World Energy Outlook 2015

Chapter 1: Introduction and scope

Introduction and scope

How do we project energy trends?

Highlights

- The New Policies Scenario – the central scenario in *WEO-2015* – takes into account the policies and implementing measures affecting energy markets that had been adopted as of mid-2015 (as well as the energy-related components of climate pledges in the run-up to COP21, submitted by 1 October), together with relevant declared policy intentions, even though specific measures needed to put them into effect may not have been adopted. The Current Policies Scenario takes into account only policies enacted as of mid-2015. 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. Against a backdrop of uncertainty over economic growth and a persistent oil market imbalance, a Low Oil Price Scenario explores the implications of sustained lower prices on the global energy system.

- The level and pattern of economic activity and demographic changes will be important determinants of future energy trends. World GDP is assumed to grow at an average annual rate of 3.5% over 2013-2040, meaning it expands to more than two-and-a-half-times its current size. Supported by the anticipated rebalancing of Chinese growth away from manufacturing, and despite Indian intentions to stimulate manufacturing, nearly two-thirds of the growth comes from the services sector, which is the least-energy intensive part of the global economy. The world's population is assumed to rise from 7.1 billion in 2013 to 9 billion in 2040, with the increase concentrated in Africa, India, Southeast Asia and the Middle East. India overtakes China to become the world's most populous country by the mid-2020s.

- The international fossil-fuel prices used in this report reflect our judgement of the price levels that would be needed to stimulate sufficient investment in supply to meet projected long-term demand. In the New Policies Scenario, the average IEA crude oil import price edges upward to $80/barrel (in year-2014 dollars) in 2020 and $128 in 2040. Natural gas prices, which have fallen sharply in Asia and Europe over the last year, rise in all markets with price spreads between regions persisting, despite a degree of convergence. The average OECD steam coal import price reaches $108 per tonne in 2040. The share of global emissions covered by carbon pricing increases from 12% of emissions today, to 27% in 2040.

- Deployment of increasingly efficient end-use technologies, renewables and other low-carbon energy options continues to expand rapidly, buoyed by declining costs and, in some cases, by dedicated policy initiatives and/or subsidies. This coincides with a gradual increase in the cost of oil and gas extraction. We assume energy technologies that are already in use or are approaching commercialisation achieve ongoing cost reductions as a result of increased learning and deployment.

Scope of the report

This edition of the *World Energy Outlook* (*WEO-2015*) presents an assessment of the prospects for global energy markets for the period to 2040 and draws out the implications for energy security, environmental protection and economic development. The objective is to provide policy-makers, industry and other stakeholders with the data, analysis and insights needed to make sound energy decisions. Based on the latest data and market developments, the *Outlook* includes energy demand and supply projections, insights into the trajectories of fossil fuels, renewables, the power sector and energy efficiency, and analysis of trends in energy-related carbon-dioxide (CO_2) emissions, subsidies to fossil fuels and renewable energy, investment in energy supply infrastructure and universal access to modern energy services.

Part A of this report (Chapters 1-10) focuses on the core projections to 2040. While results for a number of scenarios are included, emphasis is placed predominately on the results of the New Policies Scenario, to provide a clear picture of where planned policies, with generally cautious assumptions about the timing and degree of their implementation, would take us. Chapter 2 summarises the projections for global energy trends and energy sector investment. It also draws out the implications of these trends for CO_2 emissions and summarises areas for further action which have already been identified by the *Energy and Climate: World Energy Outlook Special Report* as an input to the climate change negotiations in Paris in December, 2015. Chapter 2 also continues the *WEO* practice of analysing two crucial energy sector challenges: achieving universal energy access; and phasing out fossil-fuel subsidies. Chapters 3-10 review the main pillars of the energy system in turn: the outlook for oil (including a Low Oil Price Scenario), natural gas (including a detailed look at the prospects for unconventional gas), coal, power, renewables and energy efficiency.

An in-depth focus on India is presented in Part B (Chapters 11-14). Energy is critical for India's development and the country's growing energy consumption also has broad implications for the regional and global energy outlook. This analysis starts with a review of the current state of India's energy sector. It then looks forward to how India might address the energy challenges arising from rapid economic growth and urbanisation, including the need to improve access to electricity and the reliability of power supply, to mobilise the investment that can expand domestic production of fossil fuels and renewable sources of energy, and to manage the consequences for energy security and for the environment.

Methodological approach

Modelling framework

The World Energy Model (WEM) is the principal tool used to produce the energy projections in this report.[1] The model is a large-scale simulation tool, designed to replicate how energy

1. A complete description of the WEM is available at *www.worldenergyoutlook.org/weomodel/*.

markets function. Developed over more than 20 years, it consists of three main modules covering final energy consumption (including industry, transport, buildings, agriculture and non-energy use), fossil fuel and bioenergy supply, and energy transformation (including power and heat generation, oil refining and other transformation). The primary outputs from the model for each region are energy demand and supply by fuel, investment needs and CO_2 emissions.

The WEM is a very data-intensive model that covers the entire global energy system. The current version models global energy demand on the basis of 25 distinct regions, 13 of which are individual countries. Global oil and gas supply is modelled based on 120 distinct countries and regions; global coal supply is modelled based on 31 countries and regions. Most of the historic data on energy demand, supply, and transformation, as well as on energy prices, are obtained from IEA databases of energy and economic statistics.[2] These are supplemented by additional data from many external sources, including governments, international organisations, energy companies, consulting firms and financial institutions. These sources are indicated in the relevant sections of this document.

The WEM is reviewed and updated each year to ensure that it provides as accurate a representation as possible of regional and global energy markets. The latest improvements include the following:

- The buildings module has had a number of enhancements: (i) energy use in appliances has been further disaggregated by the addition of four new sub-sectors: refrigeration; cleaning; brown goods (i.e. consumer electronics); and other appliances (which together account for around half of all electricity use in the residential sector), making it easier to capture the effects of efficiency measures, technology deployment and price responses; and (ii) a new clean cooking access module has been linked to the residential module for developing countries, enabling better representation of the drivers of demand and the possible changes in the energy system resulting from the increased use of improved cookstoves and substitution of liquefied petroleum gas (LPG) and natural gas for biomass.
- The impacts of water constraints on coal-fired power plants have been captured. This includes the development of a model for China and India that determines the least-cost location of coal-fired power plants based on water availability, coal transportation costs and the capital cost of cooling systems (differentiating between non-fresh water and freshwater).
- The electricity price module in the WEM has been revised to better represent the cost elements of the power system, from generation costs (including incorporating more complete information for all regions on historical investment costs), to the costs associated with transmission and distribution, and subsidies for fossil fuels, electricity and renewable energy technologies.

