviation sector, which has few viable alternatives to oil (on-board storage is a major limitation for hydrogen and electricity). As a result, the fuel mix in the 450 Scenario is much more diversified by 2040, and biofuels earn a share of around 17% for world transport demand as a whole. A large part of the increase in biofuels use is due to the development and deployment of advanced biofuels that can be sustainably manufactured from non-food, cellulosic feedstocks and algae, and can be used in vehicles and other transport modes, e.g. as aviation jet fuel. Advanced biofuels are assumed to be commercially available at scale from 2020 onwards in the 450 Scenario. As biofuels can readily be supplied through the existing refuelling infrastructure, the use of advanced biofuels can expand rapidly, reaching more than 10% of road transport fuel demand by 2040, and 33% in the aviation sector.

Sales of EVs also grow rapidly in the 450 Scenario. From around 2020, they make a notable impact on global vehicle sales, reaching nearly 25% by 2030 and more than 40% by 2040 (Figure 4.7). Total annual EV sales reach nearly 80 million vehicles by 2040, equivalent to the global vehicle sales of all types in 2010. Primarily, the increase in sales in the 450 Scenario is driven by the large vehicle markets: China, India, United States and European Union. Road transport provided by EVs reduces global oil demand by around 1.5 mb/d in 2030 and nearly 6 mb/d in 2040. One primary benefit of using EVs, which use a highly efficient electric motor for propulsion, is that they can shift transport emissions from millions of mobile sources to a much smaller number of stationary sources in the power sector. If centralised power generation relies on low-carbon sources, as in the 450 Scenario, EVs effectively reduce overall GHG emissions. Climate change is not the only reason to promote electric vehicles; as EVs do not emit air pollutants and make little noise, they are well suited to urban use. In China, for example, air quality concerns have already supported the introduction of 230 million electric scooters in place of diesel scooters (IEA, 2015b). Innovative programs, such as the Autolib system in France, can also serve to increase the uptake of EVs in urban areas, displacing the need for personal vehicles.[7]

A shift to EVs always reduces CO_2 emissions directly from the transport sector, as there are no emissions at the point of use. However, power sector emissions may increase due to the additional electricity demand from EVs (which also have the advantage of higher motor conversion efficiencies compared with conventional cars). Therefore, the extent to which EVs can contribute to energy-related CO_2 emissions reductions depends critically on the carbon-intensity of the power mix. Today, EVs generally offer overall CO_2 mitigation benefits compared with new gasoline internal combustion engines (ICE) cars, unless the power system is heavily dominated by coal and the overall emissions intensity of electricity is 800 g CO_2/kWh or above. Due to their relatively carbon-intensive power mix, the benefit

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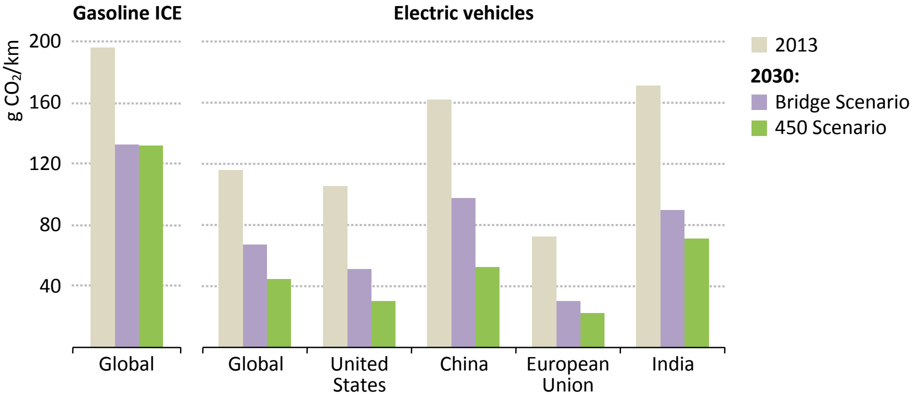
[7] Autolib is a subscription-based electric vehicle sharing programme in Paris, France. Autolib estimates that 3 000 vehicles will displace ownership of 22 500 private vehicles, *www.autolib.eu/en/*.

of EVs is lowest today in some countries in Asia, including China, India and Indonesia, but with increasing power sector decarbonisation, such as in the 450 Scenario, the emissions reductions become more pronounced over time (Figure 4.8).

Figure 4.8 ▷ On-road emissions intensity of gasoline-fuelled and electric vehicles by selected region in the Bridge and 450 Scenarios



Notes: Emissions intensity of electric vehicles is based on the emissions intensity of grid-supplied electricity by region. The global figure is based on the world average emissions intensity of electricity.

Hydrogen fuel-cell vehicles can also contribute to decarbonisation of the road transport sector. The idea of hydrogen as a transport fuel for vehicles has attracted the interest of industries, government and the public since the 1960s. There are signs of renewed attention today. Toyota has just launched the Mirai ("Future") in Japan, the first commercially available hydrogen fuel-cell car; Hyundai is targeting to sell several thousand vehicles soon (the Hyundai Tucson Fuel-Cell Electric Vehicle has been available for lease since mid-2014); and Honda has announced its intention to launch a hydrogen-powered car in 2016. During the past decade, several global public-private partnerships have been created to secure funding for co-ordinated action to promote the application of fuel-cell technology beyond the car industry (e.g. in California, Europe, Japan, Korea and recently in Dubai). But no such alternative applications on a commercial basis have yet been announced and widespread adoption of hydrogen has so far failed to materialise.

One big potential advantage of hydrogen-fuelled vehicles is that their range is not limited like that of an EV, a subject of considerable consumer anxiety. The refuelling time is also generally much lower than the charging time of a battery. If hydrogen is produced from low-carbon sources, the CO_2 benefits offered are comparable to those of EVs. There are, however, serious challenges constraining the outlook for deployment of hydrogen vehicles (discussed below) and their use in the 450 Scenario remains limited.

Challenges

For EVs, the key barriers that currently hold back their deployment include their relatively high cost, the low energy density (and correspondingly heavy weight) of batteries and the lack of recharging infrastructure. Despite recent cost reductions, batteries remain the most costly component of EVs. From an industry perspective, the prize for developing a battery that makes EVs competitive with conventional cars is potentially huge, as is already reflected in the significant level of research and investment (IEA, 2015c). Industry-wide estimates of the cost of batteries declined by approximately 14% annually between 2007 and 2014 (from above $1 000/kWh to around $400/kWh) and the cost of the battery packs of market-leading manufacturers are even lower ($300/kWh), revealing cost reductions of 6% to 9% for each doubling of cumulative production (Nykvist and Nilsson, 2015). In some cases, EVs have had significant success in the marketplace in recent years: for example, in Norway, EVs were reported to make up 10% to 15% of monthly passenger vehicle sales in 2014 supported by tax breaks and other incentives. Electric vehicle fleets – such as taxis, buses, delivery vehicles – and EV sharing schemes are increasingly common in many parts of the world, particularly in cities where concerns about the vehicle's range are less pronounced. The number of EV models has continued to increase, many from the world's largest car manufacturers. Despite these positive signals, however, total sales of EVs worldwide have been far slower than expected. Policy targets set for achievement by 2015 are likely to be missed in all regions, in particular the United States and China. In the absence of new support measures, 2020 targets might need to be adjusted as well.

The widespread adoption of EVs requires an expansion of the recharging infrastructure. The convenience of charging can be a major factor for people considering investment in an EV, including a safety net for emergency charging. By the end of 2014, the number of slow-chargers installed globally is estimated to have reached more than 94 000, while the number of fast-chargers was around 15 000 (IEA, 2015c). For comparison, the United States alone has around 120 000 gasoline filling stations. The European Union agreed upon a directive in 2014 specifically to support the deployment of infrastructure for alternative transport fuels across its member countries and similar action will be essential elsewhere to support EV deployment on the scale projected in the 450 Scenario. Global charger costs in the 450 Scenario are of the order of $20 billion per year on average to 2040. Although this is just a fraction of expected investment in land transport over the same period, it will be a demanding challenge to mobilise the required investment and to put the required infrastructure in place in a system that is currently almost entirely reliant on oil-based transport fuels.

Progress related to the production of advanced biofuels has also been slow and currently they are not commercially available at scale. However, some notable progress was registered in 2014. Five commercial-scale advanced biofuels production plants opened, three in the United States and two in Brazil (IEA, 2015b). The combined capacity of these plants, at 9 000 barrels per day (in volumetric terms), makes up about one-fifth of current global advanced biofuels production capacity but less than 1% of total biofuels production capacity today. The United States is the only country which has volume requirements for advanced biofuels in 2015 (Renewable Fuels Standard), though it has had difficulty meeting targets to date. In late 2014, Italy set national targets for advanced biofuels as a share of transport fuel demand, rising from 1.2% in 2018 rising to at least 2.0% in 2022. In April 2015, the European Union also set an indicative target of 0.5% for advanced biofuels by 2020. During 2014, several companies announced new advanced biofuels projects, but several others have been cancelled in recent years.

The two major challenges associated with advanced biofuels are reducing production costs and ensuring sustainability. Most of the technologies today have total production costs significantly greater than $3/gallon (IRENA, 2013), which is well beyond the untaxed price of petroleum products. The price level of conventional oil will be of critical importance to the long-term prospects for biofuels as a competitive fuel. The second issue, the sustainability of conventional biofuels, has been in question for many years. As a result, the European Union, to take one example, has restricted the extent to which conventional biofuels can contribute to biofuels targets. It is therefore imperative to ensure that advanced biofuels do not raise the same concerns.

As to the use of hydrogen in road transport, the challenges are numerous, ranging from the high costs of the hydrogen fuel-cell vehicle to the absence of refuelling infrastructure and consumer scepticism. Despite the recent notable step forward of the launch of the first commercial models, hydrogen fuel-cell vehicles still have many hurdles to overcome before they can achieve mass commercialisation. The most fundamental challenge is the need to build-up an entirely new hydrogen generation, transmission and distribution and retail network (IEA, 2015d). Although decentralised hydrogen production is feasible, large-scale deployment of hydrogen fuel-cell vehicles is likely to hinge on the development of such a dedicated integrated infrastructure.

Solutions

Given the variety of new technologies under development in the transport sector and the early stage of their deployment, it is important for government actions to enable innovation across a broad set of technologies in road transport. Market-driven, technology- and fuel-neutral policies (e.g. such as greenhouse-gas emissions standards per vehicle-kilometre travelled), based on sound science and offering cost-effective pathways to achieve societal goals of energy security and GHG emission reduction, are to be preferred. Technology neutral policy measures can be complemented by targeted and temporal incentives to help overcome obstacles during early advancement and market introduction. The 450 Scenario assumes the (supported) emergence of a variety of solutions, without imposing a shift to other modes of transport, i.e. to non-private, non-motorised transport modes, or measures to suppress demand for mobility. It will nevertheless be important to keep open the opportunity for more radical possibilities, especially in urban areas where good planning might induce behavioural changes which contribute significantly towards decarbonising transport or, more broadly, the demand for mobility (Box 4.2).

To put EVs on track for their role in the 450 Scenario, RD&D must continue with government support to overcome obstacles to commercial success, particularly related to batteries, in order to lower costs and increase vehicle range. Second, support to cities and regions needs to be offered for sustainable business models in the creation of battery-charging infrastructure. Third, encouragement is required for the development of smart grids which can support a larger role for the EV fleet as an electricity storage option. In addition, governments may need to consider countermeasures, such as increased fuel or emissions taxes and systems of fees or rebates for vehicles depending on their environmental credentials, if the current period of low oil prices persists, reducing the relative attractiveness of alternative transport fuels.[8]

Box 4.2 ▷ Policies to avoid or shift transport activity

Technological change is not the only route to reducing carbon emissions from transport. Policies to reduce travel needs include land-use planning instruments that favour compact urban design and mixed-use development (e.g. commercial and residential), pricing and other measures encouraging travel demand management, such as the promotion of virtual mobility (e.g. tele-working), freight delivery co-ordination and logistical optimisation to decrease travel volume by finding shorter, more efficient routes. Such measures can be complemented by policies to encourage movement from private motorised travel to more energy-efficient modes, such as public transit systems, cycling, and rail. In densely populated urban environments, the availability of affordable, frequent and seamless public transport connections can be provided cost effectively, especially when taking into account the advantages of lower road space utilisation, lower exposure to pollutant emissions and reduced congestion.

The impact of such policies can be large. Cuenot et al. (2012), using the IEA Mobility Model, have shown that a 25% reduction in car and air travel in 2050 can reduce global energy use and CO_2 from transport by 20%. The IEA's *Energy Technology Perspectives* has shown that policies such as those considered here can reduce global transport energy consumption and emissions by 15% or more by the middle of this century in a stringent mitigation case, primarily through better management of travel demand and moving passenger and freight travel to more efficient modes (IEA, 2015a).

The measures necessary to achieve these effects include integrating urban and transport planning, facilitating investment in public transport infrastructure, supporting well-integrated public transport networks and options that lead to quicker vehicle utilisation turnover (e.g. car-sharing schemes). Some developments might take place naturally: the younger generation, particularly in urban areas, tends increasingly to prefer alternative transport options to the use of personal cars (e.g. public transport, cycling, walking), recognising that what counts is the transport service, rather than the means (personal cars). Transport demand reduction may also stem from the use of modern information and communication technologies.

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[8] For more on the implications of lower global oil prices prevailing into the long term, see the IEA's *World Energy Outlook 2015*, to be published on 10 November 2015.

To address the challenges associated with advanced biofuels, government support is required for the development of cellulosic biofuel refineries to drive down costs through learning. In addition, government- and industry-funded RD&D efforts are necessary to develop innovative processes to produce advanced biofuels, particularly from agricultural and forestry waste products. Governments have a particular role in supporting the development of indicators, such as those described by Franke et al. (2012), to set standards of sustainability in the production and use of biofuels which must be met, particularly in relation to competition with food production and any direct or indirect land-use change.

Energy sector transformation needs smart policies

The transition to a low-carbon economy requires changes to the global energy system that depend upon giving the right signals to innovators and financiers within an appropriate market structure. Existing arrangements are insufficient to stimulate deployment in line with the 450 Scenario. Government intervention will be required in, at least, the following respects: accelerating the creation of sustainable markets for low-carbon technologies; investing in RD&D where there are critical funding gaps; supporting the creation of the necessary infrastructure; and encouraging international collaboration.

Sustainable low-carbon markets must provide an enduring incentive to improve technologies. As a policy, carbon pricing (i.e. penalising higher emissions technologies) has yet to be pursued sufficiently rigorously to create long-term investor confidence: the price is often low and there is political uncertainty surrounding its future. More successful forms of intervention, so far, have included capital grants, tax breaks, production subsidies and performance standards, re-shaping investment decisions in CCS projects, electric vehicle fleets and solar PV value chains. Electricity markets are beginning to require more fundamental adjustments to accommodate emerging patterns of supply and demand. Well-designed government interventions can reduce technology costs, support more efficient supply chains and financing, and help technologies to become established. As their efforts become more apparent and a low-carbon transition takes hold, affordable capital is expected to flow more freely, allowing such policies to be withdrawn.

Government investments in RD&D can provide the leadership necessary to yield major returns in terms of jobs, investment and results. Financing for large-scale CCS projects is needed in the near term to generate the improvements that will allow lower costs to emerge from large-scale activity in the long term. In the case of EVs, the commercial race to develop the best battery has already begun. For variable renewables, attention may need to be directed more to the provision of system flexibility than simply to more efficient generation technologies.

To achieve a self-sustaining low-carbon transition will require parallel investments in the enabling infrastructure. Governments have a crucial role to play in ensuring that such projects go ahead in a timely manner, in many cases, by investing directly in them, but also by providing the conditions which attract multilateral financial commitments. CO_2 storage capacity development, provision of EV charging stations and encouragement of additional transmission grid interconnections are just three examples where this may be the case. Alongside these physical considerations, technology collaboration between countries and across sectors can be highly productive.[9] Though the comparative advantages of different countries and their comparative needs for particular energy technologies will differ in a low-carbon transition, innovation can be stimulated by joint activity and sharing deployment experience. Initial deployment may not always be in countries with the highest potential (consider, for example, solar PV in Germany and Italy), but shared experience can help to reduce costs more broadly. Pooling such learning sometimes can be important in accelerating technology development and should be prioritised in appropriate international fora.

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[9] For example, IEA Energy Technology Initiatives enable independent groups of experts from industry and government to share resources and expertise in order to find solutions to energy challenges. The Innovation for Cool Earth Forum (ICEF) is another example of an international platform that brings together different stakeholders to consider how innovation can best address climate change.

Chapter 5

Building success in Paris and beyond

Features of success

Highlights

- The emergence from COP21 of unity and clarity of purpose at the highest political level, expressed as ambitious near-term action and clear commitment to a low-carbon future, can transform the energy sector. The submission of national climate goals to COP21 is not the end of a process, but the basis on which to create a "virtuous circle" of increasing ambition. Four key pillars are needed to make the Paris agreement a success:

  1. The agreement should set the conditions necessary for a **global peak** in total energy-related emissions to be reached in the near future. The integration of the energy sector measures of the Bridge Scenario into nationally determined climate goals for 2025, coupled with an immediate start to action, could achieve such a peak by 2020, without prejudice to sustained economic growth and development. Seeing global emissions peak and a growing number of countries decouple economic growth from emissions growth will transform national expectations and action.
  2. A **five-year review cycle** is needed to provide the opportunity and incentive for agreement on setting higher objectives over time. Following the Bridge Scenario to 2025 enables emissions to pass their peak and makes power sector investment fully compatible with a 2 °C scenario (committed emissions from new power generation in the INDC Scenario would be 19 Gt higher). From 2025, the level of ambition must rise beyond that of the Bridge Scenario to bring global emissions well below 2010 levels by 2030, onto a path consistent with the 2 °C goal.
  3. The current goal to keep temperature rise below 2 °C should be supplemented by re-expressing it as a **collective long-term emissions goal** coupled with nationally determined low-carbon development pathways informed by a vision of the long-term collective goal. Such supplementary expressions of the target can guide energy sector investment, retirement and operational decisions, provide an incentive for the development of new technologies, drive the necessary adaptation of market structures and spur implementation of strong domestic policies, such as carbon pricing – all necessary to achieve the required level of energy sector emissions reductions beyond 2030.
  4. The COP21 package and subsequent decisions should provide for a transparent **tracking process to measure progress** toward both short- and long-term objectives as a means of building trust and confidence. Tracking of energy sector metrics would provide much needed clarity on how quickly the energy sector is transforming and would provide key information to underpin countries' domestic energy policy efforts.

Introduction

The decisions that come out of the COP21 meeting in Paris in December 2015 must address the needs and the responsibilities of the energy sector – by far the largest greenhouse-gas emitter – if the outcome is to carry conviction about governments' determination to achieve the 2 degree Celsius (°C) climate goal and the existence of a realistic pathway to get there. To achieve the necessary transformation of the world's energy system, the energy community must be persuaded that energy investments must be redirected so as to lock-in a widespread switch to low-carbon development that delivers economic growth and social development expectations, while simultaneously making deep cuts in emissions and strengthening global energy security.

Significant climate action is already underway and, as seen in Chapter 1, there are some encouraging early signs that emissions growth may be starting to decouple from global economic growth. The cost of renewable energy continues to fall, many countries are implementing more demanding energy efficiency measures, reform of fossil-fuel subsidies has started and various forms of implementing action are being taken by cities around the world. Public demands for clean air and clean water are a strong supporting motivation for change. Governments' pledges to the United Nations Framework Convention on Climate Change (UNFCCC) for the period after 2020 have begun to arrive (Chapter 1), and China and India have both announced climate and low-carbon energy strategies. The private sector is also engaging in mitigation actions: a coalition of almost 1 450 companies has reported saving around 420 million tonnes (Mt) of carbon-dioxide equivalent (CO_2-eq) in 2013, linked to $170 billion of low-carbon investment.