2. Many of these data are available at *www.iea.org/statistics*.

Defining the scenarios

As in past editions, *WEO-2015* uses scenarios to present quantitative projections of long-term energy trends. There are three core scenarios, which differ in their assumptions about the evolution of energy-related government policies: the New Policies Scenario; the Current Policies Scenario; and the 450 Scenario.[3] For this report, we also present a Low Oil Price Scenario as a contribution to the debate about the possible consequences of a long-term low oil price environment. The base year for all of the scenarios is 2013, as comprehensive market data for all countries were available only up to the end of 2013 at the time the modelling work was completed. However, where preliminary data for 2014 were available (which was often the case), they have been incorporated.

The **New Policies Scenario** is the central scenario of this *Outlook*. In addition to incorporating the policies and measures that affect energy markets and that had been adopted as of mid-2015, it also takes account of other relevant intentions that have been announced, even when the precise implementing measures have yet to be fully defined. This includes the energy-related components of the Intended Nationally Determined Contributions (INDCs), submitted by national governments by 1 October as pledges in the run-up to the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) (Spotlight). It also includes all policies announced but yet to be implemented and we take a generally cautious view in the New Policies Scenario of the extent and timing of their implementation, given the institutional, political and economic circumstances that could stand in the way. These policies include programmes to support renewable energy and improve energy efficiency, to promote alternative fuels and vehicles, carbon pricing, reform of energy subsidies, and the introduction, expansion or phase-out of nuclear power.

As in previous *Outlooks*, we devote most attention to the results of the New Policies Scenario in order to provide the clearest picture possible of the outcome of continuing with the policies that are in place and those that are currently planned. The results however, do not constitute a forecast. New policies, as yet unformulated, will certainly be adopted over the course of the next twenty-five years. Indeed, one purpose in projecting the future is to demonstrate the need for their adoption.

The **Current Policies Scenario** takes into consideration only those policies for which implementing measures had been formally adopted as of mid-2015 and makes the assumption that these policies persist unchanged. This scenario, though clearly extremely unlikely to be realised, offers a picture of how global energy markets would evolve without new policy intervention, thereby providing a benchmark to make it possible to ascertain the value of the additional measures taken into account in the New Policies Scenario and, perhaps, to point the way to promising avenues for further improvement.

3. Details of the key policies and measures taken into account in each scenario can be found in Annex B. A policies and measures database, detailing policies addressing renewable energy, energy efficiency and climate change is available at *www.iea.org/policiesandmeasures*.

SPOTLIGHT

Recent key developments in energy and climate policy

Throughout the year, governments across the world have been submitting new greenhouse-gas reductions pledges – known as Intended Nationally Determined Contributions (INDCs) – to the UNFCCC in advance of the COP21 summit, forming a foundation for the negotiations (Table 1.1). This has brought notable commitments from a number of countries, with significant contributions from some of the world's largest emitters, including China and the United States. As of 1 October 2015, almost 150 countries across the economic spectrum, responsible for around 85% of energy-related CO_2 emissions have set out their targets. Also notable is that, for the first time, even countries that have only thus far contributed nominally to global greenhouse-gas emissions are opting to outline their strategies, including for example over 20 countries in sub-Saharan Africa, as well as many countries in Asia and Latin America. A detailed analysis of the implications of full implementation of the energy-related measures announced in the INDCs is presented in the *Energy and Climate Change: World Energy Outlook Special Report 2015*, which was released in June and took into account all INDCs and intentions announced by mid-May 2015. An update of this analysis was made in October 2015, incorporating the latest available energy sector data.[4] In this *World Energy Outlook*, in line with our usual New Policies Scenario methodology, we took those INDCs into account that had been submitted by 1 October, with a focus on explicit energy sector targets. The degree to which these pledges are implemented in the New Policies Scenario is guided by the availability of policies to support them.

The **450 Scenario** takes a different approach, adopting a specified outcome – the international goal to limit the rise in the long-term average global temperature to two degrees Celsius (2 °C) – and illustrating how that might be achieved. This scenario assumes a set of policies that bring about a trajectory of greenhouse-gas (GHG) emissions from the energy sector that is consistent with that goal. In this scenario, the concentration of greenhouse gases in the atmosphere peaks by around the middle of this century; the level is above 450 parts per million (ppm), but not so high as to be likely to precipitate changes that make the 2 °C objective ultimately unattainable. The concentration of greenhouse gases stabilises after 2100 at around 450 ppm. While the results of the 450 Scenario are included for reference purposes in many of the tables and figures throughout this report, as well in the detailed tables in Annex A, a broader discussion is limited, as the energy sector's potential role in mitigating climate change was set out in detail in *Energy and Climate: World Energy Outlook Special Report*, which was deliberately released in June 2015, ahead of this *World Energy Outlook 2015*, in order to make a timely contribution to the preparations for COP21.[5]

4. The findings of this update are available at: *www.worldenergyoutlook.org/indc/*.
5. The report can be downloaded free at: *www.worldenergyoutlook.org/energyclimate/*.

Table 1.1 ▷ Greenhouse-gas emissions reduction goals in submitted INDCs for top-ten CO_2 emitters (as of 1 October 2015)[6]

UNFCCC Party	Intended Nationally Determined Contribution (INDC)
China	Peak GHG emissions by 2030 or earlier and reduce carbon intensity of GDP by 60-65% below their 2005 levels by 2030.
United States	Reduce net GHG emissions by 26-28% below 2005 levels by 2025.
European Union	Reduce EU domestic GHG emissions by at least 40% below 1990 levels by 2030.
India	Reduce the emissions intensity of GDP by 33-35% below 2005 levels by 2030.
Russia	Reduce anthropogenic GHG emissions by 25-30% below 1990 levels by 2030 subject to the maximum possible account of absorptive capacity of forests.
Japan	Reduce energy-related CO_2 emissions by 25%, reduce non-energy CO_2 emissions by 6.7%, CH_4 by 12.3%, N_2O by 6.1%, and fluorinated gases by 25.1% compared with 2013 levels by 2030.
Korea	Reduce GHG emissions by 37% by 2030 compared with a business-as-usual scenario.
Canada	Reduce GHG emissions by 30% below 2005 levels by 2030.
Brazil	Reduce GHG emissions by 37% compared with 2005 levels by 2025.
Mexico	Reduce GHG and short-lived climate pollutant emissions unconditionally by 25% by 2030 with respect to a business-as-usual scenario.