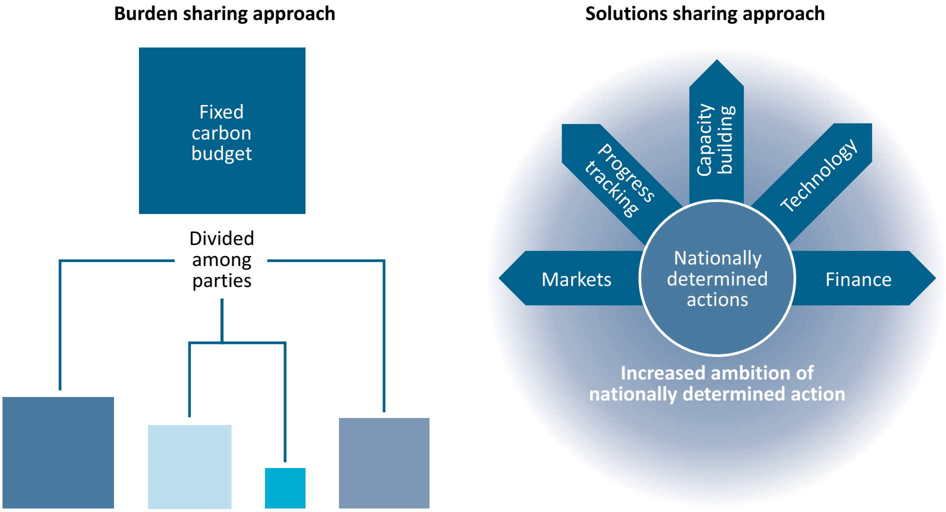
But much of the transformational change needed in the energy sector to meet the 2 °C climate goal has yet to take place. To bring this forth requires scaled-up national, regional and local action, guided by appropriate policies and standards, and mobilisation of both public and private finance for low-carbon energy supply and infrastructure. An international framework is needed to co-ordinate and generate confidence in these national efforts and then progressively to amplify them until low-carbon energy investment becomes the global norm. Clear signals of the need for transformational change are required from the highest political level, with all major emitting countries on-board.

This chapter focuses on how the decisions to be taken at COP21 can best encompass and address the challenges put forward in previous chapters. How can COP21 both recognise existing efforts and help countries to do more? How can it best facilitate a long-term transition to low-carbon energy systems, while also delivering short-term achievements? How can it overcome the dual trials of deepening the decarbonisation of the energy system while also building in greater resilience to the new challenges created by the degree of climate change which is already inevitable?

Energy sector needs from COP21

The COP21 agreement alone will not provide a comprehensive package of solutions to deliver the 2 °C goal. Instead, it is expected to establish a platform and process for country-led action that will evolve and strengthen over the coming decades, bringing collective efforts into line with the 2 °C goal over time. Building an agreement that is durable, applicable to all countries and sensitive to varying stages of economic and social development will require flexibility within an overarching framework. In this light, governments are working towards an agreement that emphasises "solution sharing", i.e. starting from what countries are already able to do and intent upon doing and then building ambition via support and collaboration. This contrasts with a "burden sharing" approach whereby a fixed budget of allowed emissions is allocated by a formula (Figure 5.1).

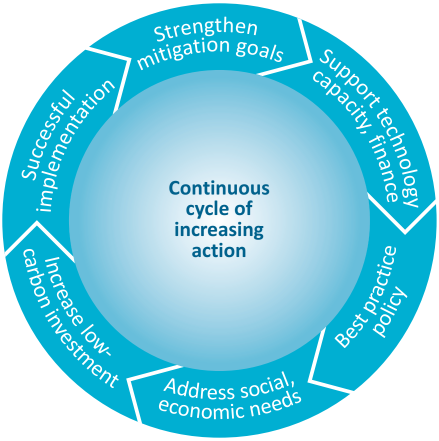
Figure 5.1 ▻ Approaches to international climate negotiations



There will inevitably be some overlap between these approaches. For example, although the solutions sharing approach is founded on nationally determined contributions, the 2 °C goal implies a carbon budget at the global level that provides a reference for the adequacy of collective efforts. Similarly, although countries are free to determine their own contributions under a solutions sharing approach, considerations of equity will create expectations about the type and ambition of various Parties' actions: in particular, the least-developed countries are concerned to ensure they are left with sufficient "carbon space" within the 2 °C goal to allow for their sustainable development.

Submitting national climate contributions for COP21 will not be the end of the process, but rather provide a basis from which to create a "virtuous circle" of growing ambition (Figure 5.2). After setting mitigation goals, many countries will need assistance in mobilising finance and technology for low-carbon investment, in building capacity and in policy implementation. Solution sharing through the provision of financial support and policy co-operation can expand the boundaries of what hitherto has been considered possible. Growing investment in low-carbon energy will result, in turn, in growing momentum towards progressively more ambitious mitigation goals. However, adoption of weak targets or evidence of lack of implementation would be perceived as wavering in countries' commitments to tackle climate change, deterring investors and perpetuating the lock-in of high-carbon energy solutions.

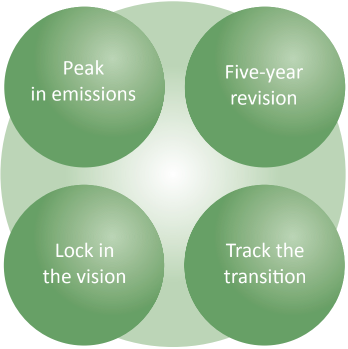
Figure 5.2 ▷ Elements to support a "virtuous cycle" of strengthening mitigation ambition over time



To send the necessary signals to the energy sector, the COP21 agreement should be built on four pillars:

- **Setting the conditions for a near-term peak in global energy-related emissions**. Building on evidence of an increasing decoupling of economic growth from energy sector emissions, short-term mitigation ambition needs to be strengthened, leading to total global energy-related emissions finally turning downwards.
- **Providing for a five-year review cycle of mitigation targets** to encourage and lock-in increasing ambition over time. Following the Bridge Scenario (Chapter 3) can keep the 2 °C climate goal within reach in the short term, but mitigation goals need to be strengthened from 2025.
- **Locking in the long-term vision** embodied in the 2 °C climate objective by elaborating a long-term global emissions goal and nationally determined low-carbon development pathways to spur long-term investment and technology research, development, demonstration and deployment (RDD&D) (Chapter 4).
- Transparent **tracking of the energy transition** (toward both short- and long-term objectives) to support successful implementation and build trust and confidence.

Figure 5.3 ▷ Four pillars of the Paris COP21 Agreement



These four pillars (Figure 5.3), which are explored in the following sections, need a set of tools to deliver them. A strong agreement on finance at COP21 is critical, to re-orient energy sector investment flows (public and private) towards delivering low-carbon, climate resilient projects and portfolios. Carbon pricing will be needed as a feature of the national and international policy response and should be supported by the COP21 agreement (Box 5.1).

Box 5.1 ▷ Pricing energy correctly

One of the strongest elements as an economy-wide signal to move to a low-carbon energy system is appropriate energy pricing: phasing out fossil-fuel subsidies and introducing carbon pricing. Where governments invest directly in the energy sector and in energy sectors with relatively few actors, much progress is possible through selective investment or regulation. However, to reach across the whole of the economy (and particularly to influence private investors) there is no substitute for correct energy pricing, including the creation of expectations of a rising trend in carbon prices. Fossil-fuel subsidies reform is picking up speed, with countries taking advantage of the current lower price environment to act while the impact will provoke less opposition. Carbon pricing efforts are also increasing, but prices to date are weak, partly due to concerns about damaging industrial competitiveness by moving too far too fast and about the social impact of rising energy prices. Three aspects of the COP21 agreement could help in this regard:

- Make sure that the COP21 agreement includes participation by all Parties, so that all countries are taking action together, even if particular policy measures differ.
- Include a provision that affirms countries may use international carbon markets, as long as this is accounted for transparently and contributes to both buying and selling countries achieving an efficient, low-carbon economy.
- Provide for policy collaboration (in the UNFCCC processes or through other partnerships) to ensure that best practice in fossil-fuel subsidy reform, emissions trading, carbon taxes and other measures becomes standard practice.

The Paris agreement can also create a process for Parties to co-operate on policies of mutual interest, as a means of closing the mitigation ambition gap and improving integration of energy policies with social and economic goals such as energy access and affordability. The economic diversification of countries or regions currently highly dependent on fossil fuels is necessary to the success of decarbonisation, and an issue many countries are already struggling with. Detailed recommendations are now available for successful implementation of fossil-fuel subsidy reform (Box 3.4): similar attention needs be given to issues such as managing employment loss in the shift away from coal mining and handling high-emissions assets which become "stranded" in the transition to a low-carbon economy.

The facilitative rather than prescriptive approach to be taken at COP21 may make it difficult immediately to assess the outcome. Success will ultimately be judged by whether it sends a clear message of worldwide commitment to decarbonisation and low-carbon development, thus providing the signal that public and private investors need to embrace this new world.

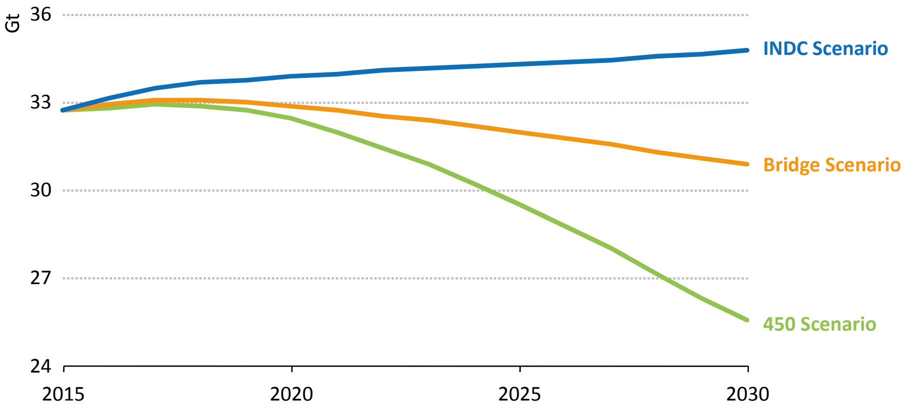
Seeing the peak: a milestone to make climate ambition credible

It is already clear that known and expected Intended Nationally Determined Contributions (INDCs) for COP21 collectively will fall well short of what is needed to be on a path to the 2 °C goal (Chapter 2). Insufficient climate action in the near term increases the need for more challenging and costly corrective action in the longer term. Such costs increase as time passes due to the need for a more rapid transition later and the eventual need to retire more high-carbon infrastructure before the end of its economic life. In the absence of prompt and determined additional action, there will also inevitably come a point at which keeping global warming below 2 °C is no longer feasible.

For the door to 2 °C to remain open, global energy-related emissions must peak as soon as possible. The analysis in Chapter 3 shows that the widespread integration into intended national climate contributions of a handful of energy sector measures would result in total global energy-related emissions ceasing to rise by 2020, without prejudice to regional economic growth and development (Figure 5.4). The Bridge Scenario is not, in itself, a 2 °C scenario, but the near-term peak in emissions that it delivers is a necessary step towards a 2 °C pathway. A near-term peak in global emissions is also critical for credibility of overall climate efforts: if investors and policymakers see global emissions slow then peak, this in itself will be a hugely significant signal that the transition is underway.

While achievement of an early peak in emissions implies success for decoupling at global level between economic growth and growth in greenhouse-gas (GHG) emissions, it does not imply that this decoupling occurs in all countries within the same timeframe. The implementation of the five energy sector policies proposed in the Bridge Scenario locks in the decoupling observed in OECD countries since 2011. It also enables the initial signs of decoupling observed in China's emissions in 2014 to hold through to 2025, enabling a near doubling of the economy with an almost flat emissions trajectory. In other countries, though there is a clear weakening in the link between development and emissions; emissions still rise, but only at one-fifth of the growth in gross domestic product (GDP).

Figure 5.4 ▷ Global energy-related CO_2 emissions by scenario



With this backdrop, countries that have yet to submit an INDC for 2025 could consider putting forward a mitigation goal that is at least in line with the scale of ambition reflected in the Bridge Scenario presented in Chapter 3. Countries that have already submitted INDCs for 2025 could consider whether to:

- Strengthen mitigation goals for the period to 2025, preferably at COP21, but at least before 2020, so that they, at a minimum, reflect the level of ambition expressed in the Bridge Scenario.
- Seek to significantly over-achieve stated 2025 goals by implementing the energy policies outlined in the Bridge Scenario.

The COP21 agreement must therefore set the conditions for a near-term peak in emissions, by creating an opportunity for countries to revisit their 2025 mitigation goals before these are finalised and encouraging consistency of goals and planned policy actions with longer term nationally determined low-carbon development pathways in line with the global 2 °C goal.

Setting strong mitigation goals for 2025 will encourage an early start to national actions, including the GDP-neutral actions of the Bridge Scenario. Strong support for pre-2020 action could be provided by mobilising public and private finance, capacity building, technology transfer and policy collaboration to assist countries to "step onto the Bridge" as soon as possible. Although the actions in the Bridge Scenario are cost-effective, considerable effort and expertise will be required to make them a reality.

Some countries or regions could choose to go beyond the Bridge Scenario. Investing in deeper emission reduction actions in line with a more optimal path to a 2 °C scenario pays off in the long term: the delays built in to the Bridge Scenario involve higher long-term costs than an optimal 2 °C Scenario. Countries that are willing to act early not only lower their transition costs, but play a significant role in demonstrating what is achievable and catalysing greater action elsewhere.

Giving visibility to the policies that underpin mitigation goals also builds confidence and can support early action. Targets need to be ambitious but demonstrably achievable, and reporting the intended policies to deliver these targets can underscore their feasibility. Particular energy sector goals (such as targets for renewable energy or energy efficiency), complementing broader GHG targets, can highlight the drivers of energy system change, not just emissions outcomes. They can also aid public justification because of their associated benefits (e.g. improved standards of living, cost savings, improved health, competitiveness, energy security) and the required implementing measures may be more readily identified. Short-term energy sector goals can also be set which are consistent with long-term decarbonisation, such as one of setting the pattern of infrastructure investment or with milestones for RDD&D (IEA, 2014a; Prag, Kimmel and Hood, 2013).

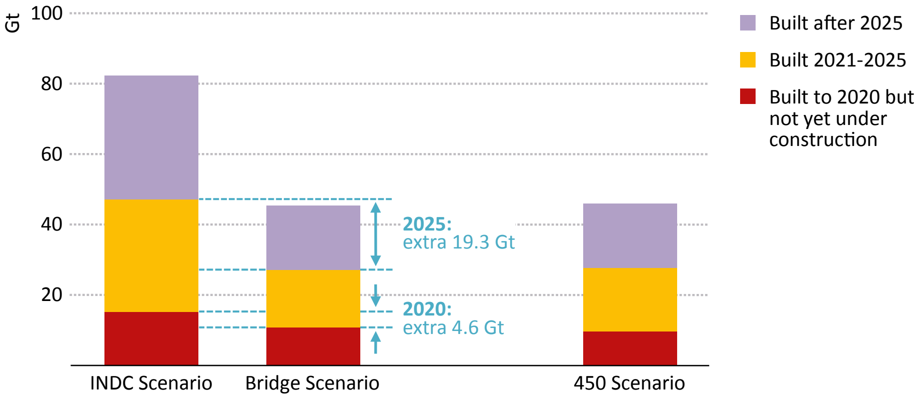
Enhancing ambition: a five-year review cycle

As a second pillar, COP21 needs to agree a clear and timely review process for the progressive strengthening of mitigation goals to meet the 2 °C goal. The environment in which these goals are being set is changing rapidly: the cost and performance of many low-carbon technologies are improving (some rapidly); countries are beginning to see success in implementation of low-carbon policies; and there is a growing sense that a low-carbon future is possible and preferable (albeit not within easy reach). Within such a rapidly changing context, agreeing a mechanism at COP21 to strengthen mitigation goals at least every five years (as opposed to the alternative proposal on the table in the negotiations of leaving them fixed for ten-year periods) creates an opportunity for political ambition to keep pace with external events. A five-year cycle that creates an expectation of rising ambition would also send a clearer message to investors of countries' long-term commitment to progressive decarbonisation. As well as setting explicit five-year goals, countries could provide information looking further out (for example, an early indication of likely 2030 goals by 2020).

An important aspect of this five-year review cycle will be the expectation, which should be set out in the COP21 agreement, that these nationally determined short-term mitigation goals should be consistent with longer term nationally determined low-carbon development pathways (which themselves would be updated over time with changing circumstances). Consistency between short- and longer-term intentions allows decarbonisation to fit within the context of development and reduces the risk that weak goals will be set in the short term to allow room for later strengthening, since the additional long-term economic cost of such an approach will be apparent.

In addition to achieving a peak in global emissions, following the Bridge Scenario to 2025 keeps new build of electricity infrastructure on track. Thanks to efficiency measures and a push towards renewables, the committed emissions from new power plants built to 2025 in the Bridge Scenario are fully compatible with a 2 °C target trajectory (Figure 5.5). By contrast, new power plants built by 2020 in the INDC Scenario would result in cumulative emissions through 2040 of 4.6 Gt CO_2 above levels consistent with a 2 °C path, rising to 19.3 gigatonnes (Gt) of CO_2 when plants built in the following five years are taken into account. From an infrastructure perspective, delaying to adopt a Bridge strategy significantly increases the size of the challenge of wrenching power sector emissions back onto a 2 °C path thereafter. Such a high level of high-carbon infrastructure also increases the risk of assets becoming stranded if strict climate policies are adopted later.

Figure 5.5 ▻ Global committed CO_2 emissions through 2040 from new power plants



Note: "Committed emissions" are the cumulative emissions to 2040 from these plants, operating under the conditions of the corresponding scenario.

With a five-year review cycle, mitigation goals for the 2025-2030 period would be set before 2025 for those that do not have them, and existing 2030 targets reviewed, and if appropriate, revised for those that do. If countries have brought their 2025 climate contributions into line with the measures recommended in the Bridge Scenario, then global energy-related GHG emissions will have already peaked by the time 2025-2030 goals are being set, building momentum for greater action after 2025.

The level of mitigation ambition countries put forward for the 2025-2030 period will be a key determinant of whether the global 2 °C goal remains within reach. The Intergovernmental Panel on Climate Change's *Fifth Assessment Report* found that very few scenarios with annual GHG emissions above 2010 levels in 2030 still had at least a 50% chance of meeting the 2 °C goal, and these all require net global CO_2 emissions to become negative before 2100.[1] In 2 °C scenarios that do not rely on net negative CO_2 emissions, GHG emissions must fall substantially below 2010 levels by 2030 (IPCC, 2014).

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[1] "Negative emissions" refers to net storage of CO_2 through measures such as afforestation, combining biomass power generation with CCS to store the resulting CO_2, or direct air capture and storage of CO_2. Achieving net negative emissions would entail total annual storage higher than total annual emissions.

Box 5.2 ▷ Reducing emissions from international aviation and shipping

The international aviation and maritime sectors are major consumers of oil; together they consumed around 7.0 million barrels per day of oil in 2013, 8% of global oil demand. These sectors' contribution to global emissions is on the rise as well; while they accounted for only 4% of global CO_2 emissions growth between 1990 and 2013, they are expected to be among the fastest growing sectors over the next decades.

This does not mean that progress has been absent. Continuous improvements have been achieved in the efficiency of new aircraft, containing emissions growth. In the maritime sector, "slow steaming"[2] has helped to reduce emissions growth in recent years (partially driven by high oil prices). Both the shipping and aviation industries have also been actively seeking to implement other forms of mitigation. The International Maritime Organization (IMO) has made the Energy Efficiency Design Index (EEDI) mandatory for new ships and the Ship Energy Efficiency Management Plan is similarly mandatory for all ships; the EEDI standards will be implemented in progressive phases, evolving towards a 30% improvement (compared with the average efficiency of ships built between 2000 and 2010) by 2025. The International Civil Aviation Organization (ICAO) has put in place a voluntary 2% annual efficiency improvement target to 2050 and an aim for "carbon neutral growth" from 2020 (ICAO, 2010). Pursuant to a resolution by the ICAO Assembly in 2013, the organisation is developing a package of measures to achieve carbon neutral growth goal, including a CO_2 emissions standard for aircraft engines and a global market-based measure (MBM) for CO_2 emissions from international aviation, for consideration at its next assembly in October 2016.

However, efforts to build a broader global framework so far have not materialised. There are a number of policy options that could help curtail further emissions growth. They include regulatory instruments, such as fuel efficiency and emission standards at an aircraft/vessel or system level or regulations targeting the GHG intensity of fuels, that could foster the deployment of low-carbon fuels; and market-based approaches such as the global MBM being developed by ICAO (and more generally including emissions trading under caps, or fuel or emission taxes – international aviation and shipping are exempted from fossil-fuel taxation). But all these instruments require agreement at an international level, a long and difficult process. Although not explicitly part of the agenda of the UNFCCC negotiations, the upcoming COP21 meeting is an opportunity to take stock of progress in these key sectors in an attempt to boost collective efforts at the IMO and ICAO.