The ***Low Oil Price Scenario*** illustrates the impact of a persistently lower oil price than that modelled in the New Policies Scenario – the subject of much recent debate – not just for the oil sector, but on the global energy system as a whole. In this scenario, market equilibrium is not attained until the 2020s, with prices in the $50-60/barrel range (in year 2014 dollars), after which the price starts to edge higher, reaching $85/barrel in 2040. A number of oil supply and demand side assumptions differentiate this scenario from the New Policies Scenario. On the supply side, the main such assumptions is persistent commitment by the countries holding the world's largest and lowest-cost resources to pursue higher market share and to keep the oil price at a level that limits substitution away from oil. Greater resilience in a lower price environment is also assumed in some important non-OPEC sources of supply, notably tight oil in the United States. A key assumption on the demand side is a slightly lower pace of near-term economic growth.

Main non-policy assumptions

The economy

Economic activity remains a primary driver of demand for energy. The projections described in this *Outlook* are, therefore, highly sensitive to the underlying assumptions about the rate and pattern of growth in gross domestic product (GDP). The modelling is undertaken on the basis of GDP expressed in real purchasing power parity (PPP) terms. PPPs allow meaningful comparisons of value between countries, just as conventional

6. A full list of the INDCs submitted can be accessed at: *www.unfccc.int/submissions/indc/*.

price indices allow prices within a country to be compared over time. They are calculated by simultaneously comparing the prices of similar goods and services among a large number of countries. Following a revision of PPPs in 2014 by the International Comparison Program and subsequently the International Monetary Fund, the estimated size of the global economy has been revised upwards significantly. Global GDP is now estimated to be about 20% higher than it was previously, with the largest upward revisions in the emerging economies. We have also gained insights on how energy policies impact the broader economy from the coupling of the World Energy Model with ENV-Linkages[7], the OECD computable general equilibrium model.

Table 1.2 ▷ Real GDP growth assumptions by region

	Compound average annual growth rate				
	1990-2013	2013-2020	2020-2030	2030-2040	2013-2040
OECD	**2.1%**	**2.2%**	**1.9%**	**1.7%**	**1.9%**
Americas	2.5%	2.6%	2.2%	2.1%	2.2%
United States	2.5%	2.5%	2.0%	2.0%	2.1%
Europe	1.8%	1.9%	1.8%	1.6%	1.7%
Asia Oceania	1.9%	1.7%	1.7%	1.3%	1.5%
Japan	0.9%	0.6%	0.9%	0.7%	0.8%
Non-OECD	**4.9%**	**4.9%**	**5.0%**	**3.8%**	**4.5%**
E. Europe/Eurasia	0.9%	1.4%	3.3%	2.8%	2.6%
Russia	0.7%	0.2%	3.1%	2.7%	2.2%
Asia	7.3%	6.3%	5.7%	3.9%	5.2%
China	9.9%	6.4%	5.3%	3.1%	4.8%
India	6.5%	7.5%	7.0%	5.3%	6.5%
Southeast Asia	5.1%	5.3%	5.0%	3.7%	4.6%
Middle East	4.3%	3.1%	3.9%	3.4%	3.5%
Africa	4.0%	4.8%	4.8%	4.3%	4.6%
Latin America	3.4%	1.7%	3.5%	3.2%	2.9%
Brazil	3.1%	1.4%	3.8%	3.3%	3.0%
World	**3.4%**	**3.7%**	**3.8%**	**3.1%**	**3.5%**
European Union	1.6%	1.8%	1.7%	1.5%	1.6%

Note: Calculated based on GDP expressed in year-2014 dollars in PPP terms.

Sources: IMF (2014); OECD (2014); Economist Intelligence Unit and World Bank databases; IEA databases and analysis.

7. The version of ENV-Linkages that has been used includes 25 regions and 18 economic sectors, with a focus on those that are most energy intensive. It models monetary flows between economic sectors, households and governments, as well as inter-regional trade in various commodities. A full description of the ENV-Linkages model is available at the OECD iLibrary: *http://dx.doi.org/10.1787/5jz2qck2b2vd-en*.

In each of the core scenarios of this *Outlook*, world GDP is assumed to grow at an average annual rate of 3.5% over 2013-2040, which means it expands to more than two-and-a-half-times its current size over the period (Table 1.2). The exception is the Low Oil Price Scenario, in which a slightly slower near-term rate of growth is one of the assumptions underpinning the scenario. The recent revisions to PPPs have contributed to a slight increase in our assumption for global GDP growth, compared with *WEO-2014*, as they have meant that emerging economies, which are typically expected to grow at faster rates than other parts of the world in the decades ahead, start the period accounting for a greater share of the global economy.

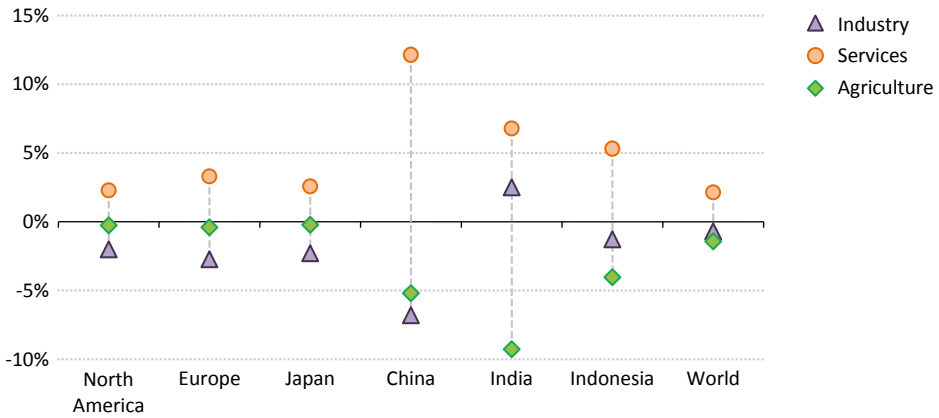
India's economic growth, at 6.5% per year on average in the period 2013-2040, outpaces all others. The recent rebasing of India's historical GDP and changes in the way its GDP is calculated have contributed to upward revisions to growth estimates for the country, which is already the world's third-largest in PPP terms. The services sector has been the main source of GDP growth in India in recent years, but the manufacturing industry is expected to play an increasingly important role. By contrast, the composition of China's GDP is expected to shift away from industry towards services, a long-anticipated rebalancing, with similarly important implications for energy demand. The growth prospects of several key oil producers, including countries in the Middle East, Russia, Canada and Brazil, have all been revised downwards, compared to last year's *Outlook*, particularly in the period to 2020, as a result of lower energy prices.