Energy-related CO_2 emissions in the Bridge Scenario are still above 2010 levels in 2030, so to follow a pathway realistically consistent with 2 °C, countries must step-up ambition from 2025. To move from the Bridge Scenario in 2025 onto a 2 °C pathway would require

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[2] This refers to ships operating at lower speeds to reduce fuel consumption thereby reducing costs and carbon emissions.

a sustained reduction in global energy CO_2 emissions intensity (energy-related CO_2/GDP), averaging 5.5% per year between 2030 and 2050 (up from 5.0% in the 450 Scenario). The challenge of delivering this rate of change should not be underestimated. Infrastructure transitions of this magnitude have been achieved in the past in exceptional circumstances in some IEA member countries, during periods of government-led reform, such as the nuclear build programmes in France and Sweden.[3] In emerging economies with greater potential for efficiency improvement, high rates of decoupling have also been shown to be possible, though they are exceptional – for example China experienced a 5.9% annual emissions intensity improvement between 1990 and 2000. However across both developed and developing countries, the average rate of improvement in emissions intensity to date has been far lower, averaging only 1.5% per year between 1990 and 2010.

Given the two-year delay in production of official emissions statistics, countries will inevitably be developing targets for the next five-year period before the final results of the current period are known – with biennial reporting of emissions inventories, countries may only have one data point from the current five-year period before they put forward their next target. This highlights the importance of developing capacity to track the evolution of the domestic energy sector (which ideally would be supplemented by capacity for energy sector modelling) to give a clearer understanding of probable developments.

Locking in the long-term vision

The international community has adopted a common goal for action on climate change – the 2 °C target – in the UNFCCC. While this is a valid long-term goal, it is not easy to translate it into practical policy and investment needs. Further steps are needed in the COP21 agreement to lock in the 2 °C vision more strongly, so that it anchors future expectations, guiding policymaking and both public and private energy sector investment decisions, and acts as a standard against which short-term government targets and actions can be assessed. These further steps form the third key pillar of our recommended approach to the COP21 agreement.

Failure to link short- and long-term decisions is costly. Many energy sector investment decisions relate to long-lived capital-intensive infrastructure, emphasising the need to make effective risk assessments about future developments. A focus only on short-term emissions targets to 2025, themselves important to avoid excess emissions in the short term, could lead to the adoption of a technology mix that is far from optimal if not devised in the light of a longer term decarbonisation plan, resulting in increasing the cost of achieving critical climate goals.

A first step to lock-in the 2 °C vision more strongly in the COP21 agreement would be to re-express that goal in terms of a long-term GHG emissions target. This would be more straightforward to apply in the energy sector and lend itself to easier accounting

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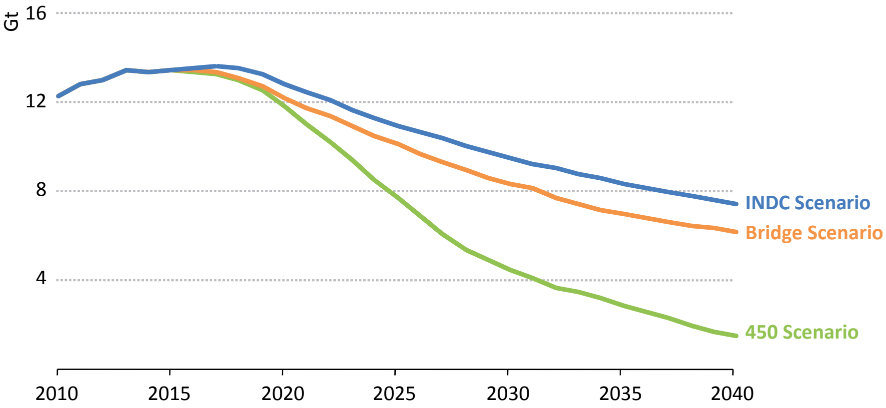
[3] The nuclear power programmes resulted in a reduction in France's energy-related CO_2/GDP ratio averaging 5.4% per year between 1978 and 1988, and in Sweden averaging 6.2% between 1979 and 1989.

for monitoring. A number of possible options for supplementing the 2 °C goal in this way have been tabled for consideration in the run-up to COP21, including a target level for 2050 emissions, a target date for net-zero emissions in the second-half of this century, or a timeline for the phase-out of unabated fossil fuels. Adoption of such specific, emissions-focused long-term goals to complement the existing 2 °C goal would be a valuable additional signal to the energy sector of the need for transformative change.[4]

The second step, needed to ensure that any long-term goal is meaningful – whether framed in terms of temperature or emissions – is to create a clear link between it and countries' actions, rather than it being just an aspirational statement. The global goal should be used by all countries to inform nationally determined decarbonisation or low-carbon development pathways (SDSN, 2014), which would in turn provide an important benchmark for the short-term goals countries set in the five-year review cycle. Whether the national pathway involves an immediate fall in total emissions (such as in the United Kingdom's carbon budget framework) or a peak then later decline (such as in South Africa's pathway) will usually depend on the country's development status. Many developing countries give priority to their economic and social development. The COP21 agreement must recognise this, embedding climate goals in plans which permit countries to achieve these aspirations.

Figure 5.6 ▷ **Global emissions from power plants, existing and under construction**



As well as assisting in sending a clear signal to investors in new long-lived assets, the newly expressed long-term goal and low-carbon development pathways will shape decisions on the operation or retirement of existing capital stock and technology development. Goals and actions reflected in the INDC Scenario result in operating existing power plants and those under construction in such a way that they emit some 275 Gt from 2015 to 2040 (Figure 5.6).

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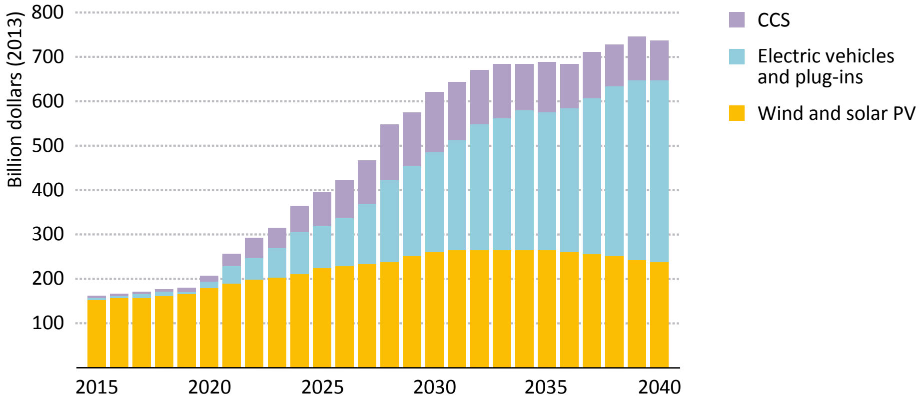
[4] The particular form of the goal would need to take into account the uncertainty in translating temperature rise probabilities into specific emissions targets and the need for flexibility to incorporate updated scientific knowledge.

The efficiency measures and the push towards renewables adopted in the Bridge Scenario would reduce this by almost 10%; but a trajectory compatible with a 2 °C objective that fully internalises a long-term decarbonisation vision would need to cut cumulative emissions by around 35% by driving action to ensure the retirement of old high-emitting capital stock, allowing only very efficient or low-carbon generating plant to operate.

A long-term global emissions goal can also boost further energy technology development. The benefits of earlier investment in solar and wind generation are now being seen in rapidly falling prices. As explored in more detail in Chapter 4, the same process will need to be followed to bring forward carbon capture and storage, battery storage, electric and other low-emissions vehicles and other emerging technologies (Figure 5.7). A clear, measurable long-term vision in the COP21 agreement will underpin investment in those key technologies that are essential to unlock long-term emission reductions compatible with a 2 °C trajectory.

Figure 5.7 ▻ **Global investment in variable renewables, CCS and electric vehicles in the 450 Scenario**



There are also a number of more detailed ways the COP21 decisions (and subsequent technical work programmes) can address aspects of technology development (IEA, 2015a): reporting on technology progress ahead of each five-year review; global goals for RDD&D levels; country reporting on low-carbon technology actions; and strengthening the link between the technology and finance aspects of the UNFCCC. The technology needs assessments and technology action plans prepared by developing countries should be integrated into wider low-carbon development strategies, improving alignment between these countries' development, mitigation and technology goals (Box 5.3). Parties should also be encouraged to increase international co-operation to scale-up low-carbon technologies. There are many existing multilateral technology and policy collaborations on topics such as carbon pricing, renewable energy and energy efficiency. Care should be taken to build on, consolidate and not duplicate these efforts.

Box 5.3 ▷ Climate resilience of the energy sector

Energy supply, transmission and demand can all directly be affected by changes to the climate, including higher temperatures, more frequent and extreme weather events, changes in water availability, sea level rise and permafrost melting. The long life of many energy sector assets, which rightly are classified as essential national infrastructure, underlines the need for governments and industry to develop and implement effective strategies to improve climate resilience (IEA, 2013). Climate-induced changes in the availability of water are a major concern for energy supply and power generation. This is because reduced water availability will constrain energy production from fossil fuels, nuclear power, biofuels, hydropower and some solar power systems. Both thermal and nuclear power plants require water for cooling; apart from reduced water availability, a rise in water temperature reduces the overall plant efficiency.[5]

The risks posed to the energy sector from climate change and the need to adapt is increasingly recognised, but there is still a long way to go in terms of improving climate resilience. Some countries have launched climate change risk assessments, as well as national adaptation strategies and programmes that include specific energy sector analysis. In recent years, the European Union, United States, Canada and China have all launched adaptation strategies.

The UNFCCC National Adaptation Programmes of Action and National Adaptation Plans (NAPs) processes can help least-developed countries to communicate their most urgent adaptation needs. Further actions that could be taken in countries' INDCs and through the COP21 decisions include:

- Exploring energy sector mitigation actions that also enhance resilience (e.g. energy efficiency, decentralised renewable generation).
- Integrating or interlinking low-carbon development strategies to underpin mitigation with NAPs to support resilient, low-carbon growth.
- Encouraging countries to include the energy sector in their NAPs.
- Incorporating climate risks to energy infrastructure, supply and demand into Green Climate Fund investment decisions.

While developing countries, especially the least developed, are often the most vulnerable to the impacts of climate change, all countries around the world will be affected and need to adapt. An important task is to protect energy infrastructure and ensure energy security. Governments should support the private sector through policy and regulatory oversight, technology development and providing information about expected future climate developments.

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[5] The link between water and energy will be analysed in a chapter of the *World Energy Outlook-2015* to be published 10 November 2015.

Tracking the energy transition

Whatever the outcome of COP21, the actions to reduce emissions will be driven largely by countries' domestic policies and, after COP21, policymakers' attention will turn to the design and implementation of effective policy packages to deliver their short- and long-term emission goals. Given its reliance on nationally determined action, the COP21 agreement will need to provide a strong framework for tracking progress. This is the fourth pillar of these recommendations. Each country needs effective tools to track policy results over time; and tangible evidence of results will reassure the international community that others are acting diligently. Tracking progress will identify countries that are struggling with implementation and enable timely assistance to be provided if needed. Successful management depends both on what is measured (the choice of metrics), and how thoroughly tracking is done (the quality of the processes for measurement and reporting of emissions and of accounting for achievement of targets).

The UNFCCC process already includes biennial reporting of GHG emission inventories and mitigation actions for both developed and developing countries,[6] as well as more detailed national communications every four years, providing a solid basis to work from. Details of the post-2020 reporting and accounting frameworks may not be agreed at COP21: these can be the subject of subsequent technical work programmes. The COP21 agreement, however, must set the high-level principles, including the need for agreed rules for the measurement and reporting of emissions (such as use of latest IPCC guidelines), and the provision for developing accounting rules for the wide range of goal types countries are likely to put forward. The COP21 agreement should provide for progress toward long-term objectives (the global goal and nationally determined low-carbon development pathways) to be reported and tracked, in addition to measuring progress towards each five-year goal. Tracking progress toward long-term objectives will require a wider focus on the drivers of change, such as energy sector investment patterns, not just GHG levels.

Some countries may express their nationally determined contributions to the COP21 agreement in terms of particular energy sector objectives, such as the share of total energy supply to come from renewables, the rate of decline in fossil-fuel subsidy levels, or the scale of energy intensity improvement, possibly within an overall GHG reduction target. The UNFCCC will need to develop processes to account for the achievement of such energy sector goals, as well as setting details of how to account for more traditional GHG targets. Even where countries frame their nationally determined contribution only as a GHG emissions goal, reporting and tracking other key energy sector details could provide useful supplemental information regarding contributing developments, while also contributing to co-operation between nations on areas of common interest, such as the effective promotion of energy efficiency or the phase-out of fossil-fuel subsidies.

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[6] The details are currently different for developed and developing countries, with developed country reports containing more detailed information such as projections of future emissions, and being subject to more stringent review processes. Developed countries also report GHG inventories annually.

Tracking progress toward deep energy sector decarbonisation is complex and requires a broader set of measurements than are collected and monitored in many countries at present. At the highest level (Table 5.1) these measurements should cover energy supply and demand and include measures of the overall state of the energy system (such as aggregate energy demand) as well as of the underlying drivers of change (such as the investment rate in low-carbon energy) (IEA, 2014a; IEA, 2015a; Prag, Kimmel and Hood, 2013).

Table 5.1 ▻ High-level metrics to track energy sector decarbonisation

Sector	Metric	Unit
Aggregate energy sector	• Carbon intensity of primary energy supply	t CO_2/toe
	• Energy intensity of GDP	toe/$
	• New investment in low-carbon energy supply and energy efficiency	$
	• Share of renewables in final energy demand	%
	• Population and share of population without access to electricity and/or reliant on traditional biomass use for cooking.	Million, %
	• Fossil-fuel subsidies	$, % of GDP
	• Percentage of energy sector emissions covered by carbon pricing	%
	• Public and private investment in low-carbon energy RDD&D	$, % of GDP
Power	• CO_2 emissions per unit of electricity	g CO_2/kWh
	• Average efficiency of all fossil-fuel plants	%
	• Share of low-carbon generation in new additions*	%
Transport	• New passenger cars: CO_2 emissions per vehicle-kilometre	g CO_2/v-km
	• Road freight vehicles: CO_2 emissions per tonne-kilometre	g CO_2/t-km
	• Carbon intensity of total transport fuel demand	t CO_2/toe
Buildings	• Residential: energy demand per dwelling	kWh/dwelling
	• Services: energy demand per square metre of floor space	kWh/m^2
	• Retrofit rate for existing buildings	%/year
Industry**	• CO_2 emissions per unit of value added	t CO_2/$1 000
	• CO_2 emissions in steel production (includes blast furnaces and coke ovens) per unit of steel produced	t CO_2/tonne
	• CO_2 emissions in cement production per unit of cement produced	t CO_2/tonne
Fossil-fuel systems	• Share of natural gas vented or lost out of total gas produced	%
	• GHG emissions from fugitive emissions, gas venting, flaring and losses per unit of energy extracted	t CO_2-eq/toe

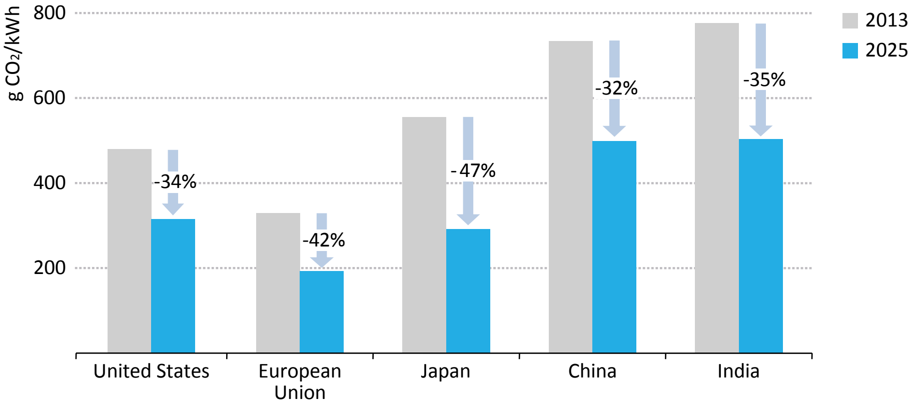
* Includes renewables, nuclear and plants incorporating carbon capture and storage (CCS). For CCS, the relevant measurement includes only the portion which is captured. ** Sub-sectoral metrics for steel and cement are shown here as examples; other sub-sectors should also be tracked.

Notes: toe = tonnes of oil equivalent, g CO_2/kWh = grammes of CO_2 per kilowatt-hour, g CO_2/v-km =grammes of CO_2 per vehicle-kilometre, g CO_2/t km= grammes of CO_2 per tonne-kilometre.

As well as high-level metrics, the IEA recommends that countries build capacity to collect detailed energy data at the sectoral and sub-sectoral level in order to better understand the changes occurring in national energy systems and better inform policymaking (IEA, 2014b). The precise set of metrics used should be tailored to fit with national targets and objectives, taking into account that some data will be quickly available (such as power generation), while others make take up to two years to collect. Support for capacity building in energy statistics will be important for many developing countries.[7]

Frameworks, both national and international, need to look beyond activities with a short-term effect and include tracking of those which may have little impact on GHG emissions in the near term. Examples include more compact urban development, public transport promotion, strengthening building codes to improve efficiency and requiring the use of best-available industrial technology in new investments.

Figure 5.8 ▻ **CO_2 emissions intensity of electricity generation by selected region in the Bridge Scenario**



Widening the range of data tracked can usefully illustrate the commonality of the challenge faced by both developing and developed countries to decarbonise their energy systems. For example, Figure 5.8 shows how the emissions intensity of electricity generation changes in key regions in the Bridge Scenario. Although the starting points vary substantially, assessing the percentage change compared to 2013 levels makes the common endeavour more obvious: all five regions reduce the GHG emissions intensity of power generation substantially by 2025.

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[7] Specific guidance on energy efficiency metrics can be found in *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014b) and *Energy Efficiency Indicators: Essentials for Policymaking* (IEA, 2014c). The *Tracking Clean Energy Progress Report* (IEA, 2015b) could be extended to cover a wider range of sectoral measurements, including individual country data, needed within the UNFCCC reporting framework to track energy sector developments.

Policies and measures

General note to the tables

The tables detail underlying assumptions about government policies for the INDC Scenario by region. This scenario represents a preliminary assessment of the implications of the submitted Intended Nationally Determined Contributions (INDCs) and statements of intended INDC content for some countries. An update, including the latest INDCs, will be published in November 2015 for the IEA Ministerial meeting.

All INDCs that had been formally submitted to the UNFCCC Secretariat by 14 May 2015 have been included in Table A.1 in the order in which they have been submitted. Liechtenstein and Andorra have not been included in Table A.1, but the high-level target is included in Chapter 1, Table 1.1. Table A.2 sets out the details about policies for countries that have made statements indicating the likely content of an INDC that has yet to be delivered (or otherwise announcing plans to reduce emissions). These declarations have been taken as the basis for policies assumptions. For countries that have not yet submitted an INDC and have not publicly stated its likely content, or specified policies for the entire energy sector, the INDC Scenario includes the policies defined in the New Policies Scenario of the *World Energy Outlook 2014*.

Table A.1 ▷ Intended Nationally Determined Contributions (INDC) by selected UNFCCC Party (submitted by 14 May 2015)

UNFCCC Party	Copenhagen pledge (GHG)	INDC	Recent developments/targets and possible strategies for the energy sector
Switzerland	20%/30% below 1990 levels by 2020.	Reduce GHG emissions by 50% below 1990 levels by 2030 (35% below by 2025).	2012 Ordinance for the Reduction of CO_2 Emissions: • Limit emissions relative to 1990 levels: from buildings to no more than 78%; from industry to no more than 93%; and from transport not to exceed 100%.
European Union	20%/30% below 1990 levels by 2020.	Reduce EU domestic GHG emissions at least 40% below 1990 levels by 2030.	2014 Climate and Energy Policy Framework for 2030: • Achieve at least 27% of renewables and energy efficiency targets for 2030.
Norway	30%/40% below 1990 levels by 2020.	Reduce GHG emissions by at least 40% compared to 1990 levels by 2030.	2015 White Paper priority areas: • Reduce emissions from transport and industry. • CCS; renewables and low-carbon shipping.
Mexico	Up to 30% below with respect to business-as-usual by 2020.	Reduce GHG and short-lived climate pollutant emissions unconditionally by 25% by 2030 with respect to business-as-usual.	2013 National Climate Change Strategy: • At least 40% of power generation from clean sources within 20 years; incentive systems to promote energy efficiency and reduce methane emissions from oil and gas production.
United States	Relative to 2005 levels: 17% below by 2020, 42% below by 2030 and 83% below by 2050.	Reduce net GHG emissions 26-28% below 2005 levels by 2025.	2013 Climate Action Plan: • Carbon pollution standards for new and existing power plants. • Post-2018 heavy-duty vehicle fuel efficiency standards. • Achieve a 40-45% reduction in methane emissions from 2012 levels by 2025 from oil and gas production.
Gabon	Several actions to reduce emissions from forestry and the energy sectors.	Reduce CO_2, CH_4, N_2O emissions by at least 50% with respect to a reference scenario by 2025.	2012 Climate Plan: • Reduction of CH_4 flaring via reinjection and use in power generation. • 80% of power generation from hydropower by 2020.
Russia	15-25% below 1990 levels by 2020 (25% affirmed by presidential decree).	Reduce anthropogenic GHG emissions by 25-30% below 1990 levels by 2030 subject to the maximum possible account of absorptive capacity of forests.	2010 Energy Strategy to 2030: • Reduce energy intensity 56% below 2005 level by 2030. • Increase the share of non-fossil fuels in primary energy demand to 13-14% by 2030.