While the fall in energy prices since mid-2014 has been an economic boon for many energy importers, alleviating fiscal strains and allowing money to be freed up to stimulate other parts of the economy, it by no means has eliminated the uncertainty about growth prospects in the world's advanced economies. In the United States, the outlook to 2020 is dampened by the strong dollar, an anticipated slowdown in productivity growth and the demographics of an ageing population. Canada slipped into recession in the first-half of 2015. In Europe, the legacy of the economic downturn continues to subdue demand and remains a hindrance to higher levels of growth, while lingering doubts over the durability of Greece's agreement with its creditors adds a further layer of uncertainty. In Japan, lower oil and natural gas prices, higher real wages, higher equity prices and a weaker yen have improved the outlook.

From an energy perspective, the contributions that different economic sectors make to total GDP can be as important as the overall rates of growth, as the extent to which they use energy as an input to generate economic output (or value added) varies significantly. Over the projection period, the services sector, which requires a relatively low level of energy per unit of output, contributes an increasing share of global GDP (Figure 1.1). While activity in the services sector has, in the past, been dominated by the OECD countries, whose services sector has accounted for a quarter of global economic growth since 1990, China is set to take a leading role into the injection of growth in the global economy through its services sector which, alone, accounts for around 15% of global growth to 2040. In India a push towards greater reliance on manufacturing will mean the effect of growth in its

services sector is more subdued than it otherwise would have been, but, its services sector still provides the second-largest contribution to the overall growth in the global economy to 2040.

Figure 1.1 ▷ Change in value-added GDP contribution by sector, 2014-2040

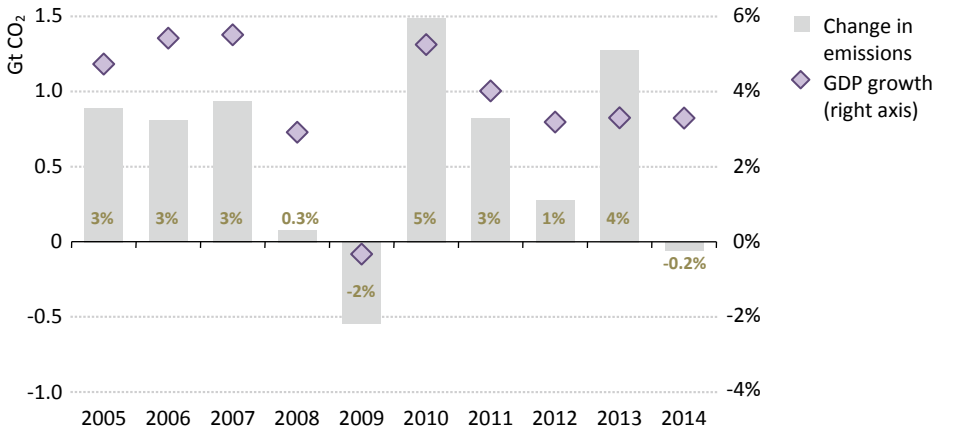


Box 1.1 ▷ Are economic growth and carbon emissions decoupling?

In most parts of the world, economic activity remains the principal driver of demand for energy and is therefore strongly correlated with carbon emissions. This has been the case for the past 40 years in which the IEA has collected emissions data. During these four decades, there have been only three instances in which emissions have remained flat or declined relative to the previous year and each case has been associated with economic weakness in major economies.

However, a noticeable shift occurred in 2014, with emissions failing to increase despite a 3.3% expansion of the global economy (Figure 1.2). This development can be largely attributed to changing patterns of energy consumption in China and OECD countries. In China, 2014 saw greater generation of electricity from renewable sources, such as hydropower, solar and wind, and less burning of coal, alongside a shift in the structure of economic output from energy-intensive industries towards the services sector. In OECD economies, recent efforts to promote more sustainable growth – including greater energy efficiency and more renewable energy – are producing the desired effect of decoupling economic growth from greenhouse-gas emissions. The experience of 2014 provides a timely reminder of the dividends that can be expected from sustained efforts to decarbonise the energy supply. But one swallow does not make a summer – emissions are more than likely to resume their upward climb in 2015. The projections in this *Outlook* continue to be highly sensitive to assumptions about the rates and patterns of GDP growth.

Figure 1.2 ▷ Energy-related CO_2 emissions and economic growth, 2005-2014



Notes: Gt CO_2 = gigatonnes of carbon dioxide. Percentage shows year-on-year change in emissions. GDP growth is calculated using 2014 dollars in PPP terms.

Demographic trends

Population and demographics are important drivers of energy demand and changes in the energy mix. This edition of the *WEO* adopts the same approach as in previous years, taking the medium variant of the latest United Nations' projections (UNPD, 2015) as the basis for population growth in all scenarios. According to these projections, the world population is expected to grow by 0.9% per year on average, from 7.1 billion in 2013 to 9 billion in 2040 (Table 1.3). The increase in the global population is concentrated in Africa, India, Southeast Asia and the Middle East. Africa experiences the fastest rate of growth, resulting in a near doubling of its population to almost 2 billion people. India overtakes China to become the world's most populous country in the mid-2020s, with its population approaching 1.6 billion people by the end of the period. A number of countries see their population peak and begin to decline in our projection period, including Japan (whose population in 2040 is almost 10% smaller than it is today), Korea, Russia and Germany. China's population peaks in the early 2030s and begins to decline thereafter.

Populations increasingly concentrate in cities and towns, pushing the urbanisation rate up from 53% in 2013 to 63% in 2040, meaning that the absolute number of people living in rural areas falls. Urbanisation tends to increase demand for modern forms of energy as such forms of energy are more readily available and levels of income and economic activity tend to be higher, although this energy growth can be mitigated through a strategic approach to planning and transport policy.