Table A.2 ▷ Assumptions for selected countries

UNFCCC Party	Copenhagen pledge (GHG)	Assumptions in the INDC Scenario	Recent developments/targets and possible strategies
Japan	25% below 1990 levels by 2020.	Target to increase renewables to over 20% of power generation by 2030. Gradual restart of electricity generation from nuclear power plants.	April 2014: New Strategic Energy Plan. March 2015: Cabinet decision on the proposed Act for the Improvement of the Energy Saving Performance of Buildings.
Korea	30% below business-as-usual emissions by 2020.	30% reduction in GHG emissions by 2020 with respect to business-as-usual.	2013 2nd National Basic Energy Plan. 1st stage of emissions trading (2015-2017). Renewable portfolio standards.
China	Emission intensity 40-45% below 2005 levels by 2020.	Peak CO_2 emissions by around 2030. Increase non-fossil fuel share in primary energy to 20% by 2030.	2011 12th Five-Year Plan: • 16% reduction in energy intensity from 2005 by 2015. 2014 Energy Development Strategic Action Plan and National Climate Change Plan (2014-2020): • Maximum 4.8 billion tonnes of coal equivalent per year (primary energy consumption). • Limit the share of coal to less than 62% of total primary energy demand in 2020. • 20% non-fossil fuel share of primary energy consumption by 2030. • 100 GW of PV and 200 GW of wind capacity.
India	Emission intensity 20-25% below 2005 levels by 2020.	Target to increase renewables to 175 GW by 2022, of which, 100 GW of solar.	2008 National Action Plan on Climate Change. 2013 12th Five-Year Plan (2012–2017). Target of 175 GW of renewables by 2022.
Brazil	36-39% below projected emissions by 2020.	36% reduction in GHG emissions by 2020 with respect to business-as-usual.	Ten-Year Plan for Energy Expansion. National Energy Efficiency Plan.

Data tables for the Bridge Scenario

General note to the tables

The tables detail projections for *energy demand*, *gross electricity generation* and *electrical capacity* and *carbon-dioxide (CO_2) emissions* from fossil-fuel combustion in the Bridge Scenario. The following regions are covered: World, OECD, OECD Americas, the United States, OECD Europe, the European Union, OECD Asia Oceania, non-OECD, Eastern Europe/Eurasia, Russia, non-OECD Asia, China, India, the Middle East, Africa and Latin America. The definitions for regional groupings can be found in Annex C.

Data for *energy demand*, *gross electricity generation* and *CO_2 emissions* from fossil-fuel combustion up to 2012 are based on IEA statistics, published in *Energy Balances of OECD Countries*, *Energy Balances of non-OECD Countries*, *CO_2 Emissions from Fuel Combustion* and the *IEA Monthly Oil Data Service*. Historical data for *gross electrical capacity* are drawn from the Platts World Electric Power Plants Database (December 2013 version) and the International Atomic Energy Agency PRIS database *(http://www.iaea.org/pris/)*. The data presented for 2013 are preliminary but, wherever possible, include the latest available country submissions. Final 2013 data will be available in *World Energy Outlook 201*5.

Both in the text of this book and in the tables, rounding may lead to minor differences between totals and the sum of their individual components. Growth rates are calculated on a compound average annual basis and are marked "n.a." when the base year is zero or the value exceeds 200%. Nil values are marked "-".

Definitional note to the tables

Total primary energy demand (TPED) is equivalent to power generation plus other energy sector excluding electricity and heat, plus total final consumption (TFC) excluding electricity and heat. TPED does not include ambient heat from heat pumps or electricity trade. Sectors comprising TFC include industry, transport, buildings (residential, services and non-specified other) and other (agriculture and non-energy use). Projected gross electrical capacity is the sum of existing capacity and additions, less retirements. Total CO_2 includes emissions from other energy sector in addition to the power generation and TFC sectors shown in the tables. CO_2 emissions and energy demand from international marine and aviation bunkers are included only at the world transport level. Gas use in international bunkers is not itemised separately. CO_2 emissions do not include emissions from industrial waste and non-renewable municipal waste.

World: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**8 790**	**13 579**	**14 623**	**14 999**	**15 370**	**100**	**100**	**0.7**
Coal	2 231	3 973	3 963	3 704	3 448	29	22	-0.8
Oil	3 235	4 235	4 415	4 373	4 313	31	28	0.1
Gas	1 672	2 880	3 152	3 389	3 547	21	23	1.2
Nuclear	526	646	841	938	1 044	5	7	2.9
Hydro	184	320	386	434	482	2	3	2.4
Bioenergy	905	1 366	1 545	1 677	1 827	10	12	1.7
Other renewables	36	159	320	484	708	1	5	9.2
Power generation	**2 987**	**5 173**	**5 516**	**5 659**	**5 846**	**100**	**100**	**0.7**
Coal	1 225	2 472	2 342	2 058	1 801	48	31	-1.8
Oil	377	300	217	171	135	6	2	-4.6
Gas	583	1 162	1 226	1 345	1 388	22	24	1.1
Nuclear	526	646	841	938	1 044	12	18	2.9
Hydro	184	320	386	434	482	6	8	2.4
Bioenergy	60	146	233	294	376	3	6	5.7
Other renewables	32	127	271	419	620	2	11	9.8
Other energy sector	**903**	**1 668**	**1 747**	**1 773**	**1 790**	**100**	**100**	**0.4**
Electricity	*183*	*334*	*362*	*377*	*394*	*20*	*22*	*1.0*
TFC	**6 298**	**9 095**	**10 027**	**10 400**	**10 729**	**100**	**100**	**1.0**
Coal	769	934	1 021	1 036	1 027	10	10	0.6
Oil	2 608	3 671	3 941	3 962	3 965	40	37	0.5
Gas	950	1 370	1 574	1 679	1 781	15	17	1.6
Electricity	834	1 666	1 938	2 089	2 240	18	21	1.8
Heat	337	294	305	308	307	3	3	0.3
Bioenergy	796	1 129	1 200	1 260	1 322	12	12	0.9
Other renewables	4	32	48	65	87	0	1	6.0
Industry	**1 804**	**2 654**	**3 045**	**3 219**	**3 350**	**100**	**100**	**1.4**
Coal	475	752	826	843	840	28	25	0.7
Oil	325	302	321	323	323	11	10	0.4
Gas	357	564	681	745	801	21	24	2.1
Electricity	381	711	849	909	958	27	29	1.8
Heat	153	134	146	150	149	5	4	0.6
Bioenergy	113	190	218	245	272	7	8	2.1
Other renewables	0	1	2	4	7	0	0	13.5
Transport	**1 575**	**2 535**	**2 795**	**2 856**	**2 914**	**100**	**100**	**0.8**
Oil	1 479	2 350	2 546	2 549	2 540	93	87	0.5
Of which: Bunkers	*201*	*357*	*386*	*408*	*431*	*14*	*15*	*1.1*
Electricity	21	26	34	43	55	1	2	4.6
Biofuels	6	63	96	127	160	2	5	5.6
Other fuels	69	96	119	137	159	4	5	3.0
Buildings	**2 252**	**2 987**	**3 111**	**3 175**	**3 251**	**100**	**100**	**0.5**
Coal	239	124	113	104	93	4	3	-1.7
Oil	326	323	288	260	234	11	7	-1.9
Gas	435	614	651	665	678	21	21	0.6
Electricity	402	876	990	1 065	1 147	29	35	1.6
Heat	175	153	153	153	153	5	5	0.0
Bioenergy	671	868	872	871	871	29	27	0.0
Other renewables	4	30	43	57	75	1	2	5.6
Other	**667**	**919**	**1 075**	**1 151**	**1 214**	**100**	**100**	**1.7**

World: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**11 825**	**23 234**	**26 734**	**28 672**	**30 620**	**100**	**100**	**1.6**
Coal	4 425	9 612	9 485	8 428	7 478	41	24	-1.5
Oil	1 310	1 116	783	618	487	5	2	-4.8
Gas	1 760	5 026	5 913	6 818	7 223	22	24	2.2
Nuclear	2 013	2 477	3 226	3 598	4 005	11	13	2.9
Hydro	2 144	3 722	4 489	5 050	5 607	16	18	2.4
Bioenergy	132	440	757	986	1 288	2	4	6.5
Wind	4	628	1 389	2 065	2 870	3	9	9.4
Geothermal	36	71	120	186	280	0	1	8.4
Solar PV	0	134	527	820	1 136	1	4	13.4
CSP	1	6	41	95	227	0	1	23.4
Marine	1	1	3	7	17	0	0	21.9

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**5 956**	**7 221**	**7 989**	**8 809**	**100**	**100**	**2.3**
Coal	1 878	2 025	1 955	1 854	32	21	-0.1
Oil	452	368	317	271	8	3	-3.0
Gas	1 530	1 811	1 965	2 107	26	24	1.9
Nuclear	392	449	490	542	7	6	1.9
Hydro	1 128	1 345	1 505	1 670	19	19	2.3
Bioenergy	106	154	193	245	2	3	5.1
Wind	317	623	884	1 173	5	13	8.0
Geothermal	12	18	28	42	0	0	7.8
Solar PV	136	414	621	837	2	9	11.3
CSP	4	13	28	63	0	1	18.4
Marine	1	1	2	6	0	0	15.4

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**20 934**	**32 192**	**32 861**	**32 005**	**30 897**	**100**	**100**	**-0.2**
Coal	8 317	14 324	14 062	12 888	11 672	44	38	-1.2
Oil	8 814	11 305	11 608	11 389	11 158	35	36	-0.1
Gas	3 803	6 564	7 191	7 728	8 067	20	26	1.2
Power generation	**7 476**	**13 534**	**12 862**	**11 805**	**10 659**	**100**	**100**	**-1.4**
Coal	4 915	9 864	9 307	8 119	6 995	73	66	-2.0
Oil	1 199	943	682	539	425	7	4	-4.6
Gas	1 362	2 728	2 873	3 146	3 239	20	30	1.0
TFC	**12 461**	**17 020**	**18 311**	**18 511**	**18 563**	**100**	**100**	**0.5**
Coal	3 262	4 168	4 458	4 479	4 399	24	24	0.3
Oil	7 061	9 733	10 294	10 243	10 151	57	55	0.2
Transport	*4 383*	*7 003*	*7 591*	*7 604*	*7 582*	*41*	*41*	*0.5*
Of which: Bunkers	*620*	*1 100*	*1 190*	*1 256*	*1 324*	*6*	*7*	*1.1*
Gas	2 138	3 119	3 559	3 790	4 012	18	22	1.5

OECD: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**4 525**	**5 293**	**5 275**	**5 083**	**4 919**	**100**	**100**	**-0.4**
Coal	1 080	1 030	853	644	470	19	10	-4.5
Oil	1 873	1 905	1 790	1 621	1 458	36	30	-1.6
Gas	843	1 357	1 411	1 468	1 459	26	30	0.4
Nuclear	451	511	589	585	604	10	12	1.0
Hydro	102	121	127	133	139	2	3	0.8
Bioenergy	147	280	342	394	455	5	9	2.9
Other renewables	29	89	163	238	333	2	7	8.0
Power generation	**1 718**	**2 196**	**2 177**	**2 108**	**2 060**	**100**	**100**	**-0.4**
Coal	759	822	651	451	285	37	14	-6.0
Oil	154	79	38	26	21	4	1	-7.6
Gas	176	489	504	561	554	22	27	0.7
Nuclear	451	511	589	585	604	23	29	1.0
Hydro	102	121	127	133	139	6	7	0.8
Bioenergy	53	94	122	140	160	4	8	3.2
Other renewables	25	79	146	213	297	4	14	8.1
Other energy sector	**405**	**502**	**507**	**493**	**483**	**100**	**100**	**-0.2**
Electricity	*105*	*127*	*125*	*123*	*120*	*25*	*25*	*-0.3*
TFC	**3 108**	**3 597**	**3 632**	**3 531**	**3 430**	**100**	**100**	**-0.3**
Coal	234	119	116	110	103	3	3	-0.9
Oil	1 593	1 703	1 637	1 491	1 348	47	39	-1.4
Gas	589	722	745	741	730	20	21	0.1
Electricity	552	799	840	854	863	22	25	0.5
Heat	43	60	60	59	58	2	2	-0.2
Bioenergy	94	184	218	252	292	5	9	2.8
Other renewables	4	10	16	24	36	0	1	7.9
Industry	**827**	**799**	**827**	**816**	**793**	**100**	**100**	**-0.0**
Coal	160	95	93	89	83	12	11	-0.8
Oil	168	96	90	84	77	12	10	-1.3
Gas	226	259	268	263	254	32	32	-0.1
Electricity	222	256	275	274	269	32	34	0.3
Heat	15	25	24	23	22	3	3	-0.7
Bioenergy	37	67	75	81	84	8	11	1.3
Other renewables	0	1	1	2	4	0	1	11.4
Transport	**940**	**1 186**	**1 172**	**1 091**	**1 026**	**100**	**100**	**-0.9**
Oil	914	1 108	1 066	953	846	93	83	-1.6
Electricity	8	9	12	17	24	1	2	6.1
Biofuels	0	43	62	81	106	4	10	5.4
Other fuels	19	26	32	41	49	2	5	3.8
Buildings	**985**	**1 224**	**1 226**	**1 218**	**1 211**	**100**	**100**	**-0.1**
Coal	69	21	19	18	16	2	1	-1.5
Oil	209	155	125	101	77	13	6	-4.0
Gas	304	411	413	405	396	34	33	-0.2
Electricity	316	524	542	552	559	43	46	0.4
Heat	27	35	36	36	36	3	3	0.2
Bioenergy	56	70	77	86	97	6	8	1.9
Other renewables	4	8	14	20	29	1	2	7.6
Other	**355**	**389**	**407**	**406**	**400**	**100**	**100**	**0.2**

OECD: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**7 628**	**10 777**	**11 246**	**11 382**	**11 453**	**100**	**100**	**0.4**
Coal	3 092	3 526	2 866	2 025	1 303	33	11	-5.7
Oil	686	343	157	106	82	3	1	-8.1
Gas	782	2 626	2 893	3 298	3 300	24	29	1.4
Nuclear	1 729	1 960	2 259	2 244	2 319	18	20	1.0
Hydro	1 181	1 408	1 480	1 544	1 611	13	14	0.8
Bioenergy	124	309	411	488	574	3	5	3.7
Wind	4	438	811	1 152	1 537	4	13	7.7
Geothermal	29	46	71	103	144	0	1	7.0
Solar PV	0	114	268	362	461	1	4	8.6
CSP	1	6	27	53	105	0	1	18.0
Marine	1	1	3	7	16	0	0	21.7

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**2 917**	**3 148**	**3 318**	**3 497**	**100**	**100**	**1.1**
Coal	661	572	500	396	23	11	-3.0
Oil	209	126	97	80	7	2	-5.5
Gas	880	982	1 025	1 061	30	30	1.1
Nuclear	315	314	304	311	11	9	-0.1
Hydro	469	490	511	531	16	15	0.7
Bioenergy	68	82	95	109	2	3	2.8
Wind	194	334	458	588	7	17	6.7
Geothermal	7	10	15	21	0	1	6.3
Solar PV	109	227	297	366	4	10	7.4
CSP	3	9	15	29	0	1	13.7
Marine	1	1	2	6	0	0	15.2

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**11 099**	**12 078**	**11 090**	**9 869**	**8 613**	**100**	**100**	**-2.0**
Coal	4 142	3 949	3 227	2 368	1 602	33	19	-5.2
Oil	5 030	4 977	4 597	4 104	3 653	41	42	-1.8
Gas	1 928	3 152	3 266	3 396	3 357	26	39	0.4
Power generation	**3 961**	**4 738**	**3 930**	**3 192**	**2 424**	**100**	**100**	**-3.9**
Coal	3 063	3 340	2 628	1 798	1 069	70	44	-6.5
Oil	487	248	121	82	66	5	3	-7.5
Gas	411	1 150	1 181	1 312	1 290	24	53	0.7
TFC	**6 545**	**6 603**	**6 400**	**5 934**	**5 464**	**100**	**100**	**-1.1**
Coal	1 015	521	508	483	451	8	8	-0.8
Oil	4 180	4 413	4 177	3 747	3 333	67	61	-1.6
Transport	*2 681*	*3 267*	*3 144*	*2 811*	*2 497*	*49*	*46*	*-1.6*
Gas	1 349	1 669	1 715	1 705	1 681	25	31	0.0

OECD Americas: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**2 262**	**2 684**	**2 731**	**2 630**	**2 550**	**100**	**100**	**-0.3**
Coal	491	479	392	268	172	18	7	-5.9
Oil	922	1 002	992	895	806	37	32	-1.3
Gas	517	746	818	870	879	28	34	1.0
Nuclear	180	244	251	251	256	9	10	0.3
Hydro	52	61	65	67	69	2	3	0.7
Bioenergy	82	120	150	180	222	4	9	3.7
Other renewables	19	33	64	98	147	1	6	9.2
Power generation	**852**	**1 068**	**1 059**	**1 021**	**989**	**100**	**100**	**-0.4**
Coal	419	428	342	221	126	40	13	-6.9
Oil	47	22	13	9	7	2	1	-6.6
Gas	95	253	287	333	338	24	34	1.7
Nuclear	180	244	251	251	256	23	26	0.3
Hydro	52	61	65	67	69	6	7	0.7
Bioenergy	41	29	40	49	59	3	6	4.3
Other renewables	19	31	60	92	134	3	14	9.0
Other energy sector	**194**	**274**	**287**	**284**	**282**	**100**	**100**	**0.2**
Electricity	*56*	*64*	*65*	*64*	*62*	*23*	*22*	*-0.2*
TFC	**1 548**	**1 810**	**1 874**	**1 819**	**1 775**	**100**	**100**	**-0.1**
Coal	61	29	29	28	26	2	1	-0.6
Oil	809	914	913	826	746	51	42	-1.2
Gas	361	377	400	401	398	21	22	0.3
Electricity	272	391	412	419	424	22	24	0.5
Heat	3	7	7	7	6	0	0	-1.2
Bioenergy	41	90	109	131	162	5	9	3.5
Other renewables	0	2	4	7	13	0	1	12.1
Industry	**361**	**352**	**380**	**378**	**371**	**100**	**100**	**0.3**
Coal	51	28	28	27	26	8	7	-0.5
Oil	60	36	36	34	32	10	9	-0.7
Gas	138	143	156	154	150	41	40	0.3
Electricity	94	104	114	114	111	30	30	0.4
Heat	1	6	6	6	5	2	1	-0.7
Bioenergy	17	35	40	43	45	10	12	1.5
Other renewables	0	0	0	1	2	0	1	18.3
Transport	**562**	**728**	**732**	**675**	**639**	**100**	**100**	**-0.8**
Oil	543	676	664	583	512	93	80	-1.6
Electricity	1	1	2	6	12	0	2	15.6
Biofuels	-	29	40	54	76	4	12	5.7
Other fuels	18	21	25	32	39	3	6	3.6
Buildings	**461**	**567**	**573**	**570**	**567**	**100**	**100**	**0.0**
Coal	10	1	1	1	0	0	0	-7.0
Oil	64	56	47	39	31	10	5	-3.5
Gas	184	201	201	197	191	35	34	-0.3
Electricity	176	281	292	295	296	50	52	0.3
Heat	2	1	1	1	1	0	0	-4.4
Bioenergy	24	25	28	33	39	4	7	2.5
Other renewables	0	2	3	6	10	0	2	11.0
Other	**164**	**163**	**190**	**195**	**197**	**100**	**100**	**1.1**