Table 1.3 ▷ Population assumptions by region

	Population growth*			Population (million)		Urbanisation	
	1990-2013	2013-25	2013-40	2013	2040	2013	2040
OECD	**0.7%**	**0.5%**	**0.4%**	**1 265**	**1 402**	**80%**	**85%**
Americas	1.1%	0.8%	0.7%	492	593	81%	86%
United States	1.0%	0.8%	0.7%	321	383	81%	86%
Europe	0.5%	0.3%	0.2%	568	604	75%	82%
Asia Oceania	0.4%	0.1%	0.0%	206	205	89%	93%
Japan	0.1%	-0.3%	-0.4%	127	115	92%	97%
Non-OECD	**1.5%**	**1.1%**	**1.0%**	**5 857**	**7 633**	**47%**	**59%**
E. Europe/Eurasia	0.0%	-0.1%	-0.2%	341	327	63%	68%
Russia	-0.1%	-0.3%	-0.4%	144	128	74%	79%
Asia	1.3%	0.9%	0.6%	3 714	4 413	43%	57%
China	0.8%	0.4%	0.1%	1 365	1 414	53%	73%
India	1.6%	1.1%	0.9%	1 252	1 599	32%	45%
Southeast Asia	1.5%	1.0%	0.8%	616	760	46%	60%
Middle East	2.4%	1.7%	1.4%	218	313	69%	76%
Africa	2.5%	2.4%	2.2%	1 111	1 999	40%	51%
Latin America	1.4%	1.0%	0.8%	473	581	79%	84%
Brazil	1.3%	0.7%	0.5%	200	229	85%	90%
World	**1.3%**	**1.0%**	**0.9%**	**7 122**	**9 036**	**53%**	**63%**
European Union	0.3%	0.1%	0.1%	508	516	74%	81%

* Compound average annual growth rates.

Sources: UN Population Division databases; IEA analysis.

Carbon-dioxide prices

The pricing of CO_2 emissions affects demand for energy and the composition of the fuel mix by altering the relative costs of using different fuels. Momentum to price the cost associated with greenhouse-gas emissions continues. As of mid-2015, a total of 39 carbon pricing initiatives had been taken, in the form of taxes or cap-and-trade schemes, covering around 3.7 gigatonnes (Gt) (12%) of global energy-related CO_2 emissions and with an aggregate value of $26 billion. Since the last *World Energy Outlook* edition, Korea launched a cap-and-trade programme to limit emissions to 2017 to just under 1.7 million tonnes (Mt) of CO_2 equivalent, and Mexico and Portugal[8] established carbon taxes. The effectiveness of the European Union Emissions Trading Scheme (EU ETS), by far the world's largest carbon market, remains constrained by a surplus of allowances that has kept the price of carbon

8. A carbon tax of €5 per tonne CO_2 equivalent was introduced for sectors not currently covered by the EU ETS.

too low to incentivise low-carbon investment. In a bid to improve its effectiveness, the EU agreed in 2015 to introduce a Market Stability Reserve in 2019 that would regulate the surplus by withdrawing allowances when necessary.

Our assumptions on carbon pricing vary across the scenarios, reflecting the extent of policy interventions to curb growth in CO_2 emissions. We assume that all the schemes currently in place remain throughout the *Outlook* period, with their prices gradually rising in each case (Table 1.4). In the New Policies Scenario, the price of CO_2 in Europe increases from $9/tonne in 2014 to $22/tonne in 2020 and $50/tonne in 2040. Having started at around $7.3/tonne, the price of permits in Korea rises to levels similar to those in Europe in 2040. China's recently-announced carbon trading scheme, which replaces a current pilot programme covering seven cities, is due to come into force by the start of 2017, and will cover six sectors including power, iron and steel; chemicals; building materials, paper, and nonferrous metals. This increases by two-and-a-half-times the share of global emissions covered by carbon pricing, which will reach 27%. We also assume that all investment decisions in the power sector in Canada, the United States and Japan are made on the basis of an implicit "shadow" carbon price[9] that starts at $13/tonne from today and rises to $40/tonne in 2040. Our assumptions in the 450 Scenario are for more widespread and aggressive carbon pricing, which is adopted in all OECD countries and reaches $140/tonne in 2040.

Table 1.4 ▷ CO_2 price assumptions in selected countries and regions by scenario ($2014 per tonne)

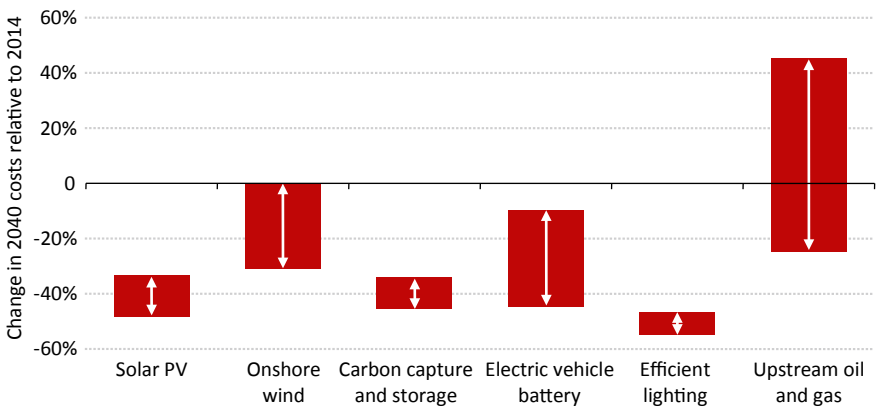
	Region	Sectors	2020	2030	2040
Current Policies Scenario	European Union	Power, industry and aviation	20	30	40
	Korea	Power and industry	20	30	40
New Policies Scenario	European Union	Power, industry and aviation	22	37	50
	Chile	Power	6	12	20
	Korea	Power and industry	22	37	50
	China	Power and industry	10	23	35
	South Africa	Power and industry	7	15	24
450 Scenario	United States and Canada	Power and industry	20	100	140
	European Union	Power, industry and aviation	22	100	140
	Japan	Power and industry	20	100	140
	Korea	Power and industry	22	100	140
	Australia and New Zealand	Power and industry	20	100	140
	China, Russia, Brazil and South Africa	Power and industry	10	75	125

9. This is an assumed price, taken into account in investment decisions, to reflect the expectation that some form of action is or will be taken to penalise CO_2 emissions in the future.

Technology

Advanced energy technologies could fundamentally alter the long-term evolution of energy markets and have a major bearing on efforts to meet environmental goals, including those linked to greenhouse-gas emissions. The projections in this report are therefore sensitive to assumptions on the rates of technological change and how they affect energy efficiency, supply costs and fuel choices. This *Outlook* does not make allowances for technological breakthroughs, as it is impossible to determine what form these will take, when they might occur, or how quickly they can be commercialised. But, each of the scenarios presented in this *Outlook* incorporates a process of technology learning on both the demand and supply sides that affects the costs of different energy technologies (both those in use today and those that are judged to be approaching commercialisation) and therefore the patterns of investment in different sources of energy supply and in energy efficiency (Table 1.5). The rate of technological improvement is related in many cases to the level of deployment (which is driven in turn by the policies assumed, as well as by energy and CO_2 prices), although the resulting costs can be offset by depletion effects of some resources in a given location. This is a discernible factor affecting renewable resources in some countries and regions, for example where the most advantageous sites for wind turbines have been fully exploited and developers have to look to second-tier sites. It is a much more important consideration for the costs of upstream oil and gas, as producers work their way through the resource base in a given area and over time move to more difficult and complex reservoirs. This depletion effect in oil and gas outweighs the impact of technology learning in many cases, explaining why the average costs of oil and gas production rise in many instances to 2040, while the costs of other energy technologies fall (Figure 1.3).

Figure 1.3 ▷ Evolution of energy technology costs per unit in the New Policies Scenario, 2014-2040



Over the projection period, the cost of renewables declines materially. For example, continued deployment of solar photovoltaics (PV) and technology improvements further reduce the cost of PV modules, which have been in rapid decline in recent years. Strong

savings are also made in "soft costs" for new installations, including design, labour, permitting and inspection. Together, these lead to cost reductions of 30-50%, relative to those of today. Onshore wind turbines also benefit from technology cost reductions, though they are offset, to a degree, by quality of resource characteristics and site availability as the most favourable sites are fully developed. In most regions, the technology cost reductions are more than enough to offset this, with the levelised cost of electricity for onshore wind projects declining by 10-20%.

Carbon capture and storage (CCS), still nascent, has only a few commercial-scale projects underway today. As deployment picks up pace, learning-by-doing presents an opportunity for substantial cost reductions over the period to 2040, though deployment will also critically depend on improved information becoming available about CO_2 storage opportunities (IEA, 2015).

Efficient batteries are the key to the future deployment of electric vehicles (EV). There remains significant scope for battery cost reductions, some of which materialise in the New Policies Scenario. But widespread market uptake of electric cars does not depend on cost reductions alone: consumers also need to be convinced that the performance of an electric vehicle is at least as attractive as that of a conventional vehicle, even if its purchase comes at higher initial cost. That means overcoming limitations to driving range, reducing long recharging times and ensuring the widespread availability of recharging stations. Between 20-25% of the reduction can be attributed to regional variations.

Technological improvements in energy efficiency provide cost savings. For example in lighting, the costs of compact fluorescent lamps (CFL) and light-emitting diode (LED) lamps have followed a particularly steep downward trajectory in some developing countries. Over the projection period, policies to ban the use of the least-efficient incandescent light bulbs in a number of countries, and the bigger market shares captured by CFL and LED lighting, serve to further reduce costs and improve efficiency, decreasing cost for the same level of lighting by 47-55%.

Sharp changes will occur in oil and gas production costs in 2040, relative to 2014, reflecting changing geological conditions and the relative maturity of extraction technologies. Technology learning will continue to bring down the extraction cost of abundant resource types that are currently very expensive to develop (kerogen oil, also known as oil shales, is a good example), while the effects of depletion will be minimal because of the huge size of the resource base. Other already more intensively developed resource types will see an opposite trend. In the New Policies Scenario tight oil output in the United States, for example, continues to benefit from rapid technology learning, but the technology cost reductions do not keep pace with the extra costs stemming from reservoir complexity as a more limited resource base is depleted and thus development costs rise.[10]

10. As discussed in the oil and gas chapters, the size of the ultimately recoverable tight oil (and shale gas) resource base is one of the most influential uncertainties in our *Outlook*. The range of cost escalation for oil and gas by 2040 is also particularly sensitive to the chosen base year due to the recent volatility of oil prices and development costs.

Table 1.5 ▷ Recent developments and key conditions for faster deployment of low-carbon energy technologies

Technology	Recent developments	Key conditions for faster deployment
Renewables power	• Installation of renewables-based power generation technologies hit a record high in 2014, helped by the continuing decline in technology costs. • Onshore wind capacity increased by 45 GW, with China alone adding 20 GW. Solar PV grew by around 40 GW.	• Ensure a predictable and reliable long-term market to mitigate investment risks. • Promote a regulatory framework that supports cost-effective remuneration, avoiding high cost incentives and the possibility of retroactive change.
Nuclear power	• In 2014, 72 GW of nuclear capacity were under construction. • Three projects began construction in 2014, down from ten in 2013. • Almost 40 countries are considering developing first nuclear plants. Three countries have committed to phasing out nuclear power.	• Promote incentives for all types of low-carbon solutions to provide financing certainty for investment. • Recognise the security of supply, reliability and predictability that nuclear power offers.
Carbon capture and storage (CCS)	• The first large-scale power plant CO_2 capture was demonstrated in 2014. • Thirteen large-scale CCS projects were online, capturing a total of 26 Mt CO_2 per year by the end of 2014. • Two large-scale CCS power projects are under construction in the United States.	• Demonstrate financial and policy commitment to CCS demonstration and deployment. Help to mitigate investment risks. • Carbon pricing that expands the commercial value of CO_2 beyond its use in enhanced oil recovery.
Biofuels	• Impacted by the price declines in crude oil, there is ongoing uncertainty over future biofuel demand and investment. • Investment in new biofuels capacity has focused on hydro-treated vegetable oil in Europe and cellulosic plants in the United States.	• Develop long-term policies, demonstration-scale and pilot plants to advance technology development. • Formulate and implement sustainability criteria and standards.
Hybrid and electric vehicles	• Global sales of light-duty passenger electric vehicles grew by 50% in 2014, compared with 2013. • Battery costs continued to fall, and vehicle range increased for several EV models.	• Continue and enhance research and development, infrastructure roll-out and government incentives to support development of EVs. • Extend promotion of EVs for modes other than passenger transport.
Energy efficiency	• The share of the world's energy consumption covered by efficiency regulations increased from 12% in 2005 to 27% in 2014 with the largest increase in China (see Chapter 10).	• Strengthen and expand efficiency regulation and increase policy action to remove barriers to implementation of energy efficiency measures.

Note: GW = gigawatt.

Source: IEA (2015).

Energy supply costs and prices

Price is one of the key drivers of energy trends: prices paid by consumers affect the amount of each fuel they choose to consume and their choice of technology and equipment to provide an energy service. The price that producers receive strongly influences their investment decisions and therefore the level of future production. In each of the scenarios in this *Outlook*, the international fossil-fuel price reflects analysis of the price level that would be needed to stimulate sufficient investment in supply to meet the projected level of demand over the period. Average retail prices in end-uses, power generation and other transformation sectors in each region are derived from iterative runs of the WEM, which take into account local market conditions, including taxes, excise duties, carbon prices and relevant subsidies. The price paths for fuels vary across the scenarios, largely reflecting the differences in the relative strength of the policies introduced to address energy security, environmental and other issues, and their respective impacts on supply and demand. These include policies for subsidies. In the Current Policies Scenario, there is no change in current subsidy rates, unless a formal programme is already in place. The New Policies Scenario, on the other hand, assumes a complete phase out of fossil-fuel subsidies in all net-importing countries and regions within ten years; while in the 450 Scenario, subsidies are removed within ten years in net-importing regions, and are removed in all net-exporting regions except the Middle East within 20 years.