OECD Americas: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**3 819**	**5 291**	**5 553**	**5 624**	**5 664**	**100**	**100**	**0.4**
Coal	1 796	1 840	1 505	996	589	35	10	-6.5
Oil	211	99	60	40	33	2	1	-6.3
Gas	406	1 390	1 677	1 979	2 044	26	36	2.3
Nuclear	687	934	962	965	982	18	17	0.3
Hydro	602	710	754	777	801	13	14	0.7
Bioenergy	91	95	138	179	227	2	4	5.3
Wind	3	182	338	483	662	3	12	7.9
Geothermal	21	25	38	52	72	0	1	6.4
Solar PV	0	14	66	117	179	0	3	16.2
CSP	1	1	15	34	72	0	1	27.7
Marine	0	0	0	0	3	0	0	31.3

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**1 373**	**1 432**	**1 507**	**1 588**	**100**	**100**	**0.9**
Coal	354	289	250	173	26	11	-4.1
Oil	89	57	45	40	6	3	-4.5
Gas	505	548	567	599	37	38	1.0
Nuclear	120	124	124	127	9	8	0.3
Hydro	195	204	210	217	14	14	0.6
Bioenergy	21	27	34	42	2	3	4.3
Wind	70	126	178	238	5	15	7.4
Geothermal	4	6	8	10	0	1	5.3
Solar PV	14	47	81	121	1	8	13.6
CSP	1	5	10	19	0	1	19.7
Marine	0	0	0	1	0	0	23.6

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**5 574**	**6 217**	**5 947**	**5 274**	**4 606**	**100**	**100**	**-1.7**
Coal	1 916	1 820	1 477	979	556	29	12	-6.7
Oil	2 469	2 666	2 579	2 286	2 034	43	44	-1.6
Gas	1 189	1 730	1 891	2 009	2 017	28	44	0.9
Power generation	**2 015**	**2 350**	**2 056**	**1 652**	**1 236**	**100**	**100**	**-3.7**
Coal	1 643	1 684	1 340	847	430	72	35	-7.7
Oil	150	75	45	29	24	3	2	-6.5
Gas	222	591	671	775	782	25	63	1.7
TFC	**3 213**	**3 423**	**3 413**	**3 145**	**2 893**	**100**	**100**	**-1.0**
Coal	270	123	124	120	113	4	4	-0.5
Oil	2 115	2 427	2 369	2 104	1 867	71	65	-1.5
Transport	*1 585*	*1 982*	*1 945*	*1 707*	*1 502*	*58*	*52*	*-1.6*
Gas	829	873	919	922	913	25	32	0.3

United States: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**1 915**	**2 185**	**2 203**	**2 091**	**1 995**	**100**	**100**	**-0.5**
Coal	460	444	358	241	152	20	8	-6.1
Oil	757	791	781	693	612	36	31	-1.5
Gas	438	598	653	693	692	27	35	0.9
Nuclear	159	214	222	224	227	10	11	0.3
Hydro	23	23	25	26	28	1	1	1.0
Bioenergy	62	90	114	140	176	4	9	4.0
Other renewables	15	26	49	74	110	1	6	8.9
Power generation	**750**	**899**	**883**	**841**	**802**	**100**	**100**	**-0.7**
Coal	396	398	315	202	114	44	14	-7.1
Oil	27	7	5	4	4	1	0	-4.2
Gas	90	210	239	281	287	23	36	1.9
Nuclear	159	214	222	224	227	24	28	0.3
Hydro	23	23	25	26	28	3	3	1.0
Bioenergy	40	22	30	36	44	2	6	4.3
Other renewables	14	24	46	68	99	3	12	8.6
Other energy sector	**150**	**210**	**213**	**204**	**193**	**100**	**100**	**-0.5**
Electricity	*49*	*51*	*50*	*49*	*47*	*24*	*24*	*-0.5*
TFC	**1 294**	**1 460**	**1 506**	**1 446**	**1 397**	**100**	**100**	**-0.3**
Coal	56	23	23	22	20	2	1	-0.9
Oil	683	735	728	644	569	50	41	-1.5
Gas	303	305	325	324	319	21	23	0.3
Electricity	226	321	336	340	341	22	24	0.4
Heat	2	6	6	6	5	0	0	-1.3
Bioenergy	23	68	84	103	131	5	9	3.9
Other renewables	0	2	3	6	11	0	1	12.1
Industry	**284**	**251**	**273**	**269**	**259**	**100**	**100**	**0.2**
Coal	46	22	23	21	20	9	8	-0.7
Oil	44	20	20	19	17	8	7	-1.1
Gas	110	104	115	113	108	41	42	0.2
Electricity	75	73	79	78	75	29	29	0.2
Heat	-	5	5	5	5	2	2	-0.7
Bioenergy	9	27	30	31	33	11	13	1.2
Other renewables	-	0	0	1	2	0	1	18.3
Transport	**488**	**609**	**611**	**557**	**524**	**100**	**100**	**-0.9**
Oil	472	562	548	471	404	92	77	-1.9
Electricity	0	1	2	5	11	0	2	19.0
Biofuels	-	28	38	52	73	5	14	5.8
Other fuels	15	19	23	29	36	3	7	3.9
Buildings	**389**	**478**	**479**	**473**	**466**	**100**	**100**	**-0.1**
Coal	10	1	1	0	0	0	0	-7.2
Oil	48	41	33	25	17	9	4	-5.0
Gas	164	175	174	169	162	37	35	-0.5
Electricity	152	245	253	254	253	51	54	0.2
Heat	2	1	1	1	1	0	0	-4.4
Bioenergy	14	13	15	19	24	3	5	3.8
Other renewables	0	2	3	5	9	0	2	11.2
Other	**133**	**122**	**144**	**147**	**148**	**100**	**100**	**1.1**

United States: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**3 203**	**4 274**	**4 449**	**4 472**	**4 467**	**100**	**100**	**0.3**
Coal	1 700	1 713	1 387	910	533	40	12	-6.6
Oil	131	33	22	19	18	1	0	-3.5
Gas	382	1 159	1 400	1 669	1 736	27	39	2.4
Nuclear	612	822	853	861	870	19	19	0.3
Hydro	273	271	296	307	320	6	7	1.0
Bioenergy	86	78	111	145	184	2	4	5.2
Wind	3	165	278	388	529	4	12	7.1
Geothermal	16	19	28	36	47	0	1	5.5
Solar PV	0	14	60	106	162	0	4	15.7
CSP	1	1	14	31	67	0	2	27.2
Marine	-	0	0	0	1	0	0	53.0

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**1 148**	**1 175**	**1 226**	**1 280**	**100**	**100**	**0.6**
Coal	332	267	229	156	29	12	-4.3
Oil	64	35	29	28	6	2	-4.8
Gas	453	486	495	519	39	41	0.8
Nuclear	105	108	109	110	9	9	0.3
Hydro	101	105	108	112	9	9	0.6
Bioenergy	16	21	27	34	1	3	4.3
Wind	60	103	142	188	5	15	6.9
Geothermal	3	4	5	7	0	1	4.2
Solar PV	13	42	72	108	1	8	13.5
CSP	1	4	9	18	0	1	19.2
Marine	0	0	0	1	0	0	44.4

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**4 850**	**5 164**	**4 881**	**4 242**	**3 605**	**100**	**100**	**-2.1**
Coal	1 797	1 678	1 344	875	480	32	13	-7.1
Oil	2 042	2 101	2 027	1 764	1 534	41	43	-1.8
Gas	1 011	1 385	1 510	1 602	1 591	27	44	0.8
Power generation	**1 848**	**2 083**	**1 807**	**1 438**	**1 059**	**100**	**100**	**-3.9**
Coal	1 550	1 568	1 234	770	383	75	36	-8.0
Oil	88	25	16	13	12	1	1	-4.2
Gas	210	490	558	655	664	24	63	1.8
TFC	**2 730**	**2 762**	**2 735**	**2 477**	**2 235**	**100**	**100**	**-1.2**
Coal	245	98	99	93	86	4	4	-0.8
Oil	1 788	1 956	1 890	1 638	1 416	71	63	-1.9
Transport	*1 376*	*1 647*	*1 604*	*1 378*	*1 184*	*60*	*53*	*-1.9*
Gas	697	707	747	745	732	26	33	0.2

OECD Europe: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**1 631**	**1 752**	**1 688**	**1 610**	**1 548**	**100**	**100**	**-0.7**
Coal	452	310	248	193	146	18	9	-4.3
Oil	616	556	501	451	401	32	26	-1.9
Gas	260	423	428	432	414	24	27	-0.1
Nuclear	205	229	222	199	206	13	13	-0.6
Hydro	38	49	51	54	56	3	4	0.8
Bioenergy	54	138	165	182	199	8	13	2.2
Other renewables	5	47	74	98	126	3	8	6.0
Power generation	**626**	**748**	**723**	**689**	**675**	**100**	**100**	**-0.6**
Coal	279	230	171	121	79	31	12	-6.1
Oil	51	19	11	7	5	3	1	-7.1
Gas	41	127	137	151	141	17	21	0.6
Nuclear	205	229	222	199	206	31	31	-0.6
Hydro	38	49	51	54	56	7	8	0.8
Bioenergy	9	55	67	73	80	7	12	2.3
Other renewables	3	39	63	83	107	5	16	6.0
Other energy sector	**152**	**147**	**136**	**127**	**120**	**100**	**100**	**-1.2**
Electricity	*39*	*46*	*43*	*42*	*41*	*31*	*34*	*-0.6*
TFC	**1 131**	**1 225**	**1 206**	**1 173**	**1 135**	**100**	**100**	**-0.4**
Coal	124	51	49	47	43	4	4	-1.0
Oil	525	499	455	414	369	41	33	-1.8
Gas	201	274	270	263	254	22	22	-0.4
Electricity	193	266	278	283	286	22	25	0.4
Heat	40	47	47	47	46	4	4	-0.1
Bioenergy	46	82	96	107	117	7	10	2.1
Other renewables	2	7	10	14	19	1	2	6.2
Industry	**324**	**290**	**286**	**279**	**268**	**100**	**100**	**-0.5**
Coal	71	30	29	28	26	10	10	-0.8
Oil	59	31	27	25	23	11	8	-1.8
Gas	78	90	84	80	74	31	28	-1.1
Electricity	88	98	103	102	99	34	37	0.1
Heat	14	17	16	15	15	6	5	-0.9
Bioenergy	14	24	27	29	30	8	11	1.3
Other renewables	0	0	0	1	2	0	1	9.6
Transport	**268**	**318**	**308**	**291**	**271**	**100**	**100**	**-0.9**
Oil	262	296	276	253	226	93	83	-1.6
Electricity	5	6	7	8	9	2	3	2.6
Biofuels	0	13	21	26	30	4	11	4.8
Other fuels	1	3	4	5	7	1	2	5.1
Buildings	**405**	**483**	**483**	**479**	**477**	**100**	**100**	**-0.1**
Coal	49	18	17	16	15	4	3	-1.2
Oil	97	61	46	34	23	13	5	-5.6
Gas	105	168	170	166	162	35	34	-0.2
Electricity	97	158	164	169	173	33	36	0.6
Heat	24	30	31	31	32	6	7	0.3
Bioenergy	30	43	46	50	55	9	12	1.5
Other renewables	2	6	9	12	16	1	3	6.3
Other	**134**	**134**	**128**	**124**	**119**	**100**	**100**	**-0.7**

OECD Europe: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**2 682**	**3 631**	**3 739**	**3 783**	**3 814**	**100**	**100**	**0.3**
Coal	1 040	946	720	515	328	26	9	-6.0
Oil	216	68	38	24	17	2	0	-8.0
Gas	168	658	748	852	792	18	21	1.1
Nuclear	787	878	852	763	792	24	21	-0.6
Hydro	446	575	592	625	656	16	17	0.8
Bioenergy	21	168	212	235	259	5	7	2.6
Wind	1	239	421	575	732	7	19	6.8
Geothermal	4	12	16	20	26	0	1	4.5
Solar PV	0	81	130	157	178	2	5	4.7
CSP	-	5	10	16	26	0	1	10.0
Marine	1	1	1	3	8	0	0	17.1

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**1 075**	**1 181**	**1 255**	**1 329**	**100**	**100**	**1.3**
Coal	200	172	143	122	19	9	-2.8
Oil	63	37	27	20	6	2	-6.5
Gas	241	276	304	312	22	23	1.5
Nuclear	129	123	110	112	12	8	-0.8
Hydro	204	215	226	235	19	18	0.8
Bioenergy	39	45	48	52	4	4	1.7
Wind	117	190	247	302	11	23	5.7
Geothermal	2	2	3	3	0	0	4.6
Solar PV	78	119	142	159	7	12	4.3
CSP	2	3	5	8	0	1	7.3
Marine	0	0	1	3	0	0	16.2

	CO$_2$ emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO$_2$	**3 959**	**3 636**	**3 233**	**2 880**	**2 497**	**100**	**100**	**-2.2**
Coal	1 708	1 204	943	722	525	33	21	-4.8
Oil	1 674	1 460	1 305	1 163	1 022	40	41	-2.1
Gas	578	973	985	995	949	27	38	-0.1
Power generation	**1 399**	**1 310**	**1 058**	**869**	**658**	**100**	**100**	**-4.0**
Coal	1 140	953	702	493	313	73	48	-6.3
Oil	164	60	35	23	17	5	3	-7.1
Gas	95	298	321	353	328	23	50	0.6
TFC	**2 382**	**2 149**	**2 013**	**1 865**	**1 704**	**100**	**100**	**-1.4**
Coal	528	219	211	200	185	10	11	-1.0
Oil	1 394	1 299	1 178	1 059	931	60	55	-1.9
Transport	*775*	*887*	*829*	*757*	*677*	*41*	*40*	*-1.6*
Gas	460	631	624	606	587	29	34	-0.4

European Union: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**1 642**	**1 620**	**1 548**	**1 471**	**1 411**	**100**	**100**	**-0.8**
Coal	456	283	217	164	121	17	9	-4.9
Oil	608	510	455	408	361	31	26	-2.0
Gas	297	391	394	399	384	24	27	-0.1
Nuclear	207	229	223	202	206	14	15	-0.6
Hydro	25	32	33	34	35	2	2	0.6
Bioenergy	47	138	165	181	196	9	14	2.1
Other renewables	3	37	62	83	107	2	8	6.4
Power generation	**646**	**698**	**665**	**630**	**615**	**100**	**100**	**-0.7**
Coal	287	220	158	109	71	32	12	-6.5
Oil	62	19	11	7	5	3	1	-7.3
Gas	55	110	118	132	126	16	21	0.8
Nuclear	207	229	223	202	206	33	33	-0.6
Hydro	25	32	33	34	35	5	6	0.6
Bioenergy	8	53	65	71	76	8	12	2.1
Other renewables	3	35	57	75	95	5	15	6.1
Other energy sector	**152**	**134**	**124**	**116**	**110**	**100**	**100**	**-1.2**
Electricity	*39*	*41*	*38*	*36*	*35*	*31*	*32*	*-1.0*
TFC	**1 131**	**1 128**	**1 102**	**1 069**	**1 030**	**100**	**100**	**-0.5**
Coal	122	36	34	31	28	3	3	-1.4
Oil	504	456	412	372	330	40	32	-1.9
Gas	226	262	258	250	242	23	24	-0.5
Electricity	186	239	246	250	251	21	24	0.3
Heat	54	49	49	48	48	4	5	-0.1
Bioenergy	38	83	98	109	118	7	11	2.1
Other renewables	1	3	5	8	12	0	1	9.7
Industry	**343**	**263**	**259**	**251**	**240**	**100**	**100**	**-0.5**
Coal	69	24	23	22	20	9	8	-1.0
Oil	58	29	25	23	21	11	9	-1.9
Gas	97	84	79	75	70	32	29	-1.1
Electricity	85	86	90	88	86	33	36	-0.0
Heat	19	16	15	15	14	6	6	-0.9
Bioenergy	14	24	27	29	29	9	12	1.2
Other renewables	-	0	0	0	1	0	0	25.4
Transport	**259**	**297**	**287**	**270**	**251**	**100**	**100**	**-1.0**
Oil	253	276	255	232	206	93	82	-1.7
Electricity	5	5	7	7	8	2	3	2.4
Biofuels	0	13	21	26	30	4	12	5.0
Other fuels	1	3	4	5	6	1	2	4.7
Buildings	**395**	**447**	**443**	**438**	**435**	**100**	**100**	**-0.2**
Coal	49	10	9	7	6	2	1	-2.7
Oil	90	54	41	31	21	12	5	-5.5
Gas	108	161	161	157	153	36	35	-0.3
Electricity	91	144	147	150	154	32	35	0.4
Heat	34	32	33	33	33	7	8	0.2
Bioenergy	24	44	47	51	56	10	13	1.4
Other renewables	1	2	5	8	11	1	3	9.5
Other	**134**	**121**	**114**	**109**	**104**	**100**	**100**	**-0.9**

European Union: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**2 576**	**3 240**	**3 286**	**3 306**	**3 314**	**100**	**100**	**0.1**
Coal	1 050	896	651	453	283	28	9	-6.6
Oil	224	68	37	22	15	2	0	-8.4
Gas	193	536	601	709	678	17	20	1.4
Nuclear	795	877	856	776	790	27	24	-0.6
Hydro	289	367	379	395	405	11	12	0.6
Bioenergy	20	165	207	227	247	5	7	2.4
Wind	1	236	404	539	670	7	20	6.3
Geothermal	3	6	9	12	18	0	1	6.5
Solar PV	0	82	130	155	174	3	5	4.5
CSP	-	5	10	16	26	0	1	10.0
Marine	1	1	1	3	8	0	0	17.2

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**996**	**1 079**	**1 136**	**1 188**	**100**	**100**	**1.0**
Coal	194	160	129	106	19	9	-3.5
Oil	62	36	25	18	6	1	-7.1
Gas	223	248	275	281	22	24	1.4
Nuclear	129	123	111	112	13	9	-0.8
Hydro	150	159	165	169	15	14	0.7
Bioenergy	39	44	47	50	4	4	1.5
Wind	117	185	236	282	12	24	5.3
Geothermal	1	1	2	2	0	0	6.5
Solar PV	79	119	141	156	8	13	4.1
CSP	2	3	5	8	0	1	7.3
Marine	0	0	1	3	0	0	16.2

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**4 051**	**3 350**	**2 923**	**2 582**	**2 235**	**100**	**100**	**-2.4**
Coal	1 732	1 101	823	607	427	33	19	-5.4
Oil	1 656	1 354	1 199	1 062	929	40	42	-2.2
Gas	663	894	901	913	878	27	39	-0.1
Power generation	**1 497**	**1 233**	**959**	**774**	**589**	**100**	**100**	**-4.2**
Coal	1 172	914	648	443	278	74	47	-6.8
Oil	197	60	35	22	17	5	3	-7.3
Gas	128	258	276	309	294	21	50	0.8
TFC	**2 379**	**1 956**	**1 817**	**1 675**	**1 523**	**100**	**100**	**-1.5**
Coal	523	160	150	140	127	8	8	-1.4
Oil	1 340	1 194	1 073	960	839	61	55	-2.1
Transport	*748*	*827*	*765*	*696*	*619*	*42*	*41*	*-1.7*
Gas	515	602	594	575	557	31	37	-0.5