In the Current Policies Scenario, policies adopted to reduce the use of fossil fuels are limited, so rising demand and supply costs combine to push prices up. Lower energy demand in the 450 Scenario means that there is less need to produce fossil fuels from resources higher up the supply cost curve. As a result, international fossil-fuel prices are lower than in the other two scenarios. But this does not flow through to lower final end-user prices as the cost savings are assumed to be offset by increased taxes. There is, however, a benefit in terms of lower national energy import bills.

Oil prices

After a period of relatively stable but historically high prices from 2010 until mid-2014, at which point oil traded at around $115/barrel, international benchmark oil prices fell by well more than 50% into 2015 and have remained in the $40-60/barrel range for much of 2015. The collapse in prices was driven by a marked slowdown in demand growth and record increases in supply, particularly tight oil from North America, as well as a decision by the Organization of Petroleum Exporting Countries (OPEC) countries not to try to rebalance the market through cuts in output (Figure 1.4).

These market developments provide a new, much lower, starting point for the formulation of the oil price trajectories used in each of the scenarios in this *Outlook*, compared with those in *WEO-2014*. Prices remain lower for much of the early part of the projection period, although the gap progressively narrows in all scenarios (except the Low Oil Price Scenario) as markets work through the current supply overhang and rebalance at higher price levels.

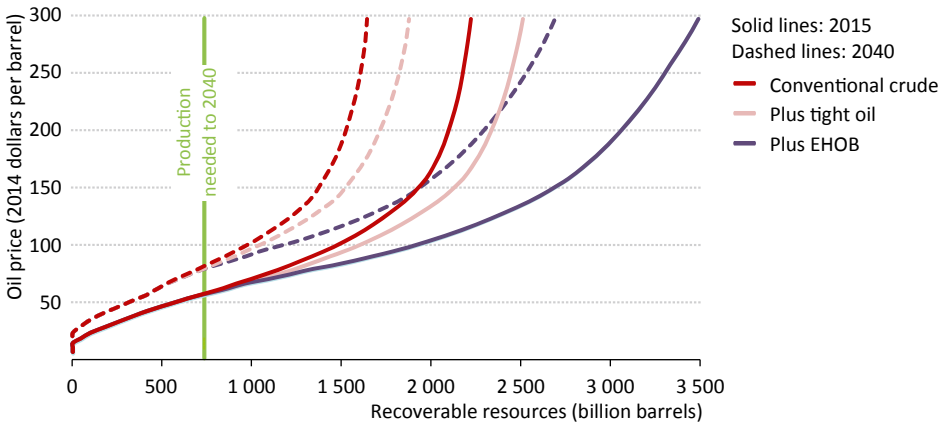
Table 1.6 ▷ Fossil-fuel import prices by scenario

		New Policies Scenario			Current Policies Scenario			450 Scenario			Low Oil Price Scenario		
	2014	2020	2030	2040	2020	2030	2040	2020	2030	2040	2020	2030	2040
Real terms (2014 prices)													
IEA crude oil imports ($/barrel)	97	80	113	128	83	130	150	77	97	95	55	70	85
Natural gas ($/MBtu)													
United States	4.4	4.7	6.2	7.5	4.7	6.3	7.8	4.5	5.7	5.9	4.7	6.2	7.5
Europe imports	9.3	7.8	11.2	12.4	8.1	12.5	13.8	7.5	9.4	8.9	5.9	8.9	11.4
Japan imports	16.2	11.0	13.0	14.1	11.4	14.9	16.0	10.7	11.8	11.1	8.8	10.7	12.4
OECD steam coal imports ($/tonne)	78	94	102	108	99	115	123	80	79	77	88	97	102
Nominal terms													
IEA crude oil imports ($/barrel)	97	89	153	210	92	176	246	85	131	156	61	95	140
Natural gas ($/MBtu)													
United States	4.4	5.2	8.3	12.3	5.2	8.6	12.8	5.0	7.6	9.7	5.2	8.3	12.3
Europe imports	9.3	8.6	15.1	20.3	9.0	16.9	22.6	8.4	12.7	14.6	6.6	12.1	18.7
Japan imports	16.2	12.2	17.6	23.1	12.6	20.1	26.3	11.9	15.9	18.2	9.8	14.4	20.3
OECD steam coal imports ($/tonne)	78	104	138	178	110	155	202	89	106	126	98	130	168

Notes: MBtu = million British thermal units. Gas prices are weighted averages expressed on a gross calorific-value basis. All prices are for bulk supplies exclusive of tax. The US price reflects the wholesale price prevailing on the domestic market. Nominal prices assume inflation of 1.9% per year from 2014.

The rebound in prices occurs most rapidly in the Current Policies Scenario, because of higher oil consumption, with the average IEA crude oil import price – used as a proxy for international oil prices – approaching $83/barrel (in year-2014 dollars) in 2020 in this scenario. In the New Policies Scenario, the market tightens less quickly and the oil price reaches $80/ barrel in 2020.

Figure 1.4 ▷ Non-OPEC supply cost curves for 2015 and 2040 in the New Policies Scenario



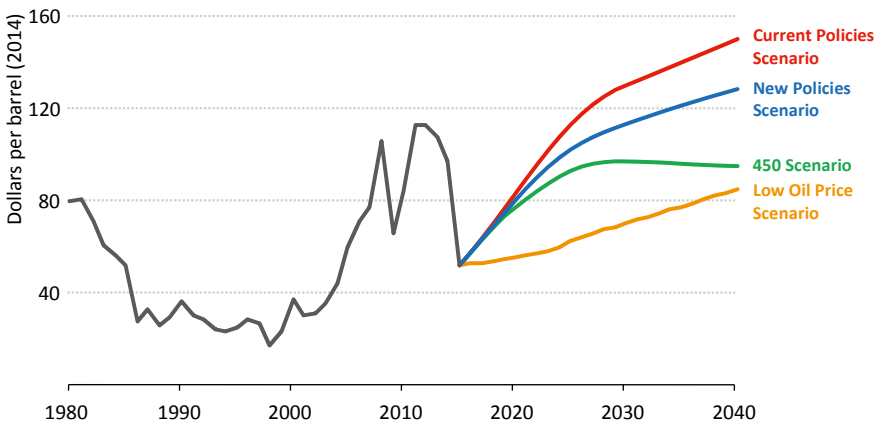
Notes: EHOB = extra-heavy oil and bitumen. The vertical green line indicates the amount of production required between 2015 and 2040 in the New Policies Scenario