OECD Asia Oceania: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**632**	**857**	**857**	**843**	**821**	**100**	**100**	**-0.3**
Coal	138	240	214	183	152	28	19	-2.7
Oil	335	347	298	275	252	40	31	-1.9
Gas	66	189	165	166	166	22	20	-0.7
Nuclear	66	39	116	134	142	5	17	8.0
Hydro	11	11	12	12	13	1	2	1.4
Bioenergy	10	22	27	31	35	3	4	2.6
Other renewables	4	10	25	41	60	1	7	11.1
Power generation	**241**	**380**	**395**	**398**	**396**	**100**	**100**	**0.2**
Coal	60	165	138	109	80	43	20	-4.2
Oil	56	38	13	10	8	10	2	-8.6
Gas	40	109	79	77	76	29	19	-2.1
Nuclear	66	39	116	134	142	10	36	8.0
Hydro	11	11	12	12	13	3	3	1.4
Bioenergy	3	11	15	18	21	3	5	4.0
Other renewables	3	9	23	38	56	2	14	11.5
Other energy sector	**59**	**81**	**83**	**82**	**80**	**100**	**100**	**-0.1**
Electricity	*11*	*17*	*18*	*18*	*17*	*21*	*21*	*0.0*
TFC	**429**	**563**	**552**	**539**	**521**	**100**	**100**	**-0.5**
Coal	49	39	38	36	33	7	6	-1.0
Oil	259	290	269	252	233	52	45	-1.3
Gas	27	71	74	77	78	13	15	0.5
Electricity	86	142	150	152	153	25	29	0.4
Heat	0	6	6	6	6	1	1	0.2
Bioenergy	7	12	12	13	14	2	3	1.0
Other renewables	2	1	2	3	4	0	1	7.7
Industry	**143**	**157**	**161**	**159**	**155**	**100**	**100**	**-0.1**
Coal	38	37	36	34	32	24	20	-0.9
Oil	49	30	27	25	23	19	15	-1.5
Gas	11	26	28	29	30	17	19	0.8
Electricity	40	54	59	59	58	34	38	0.5
Heat	-	2	2	2	2	1	1	-0.0
Bioenergy	5	9	9	9	9	5	6	0.6
Other renewables	0	0	0	0	0	0	0	4.2
Transport	**110**	**140**	**132**	**124**	**116**	**100**	**100**	**-1.1**
Oil	109	135	126	118	108	97	93	-1.3
Electricity	2	2	3	3	3	2	3	2.7
Biofuels	-	1	1	1	1	0	1	0.6
Other fuels	0	2	2	3	3	1	3	3.7
Buildings	**120**	**174**	**170**	**169**	**167**	**100**	**100**	**-0.2**
Coal	10	1	1	1	1	1	1	-2.7
Oil	47	38	31	27	23	22	14	-2.8
Gas	15	42	42	43	43	24	26	0.1
Electricity	44	85	87	89	89	49	53	0.3
Heat	0	4	4	4	4	2	2	0.4
Bioenergy	2	2	3	3	4	1	2	2.3
Other renewables	1	1	2	2	3	1	2	7.2
Other	**56**	**91**	**89**	**87**	**83**	**100**	**100**	**-0.5**

OECD Asia Oceania: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**1 127**	**1 855**	**1 954**	**1 975**	**1 975**	**100**	**100**	**0.4**
Coal	256	740	641	514	386	40	20	-3.8
Oil	259	176	59	41	33	9	2	-9.4
Gas	208	579	468	467	464	31	23	-1.3
Nuclear	255	148	445	516	545	8	28	8.0
Hydro	133	122	134	143	155	7	8	1.4
Bioenergy	12	46	61	74	88	2	4	3.9
Wind	-	17	52	94	142	1	7	13.4
Geothermal	4	9	18	31	47	0	2	10.4
Solar PV	0	18	72	89	104	1	5	10.8
CSP	-	0	2	3	7	0	0	54.7
Marine	-	0	2	3	6	0	0	90.1

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**469**	**534**	**557**	**580**	**100**	**100**	**1.3**
Coal	107	112	108	100	23	17	-0.4
Oil	58	32	25	19	12	3	-6.4
Gas	134	158	153	150	29	26	0.7
Nuclear	66	67	70	72	14	12	0.5
Hydro	70	71	75	79	15	14	0.8
Bioenergy	8	10	12	15	2	3	3.7
Wind	7	19	33	48	1	8	12.0
Geothermal	1	2	5	7	0	1	10.0
Solar PV	18	62	75	87	4	15	9.9
CSP	0	0	1	2	0	0	44.4
Marine	0	1	1	2	0	0	12.0

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**1 566**	**2 225**	**1 911**	**1 714**	**1 510**	**100**	**100**	**-2.3**
Coal	518	925	806	667	522	42	35	-3.3
Oil	887	851	713	655	597	38	40	-2.1
Gas	161	449	391	392	391	20	26	-0.8
Power generation	**548**	**1 078**	**816**	**672**	**530**	**100**	**100**	**-4.1**
Coal	280	703	586	458	326	65	62	-4.4
Oil	174	113	41	30	25	11	5	-8.6
Gas	94	261	189	184	179	24	34	-2.2
TFC	**950**	**1 031**	**974**	**925**	**867**	**100**	**100**	**-1.0**
Coal	217	178	173	163	152	17	18	-0.9
Oil	672	687	629	584	535	67	62	-1.5
Transport	*321*	*398*	*370*	*346*	*318*	*39*	*37*	*-1.3*
Gas	61	165	172	178	180	16	21	0.5

Non-OECD: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**4 064**	**7 930**	**8 956**	**9 501**	**10 009**	**100**	**100**	**1.4**
Coal	1 151	2 943	3 110	3 060	2 978	37	30	0.1
Oil	1 161	1 974	2 238	2 343	2 424	25	24	1.2
Gas	829	1 523	1 737	1 914	2 077	19	21	1.8
Nuclear	74	135	252	353	439	2	4	7.2
Hydro	83	199	259	302	344	3	3	3.3
Bioenergy	758	1 086	1 204	1 283	1 372	14	14	1.4
Other renewables	8	70	157	246	374	1	4	10.4
Power generation	**1 268**	**2 978**	**3 339**	**3 551**	**3 786**	**100**	**100**	**1.4**
Coal	466	1 650	1 690	1 607	1 515	55	40	-0.5
Oil	223	221	179	145	114	7	3	-3.8
Gas	407	673	722	784	834	23	22	1.3
Nuclear	74	135	252	353	439	5	12	7.2
Hydro	83	199	259	302	344	7	9	3.3
Bioenergy	7	52	111	154	216	2	6	8.8
Other renewables	8	48	125	205	323	2	9	11.9
Other energy sector	**498**	**1 167**	**1 240**	**1 280**	**1 308**	**100**	**100**	**0.7**
Electricity	*78*	*207*	*237*	*254*	*274*	*18*	*21*	*1.7*
TFC	**2 989**	**5 141**	**6 004**	**6 454**	**6 857**	**100**	**100**	**1.7**
Coal	535	814	905	926	924	16	13	0.7
Oil	814	1 611	1 918	2 063	2 187	31	32	1.8
Gas	361	648	824	931	1 040	13	15	2.8
Electricity	282	867	1 098	1 235	1 377	17	20	2.8
Heat	295	234	245	249	249	5	4	0.4
Bioenergy	702	946	982	1 008	1 029	18	15	0.5
Other renewables	0	22	32	41	51	0	1	5.0
Industry	**977**	**1 855**	**2 218**	**2 402**	**2 557**	**100**	**100**	**1.9**
Coal	315	657	733	754	757	35	30	0.8
Oil	158	206	231	239	245	11	10	1.0
Gas	131	304	413	482	548	16	21	3.5
Electricity	159	455	574	635	689	25	27	2.5
Heat	138	110	122	127	127	6	5	0.9
Bioenergy	76	123	143	164	188	7	7	2.5
Other renewables	0	0	1	2	3	0	0	17.2
Transport	**434**	**992**	**1 232**	**1 350**	**1 446**	**100**	**100**	**2.2**
Oil	364	886	1 094	1 188	1 263	89	87	2.1
Electricity	13	17	22	26	31	2	2	3.6
Biofuels	6	19	35	46	53	2	4	6.1
Other fuels	50	70	82	89	99	7	7	2.0
Buildings	**1 267**	**1 764**	**1 885**	**1 956**	**2 040**	**100**	**100**	**0.9**
Coal	170	103	94	86	77	6	4	-1.7
Oil	117	169	163	159	157	10	8	-0.4
Gas	131	204	238	259	282	12	14	1.9
Electricity	86	352	448	512	588	20	29	3.1
Heat	148	118	117	117	117	7	6	-0.0
Bioenergy	615	797	795	786	774	45	38	-0.2
Other renewables	0	21	29	37	45	1	2	4.5
Other	**312**	**530**	**668**	**745**	**814**	**100**	**100**	**2.6**

Non-OECD: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**4 197**	**12 457**	**15 487**	**17 290**	**19 167**	**100**	**100**	**2.6**
Coal	1 333	6 086	6 619	6 403	6 175	49	32	0.1
Oil	624	773	626	513	405	6	2	-3.7
Gas	979	2 400	3 019	3 521	3 924	19	20	2.9
Nuclear	283	517	967	1 354	1 685	4	9	7.2
Hydro	963	2 315	3 009	3 506	3 996	19	21	3.3
Bioenergy	8	131	346	498	714	1	4	10.5
Wind	0	190	578	913	1 333	2	7	12.2
Geothermal	8	25	49	82	136	0	1	10.4
Solar PV	0	21	260	458	675	0	4	22.8
CSP	-	0	14	43	123	0	1	50.2
Marine	-	0	0	0	1	0	0	25.2

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**3 039**	**4 073**	**4 670**	**5 313**	**100**	**100**	**3.3**
Coal	1 217	1 453	1 454	1 458	40	27	1.1
Oil	243	242	220	191	8	4	-1.4
Gas	650	830	941	1 046	21	20	2.8
Nuclear	78	135	186	231	3	4	6.6
Hydro	659	855	995	1 138	22	21	3.3
Bioenergy	38	72	98	136	1	3	7.8
Wind	123	289	426	585	4	11	9.6
Geothermal	4	8	13	21	0	0	9.7
Solar PV	27	187	324	470	1	9	18.3
CSP	0	5	13	35	0	1	30.9
Marine	0	0	0	0	0	0	26.1

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**9 214**	**19 015**	**20 569**	**20 864**	**20 935**	**100**	**100**	**0.6**
Coal	4 175	10 374	10 836	10 520	10 070	55	48	-0.2
Oil	3 164	5 228	5 821	6 029	6 181	27	30	1.0
Gas	1 875	3 412	3 913	4 315	4 685	18	22	1.9
Power generation	**3 514**	**8 796**	**8 931**	**8 612**	**8 235**	**100**	**100**	**-0.4**
Coal	1 852	6 524	6 678	6 321	5 927	74	72	-0.6
Oil	711	694	561	457	359	8	4	-3.8
Gas	951	1 578	1 692	1 835	1 949	18	24	1.3
TFC	**5 296**	**9 317**	**10 710**	**11 304**	**11 750**	**100**	**100**	**1.4**
Coal	2 247	3 647	3 950	3 996	3 949	39	34	0.5
Oil	2 260	4 220	4 928	5 240	5 495	45	47	1.6
Transport	*1 082*	*2 637*	*3 257*	*3 537*	*3 761*	*28*	*32*	*2.1*
Gas	789	1 450	1 832	2 068	2 306	16	20	2.8

E. Europe/Eurasia: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**1 544**	**1 168**	**1 157**	**1 168**	**1 182**	**100**	**100**	**0.1**
Coal	368	237	214	197	187	20	16	-1.4
Oil	470	240	241	237	231	21	20	-0.2
Gas	607	564	555	560	556	48	47	-0.1
Nuclear	59	76	88	102	111	7	9	2.2
Hydro	23	26	28	30	34	2	3	1.5
Bioenergy	17	22	26	32	44	2	4	4.2
Other renewables	0	1	6	11	18	0	2	16.4
Power generation	**742**	**579**	**559**	**557**	**565**	**100**	**100**	**-0.1**
Coal	197	143	123	106	97	25	17	-2.3
Oil	125	20	17	13	10	4	2	-4.1
Gas	333	306	289	285	275	53	49	-0.6
Nuclear	59	76	88	102	111	13	20	2.2
Hydro	23	26	28	30	34	5	6	1.5
Bioenergy	4	6	8	11	20	1	4	7.1
Other renewables	0	1	5	10	18	0	3	17.3
Other energy sector	**199**	**210**	**199**	**193**	**188**	**100**	**100**	**-0.6**
Electricity	*35*	*41*	*41*	*42*	*43*	*19*	*23*	*0.3*
TFC	**1 082**	**720**	**744**	**769**	**785**	**100**	**100**	**0.5**
Coal	114	54	55	57	57	8	7	0.4
Oil	281	172	182	188	190	24	24	0.6
Gas	266	215	222	228	232	30	29	0.4
Electricity	127	107	115	122	128	15	16	1.0
Heat	281	156	153	154	155	22	20	-0.1
Bioenergy	13	15	17	20	23	2	3	2.5
Other renewables	-	0	0	1	1	0	0	7.3
Industry	**396**	**241**	**246**	**257**	**264**	**100**	**100**	**0.5**
Coal	56	43	44	46	47	18	18	0.6
Oil	52	19	20	20	21	8	8	0.7
Gas	86	72	72	75	76	30	29	0.3
Electricity	75	48	52	55	56	20	21	1.0
Heat	127	57	56	58	59	24	22	0.2
Bioenergy	0	2	3	3	5	1	2	5.7
Other renewables	-	0	0	0	0	0	0	12.1
Transport	**172**	**146**	**155**	**162**	**166**	**100**	**100**	**0.8**
Oil	123	103	109	114	115	71	69	0.6
Electricity	12	10	10	11	12	7	7	1.5
Biofuels	0	0	1	1	2	0	1	7.6
Other fuels	37	33	35	36	37	23	22	0.7
Buildings	**392**	**269**	**271**	**272**	**273**	**100**	**100**	**0.1**
Coal	56	10	10	9	9	4	3	-0.9
Oil	37	17	16	14	12	6	4	-2.2
Gas	115	90	93	93	93	33	34	0.2
Electricity	26	46	47	49	52	17	19	0.7
Heat	145	93	92	92	91	34	33	-0.1
Bioenergy	12	13	13	15	16	5	6	1.5
Other renewables	-	0	0	0	1	0	0	6.3
Other	**122**	**64**	**72**	**77**	**82**	**100**	**100**	**1.5**

E. Europe/Eurasia: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**1 894**	**1 730**	**1 822**	**1 909**	**1 996**	**100**	**100**	**0.8**
Coal	429	406	364	309	284	23	14	-2.1
Oil	256	37	25	15	8	2	0	-8.7
Gas	715	676	737	778	758	39	38	0.7
Nuclear	226	291	338	388	426	17	21	2.3
Hydro	267	306	321	353	394	18	20	1.5
Bioenergy	0	4	12	23	57	0	3	16.5
Wind	-	7	17	26	43	0	2	11.2
Geothermal	0	0	4	8	15	0	1	23.9
Solar PV	-	2	5	8	11	0	1	9.3
CSP	-	-	-	-	-	0	0	n.a.
Marine	-	-	-	-	0	0	0	n.a.

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**443**	**452**	**468**	**489**	**100**	**100**	**0.6**
Coal	111	98	83	72	25	15	-2.5
Oil	23	17	11	6	5	1	-7.3
Gas	161	171	182	186	36	38	0.9
Nuclear	43	48	55	60	10	12	2.0
Hydro	96	102	111	122	22	25	1.4
Bioenergy	2	3	5	11	0	2	11.1
Wind	4	9	13	19	1	4	9.1
Geothermal	0	1	1	2	0	0	19.7
Solar PV	3	4	7	10	1	2	7.4
CSP	-	-	-	-	0	0	n.a.
Marine	-	-	-	0	0	0	n.a.

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**3 986**	**2 734**	**2 625**	**2 560**	**2 495**	**100**	**100**	**-0.5**
Coal	1 336	869	785	724	687	32	28	-1.4
Oil	1 245	592	591	583	570	22	23	-0.2
Gas	1 405	1 273	1 249	1 253	1 238	47	50	-0.2
Power generation	**1 976**	**1 375**	**1 242**	**1 149**	**1 075**	**100**	**100**	**-1.4**
Coal	799	591	508	437	397	43	37	-2.3
Oil	399	66	55	43	32	5	3	-4.1
Gas	778	718	679	669	645	52	60	-0.6
TFC	**1 897**	**1 216**	**1 241**	**1 271**	**1 281**	**100**	**100**	**0.3**
Coal	526	269	269	278	281	22	22	0.3
Oil	780	460	472	481	481	38	38	0.3
Transport	*365*	*304*	*322*	*334*	*338*	*25*	*26*	*0.6*
Gas	591	486	499	511	518	40	40	0.4

Russia: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**880**	**733**	**706**	**706**	**709**	**100**	**100**	**-0.2**
Coal	191	124	111	105	99	17	14	-1.3
Oil	264	157	149	144	139	21	20	-0.7
Gas	367	384	361	357	348	52	49	-0.6
Nuclear	31	45	56	64	71	6	10	2.7
Hydro	14	16	16	18	20	2	3	1.6
Bioenergy	12	8	9	12	20	1	3	5.9
Other renewables	0	0	3	7	12	0	2	23.3
Power generation	**444**	**393**	**379**	**380**	**386**	**100**	**100**	**-0.1**
Coal	105	72	64	60	56	18	15	-1.5
Oil	62	17	15	11	9	4	2	-3.7
Gas	228	239	219	213	202	61	52	-1.0
Nuclear	31	45	56	64	71	12	18	2.7
Hydro	14	16	16	18	20	4	5	1.6
Bioenergy	4	4	6	8	15	1	4	7.6
Other renewables	0	0	3	7	12	0	3	23.3
Other energy sector	**127**	**142**	**129**	**121**	**115**	**100**	**100**	**-1.3**
Electricity	*21*	*26*	*27*	*27*	*28*	*19*	*24*	*0.3*
TFC	**625**	**441**	**437**	**449**	**456**	**100**	**100**	**0.2**
Coal	55	23	22	23	23	5	5	0.0
Oil	145	100	100	103	104	23	23	0.2
Gas	143	128	126	128	129	29	28	0.1
Electricity	71	63	65	69	73	14	16	0.9
Heat	203	124	121	122	123	28	27	-0.1
Bioenergy	8	3	3	4	4	1	1	2.9
Other renewables	-	-	0	0	0	0	0	n.a.
Industry	**208**	**157**	**151**	**157**	**160**	**100**	**100**	**0.1**
Coal	15	19	19	20	20	12	13	0.3
Oil	24	11	11	12	12	7	8	0.5
Gas	30	50	45	46	45	32	28	-0.6
Electricity	41	29	30	32	33	18	21	0.8
Heat	98	47	45	47	48	30	30	0.1
Bioenergy	-	0	1	1	1	0	1	6.6
Other renewables	-	-	-	-	-	0	0	n.a.
Transport	**116**	**96**	**98**	**102**	**105**	**100**	**100**	**0.5**
Oil	73	61	62	64	64	64	61	0.3
Electricity	9	8	8	9	10	8	10	1.5
Biofuels	-	-	-	-	-	0	0	n.a.
Other fuels	34	27	29	30	30	28	29	0.7
Buildings	**228**	**152**	**149**	**148**	**148**	**100**	**100**	**-0.2**
Coal	40	4	3	3	3	2	2	-1.8
Oil	12	9	7	6	5	6	3	-3.4
Gas	57	42	42	42	41	27	28	-0.0
Electricity	15	25	25	25	26	16	18	0.3
Heat	98	71	70	70	70	47	47	-0.1
Bioenergy	7	2	2	2	3	1	2	1.6
Other renewables	-	-	0	0	0	0	0	n.a.
Other	**72**	**36**	**38**	**41**	**44**	**100**	**100**	**1.1**

Russia: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**1 082**	**1 053**	**1 084**	**1 136**	**1 187**	**100**	**100**	**0.7**
Coal	157	163	146	129	122	15	10	-1.7
Oil	129	27	19	11	5	3	0	-9.2
Gas	512	506	503	511	482	48	41	-0.3
Nuclear	118	172	215	246	271	16	23	2.7
Hydro	166	182	189	210	238	17	20	1.6
Bioenergy	0	3	7	15	43	0	4	17.1
Wind	-	0	3	6	13	0	1	60.5
Geothermal	0	0	3	7	13	0	1	22.6
Solar PV	-	-	0	1	1	0	0	n.a.
CSP	-	-	-	-	-	0	0	n.a.
Marine	-	-	-	-	-	0	0	n.a.

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**249**	**247**	**254**	**264**	**100**	**100**	**0.4**
Coal	51	42	34	28	21	11	-3.5
Oil	6	5	3	2	2	1	-7.3
Gas	114	112	116	115	46	44	0.0
Nuclear	25	30	34	37	10	14	2.3
Hydro	51	53	58	66	20	25	1.5
Bioenergy	1	2	3	8	1	3	10.7
Wind	0	1	3	5	0	2	40.9
Geothermal	0	0	1	2	0	1	18.9
Solar PV	0	0	1	2	0	1	40.0
CSP	-	-	-	-	0	0	n.a.
Marine	-	-	-	-	0	0	n.a.

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**2 179**	**1 682**	**1 576**	**1 537**	**1 489**	**100**	**100**	**-0.7**
Coal	687	441	403	386	373	26	25	-1.0
Oil	625	366	350	339	328	22	22	-0.6
Gas	866	876	823	812	787	52	53	-0.6
Power generation	**1 162**	**918**	**832**	**787**	**739**	**100**	**100**	**-1.3**
Coal	432	304	271	251	237	33	32	-1.5
Oil	198	53	47	36	28	6	4	-3.7
Gas	532	561	514	500	474	61	64	-1.0
TFC	**960**	**688**	**670**	**681**	**683**	**100**	**100**	**-0.0**
Coal	253	133	128	131	133	19	19	-0.0
Oil	389	264	256	259	259	38	38	-0.1
Transport	*217*	*180*	*181*	*187*	*189*	*26*	*28*	*0.3*
Gas	318	291	286	290	292	42	43	0.0

Non-OECD Asia: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**1 587**	**4 703**	**5 452**	**5 811**	**6 142**	**100**	**100**	**1.6**
Coal	694	2 575	2 754	2 721	2 647	55	43	0.2
Oil	318	956	1 145	1 231	1 315	20	21	1.9
Gas	69	375	516	628	736	8	12	4.0
Nuclear	10	49	147	226	291	1	5	11.0
Hydro	24	103	140	163	187	2	3	3.6
Bioenergy	466	583	623	653	697	12	11	1.1
Other renewables	7	62	127	190	269	1	4	9.1
Power generation	**330**	**1 839**	**2 173**	**2 343**	**2 504**	**100**	**100**	**1.8**
Coal	226	1 434	1 491	1 430	1 352	78	54	-0.3
Oil	46	42	34	27	21	2	1	-4.0
Gas	16	137	181	229	270	7	11	4.1
Nuclear	10	49	147	226	291	3	12	11.0
Hydro	24	103	140	163	187	6	7	3.6
Bioenergy	0	32	82	115	158	2	6	9.8
Other renewables	7	41	98	154	226	2	9	10.6
Other energy sector	**167**	**685**	**733**	**751**	**765**	**100**	**100**	**0.7**
Electricity	*26*	*118*	*140*	*152*	*164*	*17*	*21*	*2.0*
TFC	**1 216**	**2 947**	**3 532**	**3 816**	**4 081**	**100**	**100**	**1.9**
Coal	395	728	813	829	822	25	20	0.7
Oil	238	844	1 043	1 138	1 232	29	30	2.2
Gas	31	176	284	353	423	6	10	5.3
Electricity	83	561	742	841	940	19	23	3.1
Heat	14	77	92	95	94	3	2	1.2
Bioenergy	455	539	529	525	526	18	13	-0.1
Other renewables	0	21	29	36	44	1	1	4.4
Industry	**400**	**1 223**	**1 509**	**1 640**	**1 743**	**100**	**100**	**2.1**
Coal	239	590	660	674	673	48	39	0.8
Oil	51	105	122	126	130	9	7	1.2
Gas	8	81	148	192	234	7	13	6.4
Electricity	51	337	441	492	537	28	31	2.8
Heat	11	52	67	69	68	4	4	1.6
Bioenergy	39	56	71	85	99	5	6	3.5
Other renewables	0	0	1	2	2	0	0	15.1
Transport	**104**	**471**	**630**	**709**	**791**	**100**	**100**	**3.1**
Oil	91	438	580	646	712	93	90	2.9
Electricity	1	7	11	14	18	1	2	6.0
Biofuels	-	4	10	16	22	1	3	10.7
Other fuels	12	23	29	33	40	5	5	3.3
Buildings	**590**	**938**	**988**	**1 013**	**1 049**	**100**	**100**	**0.7**
Coal	111	87	79	71	63	9	6	-1.8
Oil	34	91	85	80	77	10	7	-1.0
Gas	5	49	73	88	103	5	10	4.5
Electricity	22	187	253	292	338	20	32	3.5
Heat	3	25	26	26	26	3	2	0.2
Bioenergy	415	480	447	423	402	51	38	-1.0
Other renewables	0	20	27	33	40	2	4	4.1
Other	**121**	**315**	**404**	**455**	**498**	**100**	**100**	**2.7**

Non-OECD Asia: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**1 274**	**7 882**	**10 244**	**11 529**	**12 822**	**100**	**100**	**2.9**
Coal	729	5 391	5 941	5 788	5 595	68	44	0.2
Oil	165	147	114	88	68	2	1	-4.4
Gas	59	678	975	1 275	1 552	9	12	5.0
Nuclear	39	190	563	866	1 116	2	9	11.0
Hydro	274	1 193	1 629	1 900	2 171	15	17	3.6
Bioenergy	1	75	255	372	521	1	4	12.0
Wind	0	172	499	784	1 134	2	9	11.7
Geothermal	7	19	31	49	74	0	1	8.2
Solar PV	0	18	232	392	541	0	4	22.3
CSP	-	0	6	15	49	0	0	43.9
Marine	-	0	0	0	1	0	0	25.0

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**1 873**	**2 697**	**3 151**	**3 616**	**100**	**100**	**3.9**
Coal	1 057	1 293	1 306	1 319	56	36	1.3
Oil	65	62	58	53	3	1	-1.2
Gas	185	274	331	387	10	11	4.4
Nuclear	29	77	117	151	2	4	10.2
Hydro	375	508	596	685	20	19	3.6
Bioenergy	22	50	70	96	1	3	9.0
Wind	113	259	379	512	6	14	9.3
Geothermal	3	5	8	12	0	0	7.6
Solar PV	23	168	281	387	1	11	18.0
CSP	0	2	4	13	0	0	33.9
Marine	0	0	0	0	0	0	25.8

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**3 556**	**12 354**	**13 679**	**13 893**	**13 945**	**100**	**100**	**0.7**
Coal	2 559	9 075	9 586	9 340	8 939	73	64	-0.1
Oil	862	2 439	2 909	3 102	3 293	20	24	1.8
Gas	135	839	1 184	1 451	1 713	7	12	4.3
Power generation	**1 072**	**6 098**	**6 398**	**6 223**	**5 973**	**100**	**100**	**-0.1**
Coal	886	5 643	5 868	5 603	5 274	93	88	-0.4
Oil	149	134	107	85	67	2	1	-4.0
Gas	38	321	424	535	632	5	11	4.1
TFC	**2 327**	**5 786**	**6 789**	**7 176**	**7 479**	**100**	**100**	**1.5**
Coal	1 613	3 243	3 525	3 550	3 486	56	47	0.4
Oil	654	2 155	2 639	2 852	3 061	37	41	2.1
Transport	*271*	*1 308*	*1 734*	*1 931*	*2 128*	*23*	*28*	*2.9*
Gas	60	388	625	775	932	7	12	5.3

China: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**879**	**3 057**	**3 494**	**3 648**	**3 751**	**100**	**100**	**1.2**
Coal	533	2 080	2 158	2 095	2 002	68	53	-0.2
Oil	122	482	583	620	646	16	17	1.7
Gas	13	140	231	290	347	5	9	5.5
Nuclear	-	29	111	177	221	1	6	12.7
Hydro	11	75	106	117	123	2	3	2.9
Bioenergy	200	217	229	242	264	7	7	1.2
Other renewables	0	34	75	106	147	1	4	9.1
Power generation	**181**	**1 277**	**1 490**	**1 585**	**1 658**	**100**	**100**	**1.5**
Coal	153	1 106	1 109	1 060	1 001	87	60	-0.6
Oil	16	5	5	5	4	0	0	-1.3
Gas	1	30	60	82	104	2	6	7.7
Nuclear	-	29	111	177	221	2	13	12.7
Hydro	11	75	106	117	123	6	7	2.9
Bioenergy	-	18	51	71	96	1	6	10.3
Other renewables	0	13	48	74	109	1	7	13.2
Other energy sector	**100**	**537**	**570**	**571**	**568**	**100**	**100**	**0.3**
Electricity	*15*	*79*	*90*	*94*	*98*	*15*	*17*	*1.3*
TFC	**669**	**1 797**	**2 140**	**2 259**	**2 344**	**100**	**100**	**1.6**
Coal	318	584	628	609	570	32	24	-0.1
Oil	87	441	542	584	615	25	26	2.0
Gas	9	90	159	200	241	5	10	6.0
Electricity	41	388	514	569	618	22	26	2.8
Heat	13	76	91	93	93	4	4	1.1
Bioenergy	200	199	178	171	168	11	7	-1.0
Other renewables	0	20	27	32	39	1	2	3.8
Industry	**245**	**863**	**1 044**	**1 097**	**1 119**	**100**	**100**	**1.5**
Coal	181	462	491	470	435	54	39	-0.3
Oil	21	57	63	63	61	7	5	0.4
Gas	3	32	72	99	123	4	11	8.2
Electricity	30	260	344	382	411	30	37	2.7
Heat	11	52	66	69	68	6	6	1.6
Bioenergy	-	-	7	13	19	0	2	n.a.
Other renewables	-	0	1	1	2	0	0	13.0
Transport	**35**	**252**	**341**	**377**	**410**	**100**	**100**	**2.9**
Oil	25	230	310	340	363	92	88	2.7
Electricity	1	5	9	12	15	2	4	6.8
Biofuels	-	1	4	7	11	0	3	13.8
Other fuels	10	15	18	18	21	6	5	2.0
Buildings	**314**	**497**	**512**	**511**	**516**	**100**	**100**	**0.2**
Coal	95	71	63	57	49	14	9	-2.2
Oil	7	42	33	27	20	8	4	-4.2
Gas	2	35	55	66	78	7	15	4.7
Electricity	6	108	144	158	173	22	34	2.8
Heat	2	24	25	25	25	5	5	0.2
Bioenergy	200	198	167	149	136	40	26	-2.2
Other renewables	0	20	26	31	36	4	7	3.7
Other	**75**	**186**	**243**	**274**	**298**	**100**	**100**	**2.8**

China: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**650**	**5 427**	**7 019**	**7 710**	**8 330**	**100**	**100**	**2.6**
Coal	471	4 110	4 339	4 171	3 993	76	48	-0.2
Oil	49	5	5	4	4	0	0	-1.8
Gas	3	126	300	433	569	2	7	9.3
Nuclear	-	111	427	681	849	2	10	12.7
Hydro	127	875	1 231	1 358	1 431	16	17	2.9
Bioenergy	-	48	174	246	329	1	4	11.9
Wind	0	137	399	591	840	3	10	11.2
Geothermal	-	0	1	3	6	0	0	21.4
Solar PV	0	14	140	212	274	0	3	19.2
CSP	-	0	4	11	35	0	0	80.8
Marine	-	0	0	0	1	0	0	23.1

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**1 306**	**1 830**	**2 077**	**2 296**	**100**	**100**	**3.4**
Coal	829	951	957	955	63	42	0.8
Oil	11	10	9	9	1	0	-1.1
Gas	49	93	116	135	4	6	6.2
Nuclear	17	58	92	114	1	5	11.8
Hydro	280	375	414	436	21	19	2.6
Bioenergy	9	30	43	57	1	2	11.5
Wind	91	205	280	367	7	16	8.5
Geothermal	0	0	0	1	0	0	22.9
Solar PV	20	107	164	212	2	9	15.0
CSP	0	1	3	9	0	0	45.0
Marine	0	0	0	0	0	0	24.0

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**2 278**	**8 692**	**9 297**	**9 171**	**8 899**	**100**	**100**	**0.1**
Coal	1 942	7 187	7 313	6 962	6 499	83	73	-0.6
Oil	308	1 193	1 440	1 517	1 559	14	18	1.6
Gas	28	311	544	692	840	4	9	6.0
Power generation	**651**	**4 451**	**4 533**	**4 365**	**4 164**	**100**	**100**	**-0.4**
Coal	597	4 364	4 376	4 158	3 906	98	94	-0.7
Oil	52	17	17	15	14	0	0	-1.3
Gas	2	70	140	192	244	2	6	7.7
TFC	**1 541**	**3 959**	**4 465**	**4 510**	**4 448**	**100**	**100**	**0.7**
Coal	1 294	2 644	2 756	2 631	2 429	67	55	-0.5
Oil	229	1 115	1 359	1 438	1 487	28	33	1.7
Transport	*73*	*689*	*927*	*1 017*	*1 085*	*17*	*24*	*2.7*
Gas	18	200	351	441	532	5	12	5.9

India: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**316**	**770**	**940**	**1 054**	**1 182**	**100**	**100**	**2.6**
Coal	103	340	388	405	416	44	35	1.2
Oil	61	177	232	267	311	23	26	3.4
Gas	11	44	69	89	114	6	10	5.8
Nuclear	2	9	17	28	44	1	4	10.0
Hydro	6	12	15	21	30	2	3	5.3
Bioenergy	133	185	203	213	223	24	19	1.1
Other renewables	0	4	17	30	44	0	4	15.8
Power generation	**72**	**283**	**337**	**368**	**406**	**100**	**100**	**2.2**
Coal	56	230	242	226	208	81	51	-0.6
Oil	5	7	6	5	4	2	1	-2.4
Gas	3	13	24	34	48	5	12	7.8
Nuclear	2	9	17	28	44	3	11	10.0
Hydro	6	12	15	21	30	4	7	5.3
Bioenergy	-	9	18	24	32	3	8	7.7
Other renewables	0	3	15	28	41	1	10	16.5
Other energy sector	**20**	**73**	**85**	**99**	**114**	**100**	**100**	**2.7**
Electricity	*7*	*26*	*34*	*39*	*45*	*36*	*39*	*3.2*
TFC	**250**	**519**	**657**	**754**	**861**	**100**	**100**	**3.0**
Coal	42	91	120	147	173	17	20	3.9
Oil	50	150	209	244	289	29	34	3.9
Gas	6	23	36	44	52	4	6	4.9
Electricity	18	78	106	128	154	15	18	4.0
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	133	176	184	189	191	34	22	0.5
Other renewables	0	1	1	2	3	0	0	10.4
Industry	**69**	**175**	**237**	**286**	**334**	**100**	**100**	**3.9**
Coal	29	80	109	137	163	45	49	4.3
Oil	8	18	27	31	35	10	11	4.0
Gas	1	13	21	25	29	7	9	4.8
Electricity	9	35	45	53	62	20	19	3.5
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	23	30	35	40	45	17	13	2.4
Other renewables	0	0	0	0	1	0	0	18.0
Transport	**21**	**75**	**115**	**142**	**177**	**100**	**100**	**5.2**
Oil	18	71	108	132	163	96	92	5.0
Electricity	0	1	2	2	2	2	1	2.0
Biofuels	-	0	1	3	4	0	2	17.4
Other fuels	2	2	4	6	8	2	5	10.0
Buildings	**138**	**215**	**233**	**245**	**258**	**100**	**100**	**1.1**
Coal	11	11	11	10	10	5	4	-0.8
Oil	11	27	30	32	36	13	14	1.7
Gas	0	2	3	3	4	1	2	3.0
Electricity	5	29	40	51	64	13	25	4.9
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	111	145	148	146	142	67	55	-0.1
Other renewables	0	1	1	2	2	0	1	9.2
Other	**22**	**54**	**71**	**81**	**92**	**100**	**100**	**3.2**

India: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**293**	**1 211**	**1 613**	**1 935**	**2 303**	**100**	**100**	**3.9**
Coal	192	892	1 000	983	955	74	41	0.4
Oil	13	21	19	17	14	2	1	-2.1
Gas	10	70	137	204	292	6	13	8.8
Nuclear	6	33	64	109	168	3	7	10.0
Hydro	72	144	174	247	346	12	15	5.3
Bioenergy	-	16	46	64	91	1	4	10.7
Wind	0	33	87	149	210	3	9	11.6
Geothermal	-	-	0	1	2	0	0	n.a.
Solar PV	-	3	83	157	211	0	9	29.3
CSP	-	0	2	4	13	0	1	33.3
Marine	-	-	-	-	0	0	0	n.a.

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**266**	**460**	**586**	**718**	**100**	**100**	**6.0**
Coal	157	229	224	224	59	31	2.1
Oil	8	9	8	8	3	1	0.0
Gas	24	42	61	82	9	11	7.4
Nuclear	6	10	16	24	2	3	8.8
Hydro	43	58	82	114	16	16	6.0
Bioenergy	6	10	13	18	2	3	6.4
Wind	20	48	80	109	8	15	10.4
Geothermal	-	0	0	0	0	0	n.a.
Solar PV	2	54	100	135	1	19	27.2
CSP	0	1	1	4	0	1	28.5
Marine	-	-	-	0	0	0	n.a.

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**580**	**1 858**	**2 249**	**2 450**	**2 664**	**100**	**100**	**2.1**
Coal	396	1 282	1 461	1 522	1 558	69	58	1.2
Oil	164	478	633	725	847	26	32	3.4
Gas	21	98	156	203	259	5	10	5.9
Power generation	**239**	**941**	**1 012**	**974**	**930**	**100**	**100**	**-0.1**
Coal	215	890	938	877	805	95	87	-0.6
Oil	16	21	19	17	14	2	1	-2.4
Gas	8	31	55	80	111	3	12	7.8
TFC	**323**	**843**	**1 153**	**1 385**	**1 633**	**100**	**100**	**4.0**
Coal	175	389	518	639	748	46	46	3.9
Oil	139	404	557	650	772	48	47	3.9
Transport	*55*	*215*	*327*	*397*	*491*	*26*	*30*	*5.0*
Gas	9	50	79	96	114	6	7	5.0

Middle East: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**211**	**689**	**792**	**840**	**888**	**100**	**100**	**1.5**
Coal	1	3	4	4	4	0	0	2.0
Oil	137	337	372	377	374	49	42	0.6
Gas	72	345	403	433	464	50	52	1.8
Nuclear	-	1	5	13	18	0	2	18.0
Hydro	1	2	2	3	3	0	0	4.1
Bioenergy	0	1	3	5	9	0	1	15.2
Other renewables	0	0	2	6	15	0	2	29.1
Power generation	**62**	**235**	**247**	**255**	**269**	**100**	**100**	**0.8**
Coal	0	0	1	1	1	0	0	13.7
Oil	27	100	79	64	50	42	19	-4.0
Gas	34	132	157	168	180	56	67	1.8
Nuclear	-	1	5	13	18	0	7	18.0
Hydro	1	2	2	3	3	1	1	4.1
Bioenergy	-	0	1	2	4	0	1	43.7
Other renewables	0	0	1	4	12	0	4	46.4
Other energy sector	**18**	**73**	**76**	**80**	**82**	**100**	**100**	**0.7**
Electricity	*4*	*15*	*18*	*20*	*21*	*21*	*26*	*1.9*
TFC	**150**	**461**	**566**	**612**	**655**	**100**	**100**	**2.1**
Coal	0	2	2	2	2	0	0	-0.9
Oil	102	229	281	298	311	50	47	1.8
Gas	31	164	201	219	237	36	36	2.2
Electricity	16	65	79	87	97	14	15	2.4
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	0	1	2	3	5	0	1	12.0
Other renewables	0	0	1	2	3	0	0	18.0
Industry	**40**	**149**	**182**	**197**	**214**	**100**	**100**	**2.2**
Coal	0	2	2	2	2	1	1	-1.0
Oil	19	33	37	37	37	22	17	0.7
Gas	17	100	125	138	150	67	70	2.5
Electricity	4	14	17	19	21	10	10	2.3
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	-	-	1	2	4	0	2	n.a.
Other renewables	-	0	0	0	0	0	0	32.9
Transport	**48**	**128**	**161**	**174**	**180**	**100**	**100**	**2.0**
Oil	48	121	153	164	170	95	94	2.0
Electricity	-	0	0	0	0	0	0	0.4
Biofuels	-	-	-	-	-	0	0	n.a.
Other fuels	-	6	8	10	11	5	6	3.1
Buildings	**33**	**111**	**127**	**135**	**146**	**100**	**100**	**1.6**
Coal	-	0	0	0	0	0	0	-1.6
Oil	18	19	17	15	14	17	10	-1.5
Gas	3	45	50	53	56	40	39	1.4
Electricity	11	47	58	64	71	42	49	2.4
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	0	1	1	1	1	1	1	4.0
Other renewables	0	0	1	1	2	0	2	16.3
Other	**29**	**73**	**96**	**105**	**115**	**100**	**100**	**2.7**

Middle East: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**224**	**930**	**1 129**	**1 241**	**1 374**	**100**	**100**	**2.3**
Coal	0	0	3	4	5	0	0	16.2
Oil	98	340	277	233	187	37	14	-3.5
Gas	114	565	786	881	963	61	70	3.2
Nuclear	-	4	20	48	71	0	5	18.0
Hydro	12	20	28	35	40	2	3	4.1
Bioenergy	-	0	3	6	14	0	1	43.7
Wind	0	0	3	9	23	0	2	31.9
Geothermal	-	0	0	0	0	0	0	n.a.
Solar PV	-	0	5	14	42	0	3	87.1
CSP	-	0	3	10	28	0	2	109.1
Marine	-	-	-	-	-	0	0	n.a.

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**277**	**340**	**371**	**413**	**100**	**100**	**2.4**
Coal	0	1	1	1	0	0	7.8
Oil	78	85	78	64	28	15	-1.2
Gas	183	226	247	269	66	65	2.3
Nuclear	1	3	7	10	0	2	14.4
Hydro	14	18	22	24	5	6	3.1
Bioenergy	0	0	1	2	0	1	48.0
Wind	0	2	4	10	0	2	29.2
Geothermal	0	0	0	0	0	0	n.a.
Solar PV	0	3	8	24	0	6	39.7
CSP	0	1	3	9	0	2	28.4
Marine	-	-	-	-	0	0	n.a.

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**550**	**1 703**	**1 879**	**1 935**	**1 973**	**100**	**100**	**0.9**
Coal	1	10	12	13	14	1	1	1.9
Oil	392	930	968	957	927	55	47	-0.0
Gas	157	763	898	965	1 032	45	52	1.8
Power generation	**165**	**621**	**616**	**595**	**578**	**100**	**100**	**-0.4**
Coal	0	1	3	4	5	0	1	13.7
Oil	86	311	244	200	156	50	27	-4.0
Gas	79	309	368	391	417	50	72	1.8
TFC	**348**	**959**	**1 141**	**1 213**	**1 270**	**100**	**100**	**1.7**
Coal	1	9	8	8	7	1	1	-0.9
Oil	282	578	678	709	726	60	57	1.4
Transport	*142*	*359*	*453*	*487*	*502*	*37*	*40*	*2.0*
Gas	65	373	455	496	537	39	42	2.2

Africa: Bridge Scenario

	Energy demand (Mtoe)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
TPED	**391**	**750**	**880**	**960**	**1 039**	**100**	**100**	**1.9**
Coal	74	104	110	110	109	14	11	0.3
Oil	86	169	201	216	227	23	22	1.7
Gas	30	98	116	134	149	13	14	2.5
Nuclear	2	3	3	3	6	0	1	4.6
Hydro	5	10	16	21	27	1	3	6.0
Bioenergy	194	363	422	452	473	48	45	1.6
Other renewables	0	2	12	24	48	0	5	21.0
Power generation	**68**	**156**	**183**	**206**	**241**	**100**	**100**	**2.6**
Coal	39	65	67	65	61	41	25	-0.3
Oil	11	25	24	23	21	16	9	-0.9
Gas	11	51	58	65	70	33	29	1.9
Nuclear	2	3	3	3	6	2	3	4.6
Hydro	5	10	16	21	27	6	11	6.0
Bioenergy	0	1	3	6	9	1	4	14.2
Other renewables	0	2	11	23	46	1	19	21.3
Other energy sector	**58**	**113**	**141**	**160**	**173**	**100**	**100**	**2.5**
Electricity	*5*	*12*	*15*	*17*	*20*	*11*	*11*	*2.7*
TFC	**292**	**545**	**639**	**690**	**739**	**100**	**100**	**1.8**
Coal	20	19	21	22	24	4	3	1.2
Oil	71	143	175	191	203	26	28	2.1
Gas	9	28	36	41	48	5	7	3.2
Electricity	22	52	67	79	94	10	13	3.6
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	171	303	339	356	368	56	50	1.2
Other renewables	0	0	1	1	2	0	0	15.2
Industry	**55**	**84**	**102**	**114**	**128**	**100**	**100**	**2.5**
Coal	14	11	13	15	17	13	13	2.5
Oil	15	15	18	20	21	18	16	2.1
Gas	5	16	21	24	28	19	22	3.4
Electricity	12	21	26	28	31	25	24	2.1
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	10	21	24	27	31	25	24	2.3
Other renewables	-	-	0	0	0	0	0	n.a.
Transport	**38**	**89**	**110**	**120**	**126**	**100**	**100**	**2.1**
Oil	37	87	108	117	122	98	97	2.0
Electricity	0	0	1	1	1	1	1	1.9
Biofuels	-	0	1	1	1	0	1	39.0
Other fuels	0	1	1	1	2	1	1	1.9
Buildings	**184**	**345**	**393**	**420**	**445**	**100**	**100**	**1.5**
Coal	3	6	6	5	5	2	1	-1.4
Oil	11	24	28	32	35	7	8	2.3
Gas	1	7	8	10	11	2	3	2.9
Electricity	9	29	39	48	60	8	13	4.4
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	160	279	311	325	332	81	75	1.0
Other renewables	0	0	0	1	1	0	0	12.3
Other	**15**	**27**	**34**	**37**	**40**	**100**	**100**	**2.2**

Africa: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**316**	**742**	**944**	**1 103**	**1 310**	**100**	**100**	**3.4**
Coal	165	257	277	276	268	35	20	0.2
Oil	41	91	92	89	84	12	6	-0.5
Gas	45	260	330	377	426	35	32	2.9
Nuclear	8	12	13	13	25	2	2	4.6
Hydro	56	116	181	242	312	16	24	6.0
Bioenergy	0	2	9	18	31	0	2	18.0
Wind	-	2	16	24	36	0	3	17.1
Geothermal	0	2	9	18	35	0	3	19.3
Solar PV	-	0	13	31	55	0	4	34.9
CSP	-	0	5	16	40	0	3	113.5
Marine	-	-	-	-	-	0	0	n.a.

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**175**	**246**	**298**	**365**	**100**	**100**	**4.4**
Coal	42	53	56	58	24	16	1.9
Oil	36	36	35	35	20	10	-0.2
Gas	68	95	109	126	39	34	3.7
Nuclear	2	2	2	4	1	1	3.7
Hydro	25	41	56	73	14	20	6.5
Bioenergy	0	2	4	6	0	2	17.2
Wind	1	6	10	14	1	4	15.1
Geothermal	0	1	3	5	0	1	20.7
Solar PV	0	8	19	33	0	9	31.2
CSP	0	2	5	11	0	3	29.5
Marine	-	-	-	-	0	0	n.a.

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**545**	**1 052**	**1 190**	**1 260**	**1 304**	**100**	**100**	**1.3**
Coal	234	328	346	340	323	31	25	-0.1
Oil	249	502	588	629	658	48	50	1.6
Gas	62	222	256	291	323	21	25	2.2
Power generation	**212**	**447**	**472**	**472**	**457**	**100**	**100**	**0.1**
Coal	152	251	260	250	228	56	50	-0.6
Oil	35	77	76	71	66	17	14	-0.9
Gas	25	119	136	151	164	27	36	1.9
TFC	**302**	**543**	**653**	**710**	**762**	**100**	**100**	**2.0**
Coal	82	78	86	90	95	14	12	1.2
Oil	202	405	491	533	566	75	74	2.0
Transport	*109*	*259*	*321*	*347*	*364*	*48*	*48*	*2.0*
Gas	18	60	76	87	101	11	13	3.1

Latin America: Bridge Scenario

	Energy demand (Mtoe)					Shares (%)		CAAGR (%)
	1990	2013	2020	2025	2030	2013	2030	2013-30
TPED	**331**	**621**	**675**	**722**	**759**	**100**	**100**	**1.2**
Coal	15	24	27	28	31	4	4	1.6
Oil	150	272	280	283	277	44	37	0.1
Gas	52	141	147	160	172	23	23	1.2
Nuclear	2	5	9	10	12	1	2	5.1
Hydro	30	58	73	84	93	9	12	2.8
Bioenergy	80	117	130	142	149	19	20	1.5
Other renewables	1	5	10	16	24	1	3	10.3
Power generation	**66**	**169**	**177**	**190**	**207**	**100**	**100**	**1.2**
Coal	3	8	8	6	5	5	2	-2.7
Oil	14	34	25	18	12	20	6	-5.8
Gas	14	47	36	38	39	28	19	-1.1
Nuclear	2	5	9	10	12	3	6	5.1
Hydro	30	58	73	84	93	35	45	2.8
Bioenergy	2	12	17	20	24	7	11	4.1
Other renewables	1	4	9	14	22	2	11	10.7
Other energy sector	**57**	**86**	**91**	**96**	**98**	**100**	**100**	**0.8**
Electricity	*8*	*20*	*22*	*24*	*26*	*23*	*26*	*1.4*
TFC	**250**	**468**	**523**	**567**	**597**	**100**	**100**	**1.4**
Coal	6	11	14	16	18	2	3	2.9
Oil	122	222	238	249	251	48	42	0.7
Gas	24	64	81	90	100	14	17	2.6
Electricity	35	81	94	106	118	17	20	2.2
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	63	88	95	103	107	19	18	1.2
Other renewables	-	1	1	2	2	0	0	7.4
Industry	**86**	**158**	**180**	**194**	**207**	**100**	**100**	**1.6**
Coal	6	11	14	16	18	7	9	2.9
Oil	21	34	35	36	36	21	17	0.4
Gas	15	35	47	53	59	22	29	3.1
Electricity	17	35	39	42	44	22	21	1.5
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	27	44	44	47	49	28	24	0.7
Other renewables	-	-	0	0	0	0	0	n.a.
Transport	**72**	**159**	**175**	**185**	**184**	**100**	**100**	**0.9**
Oil	65	136	143	147	144	86	79	0.3
Electricity	0	0	0	1	1	0	0	2.6
Biofuels	6	15	23	28	29	9	16	3.9
Other fuels	0	7	8	9	10	4	5	2.0
Buildings	**67**	**100**	**107**	**117**	**127**	**100**	**100**	**1.4**
Coal	0	0	0	0	0	0	0	4.5
Oil	17	17	18	18	19	17	15	0.4
Gas	6	13	14	16	18	13	14	1.8
Electricity	17	43	51	59	68	43	53	2.6
Heat	-	-	-	-	-	0	0	n.a.
Bioenergy	27	25	23	22	22	25	17	-1.0
Other renewables	-	1	1	1	2	1	1	6.0
Other	**26**	**50**	**62**	**71**	**79**	**100**	**100**	**2.6**

Latin America: Bridge Scenario

	Electricity generation (TWh)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total generation	**489**	**1 173**	**1 349**	**1 508**	**1 665**	**100**	**100**	**2.1**
Coal	9	32	34	25	23	3	1	-1.8
Oil	64	158	119	88	58	13	4	-5.7
Gas	45	222	192	210	225	19	14	0.1
Nuclear	10	21	33	39	48	2	3	5.1
Hydro	354	679	850	977	1 079	58	65	2.8
Bioenergy	7	49	67	78	91	4	5	3.7
Wind	-	8	43	69	97	1	6	15.7
Geothermal	1	4	5	8	12	0	1	7.0
Solar PV	-	0	5	13	25	0	2	36.2
CSP	-	-	-	1	6	0	0	n.a.
Marine	-	-	-	-	-	0	0	n.a.

	Electrical capacity (GW)				**Shares** (%)		**CAAGR** (%)
	2013	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total capacity	**271**	**338**	**383**	**430**	**100**	**100**	**2.8**
Coal	7	8	8	8	2	2	1.5
Oil	41	42	38	33	15	8	-1.2
Gas	54	63	71	78	20	18	2.2
Nuclear	3	5	6	7	1	2	5.1
Hydro	148	185	210	234	55	54	2.7
Bioenergy	14	16	18	20	5	5	2.3
Wind	4	14	21	30	2	7	11.8
Geothermal	1	1	1	2	0	0	6.5
Solar PV	0	4	9	17	0	4	31.5
CSP	-	-	0	1	0	0	n.a.
Marine	-	-	-	-	0	0	n.a.

	CO_2 emissions (Mt)					**Shares** (%)		**CAAGR** (%)
	1990	**2013**	**2020**	**2025**	**2030**	**2013**	**2030**	**2013-30**
Total CO_2	**577**	**1 172**	**1 196**	**1 216**	**1 218**	**100**	**100**	**0.2**
Coal	45	92	106	103	107	8	9	0.9
Oil	416	765	765	758	733	65	60	-0.3
Gas	116	314	326	355	379	27	31	1.1
Power generation	**90**	**256**	**204**	**173**	**151**	**100**	**100**	**-3.0**
Coal	15	40	40	27	22	15	15	-3.3
Oil	44	106	79	58	38	42	25	-5.8
Gas	32	110	85	88	91	43	60	-1.1
TFC	**423**	**813**	**886**	**933**	**959**	**100**	**100**	**1.0**
Coal	26	49	61	71	79	6	8	2.9
Oil	342	622	647	665	661	77	69	0.4
Transport	*194*	*406*	*427*	*438*	*430*	*50*	*45*	*0.3*
Gas	54	142	178	198	219	17	23	2.6

Annex C

Definitions

This annex provides general information on units and conversion factors for energy units and currencies; abbreviations and acronyms; and regional and country groupings.

Units

Coal	Mtce	million tonnes of coal equivalent (equals 0.7 Mtoe)
Emissions	ppm	parts per million (by volume)
	Gt CO_2-eq	gigatonnes of carbon-dioxide equivalent (using 100-year global warming potentials for different greenhouse gases)
	g CO_2/km	grammes of carbon dioxide per kilometre
	g CO_2/kWh	grammes of carbon dioxide per kilowatt-hour
Energy	Mtoe	million tonnes of oil equivalent
	MBtu	million British thermal units
	Gcal	gigacalorie (1 calorie x 10^9)
	TJ	terajoule (1 joule x 10^{12})
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
Gas	bcm	billion cubic metres
Mass	kg	kilogramme (1 000 kg = 1 tonne)
	kt	kilotonnes (1 tonne x 10^3)
	Mt	million tonnes (1 tonne x 10^6)
	Gt	gigatonnes (1 tonne x 10^9)
Monetary	$ million	1 US dollar x 10^6
	$ billion	1 US dollar x 10^9
	$ trillion	1 US dollar x 10^{12}
Oil	b/d	barrel per day
	mb/d	million barrels per day
Power	kW	kilowatt (1 watt x 10^3)
	MW	megawatt (1 watt x 10^6)
	GW	gigawatt (1 watt x 10^9)

General conversion factors for energy

Convert to:	TJ	Gcal	Mtoe	MBtu	GWh
From:	multiply by:				
TJ	1	238.8	2.388 x 10^{-5}	947.8	0.2778
Gcal	4.1868 x 10^{-3}	1	10^{-7}	3.968	1.163 x 10^{-3}
Mtoe	4.1868 x 10^{4}	10^{7}	1	3.968 x 10^{7}	11 630
MBtu	1.0551 x 10^{-3}	0.252	2.52 x 10^{-8}	1	2.931 x 10^{-4}
GWh	3.6	860	8.6 x 10^{-8}	3 412	1

Note: There is no generally accepted definition of boe; typically the conversion factors used vary from 7.15 to 7.35 boe per toe.

Currency conversions

Exchange rates *(2013 annual average)*	**1 US Dollar equals:**
British Pound	0.64
Chinese Yuan	6.20
Euro	0.75
Indian Rupee	60.52
Japanese Yen	97.60
Russian Ruble	31.76

Abbreviations and Acronyms

ASEAN	Association of Southeast Asian Nations
CAAGR	compound average annual growth rate
CAFE	corporate average fuel-economy standards (United States)
CBM	coalbed methane
CCGT	combined-cycle gas turbine
CCS	carbon capture and storage
CH_4	methane
CO_2	carbon dioxide
CO_2-eq	carbon-dioxide equivalent
COP	Conference of Parties (UNFCCC)
CPS	Current Policies Scenario
CSP	concentrating solar power
EPA	Environmental Protection Agency (United States)
EU	European Union
EU ETS	European Union Emissions Trading System

EV	electric vehicle
F-gases	fluorinated gases, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)
GDP	gross domestic product
GHG	greenhouse gases
GT	gas turbine
GWP	global warming potential
ICAO	International Civil Aviation Organization
IMF	International Monetary Fund
IMO	International Maritime Organization
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
LCOE	levelised cost of electricity
LPG	liquefied petroleum gas
LULUCF	land-use, land-use change and forestry
MBM	market-based measure
MER	market exchange rate
MEPS	minimum energy performance standards
NAP	national adaptation plan
NAPA	national adaptation programmes of action
N_2O	nitrous oxide
NPS	New Policies Scenario
OECD	Organisation for Economic Co-operation and Development
PLDV	passenger light-duty vehicle
PPP	purchasing power parity
PV	photovoltaic
R&D	research and development
RD&D	research, development and demonstration
RDD&D	research, development, demonstration and deployment
SO_2	sulphur dioxide
TFC	total final consumption
TPED	total primary energy demand
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
WEO	World Energy Outlook
WEM	World Energy Model

Regional and country groupings

Africa: Includes North Africa and sub-Saharan Africa.

Caspian: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan.

China: Refers to the People's Republic of China, including Hong Kong.

Developing countries: Non-OECD Asia, Middle East, Africa and Latin America regional groupings.

Eastern Europe/Eurasia: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Georgia, Kazakhstan, Kosovo, Kyrgyz Republic, Latvia, Lithuania, the former Yugoslav Republic of Macedonia, the Republic of Moldova, Montenegro, Romania, Russian Federation, Serbia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan. For statistical reasons, this region also includes Cyprus[1,2], Gibraltar and Malta.

European Union: Austria, Belgium, Bulgaria, Croatia, Cyprus[1,2], Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden and United Kingdom.

G20: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russian Federation, Saudi Arabia, South Africa, Korea, Turkey, United Kingdom, United States and European Union.

Latin America: Argentina, Bolivia, Brazil, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela and other non-OECD America countries and territories.[3]

Middle East: Bahrain, the Islamic Republic of Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates and Yemen.

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1. Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

2. Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

3. Individual data are not available and are estimated in aggregate for: Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands (Malvinas), French Guyana, Grenada, Guadeloupe, Guyana, Martinique, Montserrat, St. Kitts and Nevis, St Lucia, St Pierre et Miquelon, St. Vincent and the Grenadines, Suriname and Turks and Caicos Islands.

Non-OECD Asia: Bangladesh, Brunei Darussalam, Cambodia, China, Chinese Taipei, India, Indonesia, the Democratic People's Republic of Korea, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Singapore, Sri Lanka, Thailand, Vietnam and other Asian countries and territories.[4]

North Africa: Algeria, Egypt, Libya, Morocco, Tunisia and Western Sahara (under UN mandate).

OECD: Includes OECD Americas, OECD Asia Oceania and OECD Europe regional groupings.

OECD Americas: Canada, Chile, Mexico and United States.

OECD Asia Oceania: Australia, Japan, Korea and New Zealand.

OECD Europe: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom. For statistical reasons, this region also includes Israel.[5]

OPEC (Organization of Petroleum Exporting Countries): Algeria, Angola, Ecuador, the Islamic Republic of Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela.

Southeast Asia: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. These countries are all members of the Association of Southeast Asian Nations (ASEAN).

Sub-Saharan Africa: Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde Cameroon, Comoros, Central African Republic (CAR), Chad, Congo, Côte d'Ivoire, Democratic Republic of Congo (DR Congo), Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Somalia, South Sudan, Sudan, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia and Zimbabwe.

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[4] Individual data are not available and are estimated in aggregate for: Afghanistan, Bhutan, Cook Islands, East Timor, Fiji, French Polynesia, Kiribati, Lao PDR, Macao (China), Maldives, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu.

[5] The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

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Energy and Climate Change

The world is moving towards a crucial climate change meeting in Paris in December 2015 (COP21). The negotiations there will be based on national pledges, formally known as Intended Nationally Determined Contributions, with the goal of setting the world on a sustainable path.

The International Energy Agency has long emphasised to its members and the world at large that energy production and use which is not compatible with international environmental requirements is not sustainable: it fails the test of energy security. The IEA, therefore, feels an obligation to make a contribution to COP21 – a contribution which reconciles climate and energy needs. That is the purpose of this special report in the *World Energy Outlook* series.

The report:

- Presents a detailed first assessment of the energy sector impact of known and signalled national climate pledges for COP21.
- Proposes a bridging strategy to deliver a near-term peak in global energy-related greenhouse-gas emissions, based on five pragmatic measures that can advance climate goals through the energy sector without blunting economic growth.
- Highlights the urgent need to accelerate the development of emerging technologies that are, ultimately, essential to transforming the global energy system into one that is consistent with the world's climate goals.
- Recommends four key pillars on which COP21 can build success, from an energy sector perspective.

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