The oil price trajectories are determined by the level needed to stimulate sufficient investment in supply in order to meet projected demand in each scenario. Higher demand in the Current Policies Scenario means a higher call on oil from costly fields in non-OPEC countries. Conversely, in the 450 Scenario, more aggressive policy action to curb demand means that market equilibrium can be found at a lower price. The non-OPEC supply cost curves for 2015 and 2040, derived from the WEM, help to illustrate the underlying logic behind the various long-term trajectories (Figure 1.4). As might be expected, a higher oil price allows an increased volume of resources to be developed, including larger volumes of unconventional oil. But the picture also changes over time: the 2040 cost curves, illustrated here for different non-OPEC resource categories in the New Policies Scenario, are higher and steeper than those for 2015, as capital and operating costs are pushed higher by the gradual depletion of the resource base and the need to develop more challenging or remote fields.[11] The relationship between the supply cost curves and oil prices is not straightforward, but the inference is that a price in the range of $80-120/barrel is likely to be required to enable supply to meet demand in

11. The situation is complicated by the two-way interaction between costs and prices: an increasing oil price pushes up industry activity levels, tightening markets for upstream supplies and services (and meaning that higher prices also tend to lead to higher costs). Likewise, as shown in 2014-2015, an oil price fall is accompanied by strong pressure on supply and service providers to reduce costs. This correlation between oil prices and industry costs is captured in the way that costs are modelled in the World Energy Model.

the New Policies Scenario to 2040. Provision for various limitations, including geopolitical and logistical constraints on the rate of growth in both OPEC and non-OPEC countries, leads to a situation in which oil prices are typically maintained at a higher level than the supply cost curves would suggest, which is why the oil price in the New Policies Scenario in 2040 reaches $128/barrel.

Figure 1.5 ▷ Average IEA crude oil import price by scenario



In this *Outlook*, we change some of the key assumptions underlying the New Policies Scenario to model a Low Oil Price Scenario, in which lower cost oil from OPEC countries is much more readily available and production from some key non-OPEC producers – notably the United States – is also assumed to be more resilient at lower prices. There are also some changes to assumptions on the demand side, including a diminished near-term GDP outlook in some emerging economies. These factors allow the oil price to remain lower for longer, prices remaining flat until the 2020s, in the $50-60/barrel range, and rising only gradually thereafter, to $85/barrel by 2040 (Figure 1.5).

Box 1.2 ▷ Run-up to an oil price fall

To better understand the reasons behind the fall in the price of crude oil in 2014-2015, it is worthwhile first to examine the factors behind the rise that preceded it and why these were not sustained. At one level, the explanation for the price decline is ultimately quite simple – high oil prices encouraged a growing imbalance between buoyant supply and flagging demand – but some of the underlying dynamics and reasons for the timing of the eventual fall are more complex.

There were fundamental reasons for tighter markets after the 2008 global economic crises, notably the strong rebound in demand, but also on the supply side, there were a number of one-off factors that kept prices high. These included output disruptions in 2011 and 2012 in Libya, Syria and Nigeria, as well as the tightening of sanctions against Iran at that time. A rapid expansion of refinery runs in Russia also contributed

to the decreasing availability of crude oil in international markets[12], while the refining sector in Europe (and to a lesser degree elsewhere) did not adjust its crude intake and rationalise capacity as quickly as market conditions would have implied. Between 2008 and 2013, while oil demand in OECD Europe declined by 1.8 million barrels per day (mb/d), refinery runs decreased by only 1.3 mb/d, while imports of middle distillates, the only deficit product in Europe, were increasing. Effectively, crude oil prices were being supported at higher levels by refiners absorbing negative refining margins.

Into this picture came increasing volumes of US oil production, which had bottomed out in 2008 after two decades of decline. Between 2012 and 2014, the output of oil by producers in the Atlantic basin[13] increased by 3.8 mb/d (compared with no growth over 2009-2011). Refiners in the United States started processing increasing volumes of tight oil and of heavy crudes, which were trading at a discount to international crudes, displacing West and North African oil and some heavier Middle Eastern crudes from the North American market. At the same time, increasing output of natural gas liquids (NGLs) meant more competition from ethane and LPG for petrochemical feedstocks based on crude oil (naphtha). On the oil demand side, annual consumption growth of 0.5 mb/d in 2014 was one of the lowest in a number of years. The growth in oil demand in China decelerated perceptibly, reflecting a cooling economy and the start of a rebalancing away from heavier manufacturing industry. The weaker exchange rates of many currencies against the dollar, in both the emerging markets and the European Union, also curbed the appetite for oil consumption and dollar-denominated imports.[14]

Accelerating production growth from the United States, rising production from Iraq, slowing demand and an easing of some of the special one-off elements that had kept markets tight started to push crude prices down from the late second-quarter 2014. This presented a challenging picture to OPEC delegates when they met in November, ultimately convincing Saudi Arabia and other OPEC member countries that an attempt to rebalance the market by cutting back OPEC output would not be effective. The decision to leave the OPEC production target unchanged was then the trigger for further price falls – setting the stage for a different type of market rebalancing, with the oil price as the mediator – and non-OPEC production on the front line.

12. The refined products were being exported to international markets, so the total oil exports out of Russia were growing, but crude oil prices first of all are affected by crude oil supply and demand, while product markets then affect the difference between product and crude prices, i.e. cracking and refining margins.

13. In oil trading, the world is typically considered (at the highest level of aggregation) in two parts: the Atlantic basin and the East of Suez region. The former includes countries around the Atlantic rim, i.e. the Americas, Europe, West and North Africa, and also Russia and Caspian countries that generally export towards Europe. The East of Suez region consists of the Middle East, Asia, East Africa and Australia.

14. Another factor that may ultimately have weighed down on the oil price was the switch in the Atlantic basin in 2012-2013 from being a net importer to a net exporter of crude oil to the rest of the world. The two most important oil futures, Brent and WTI, are in the Atlantic basin (Brent in the North Sea and WTI essentially for North and Central American output); these prices no longer need to incentivise net inflows of oil to Atlantic markets, but rather the net evacuation of oil from the Atlantic region towards the growing refining sector of Asia.

Natural gas prices

There is for the moment no global pricing benchmark for natural gas, as there is for oil. Instead, there are three major regional markets – North America, Asia-Pacific, and Europe – each with different pricing mechanisms and gas market conditions. In North America, gas prices are determined at hubs, and reflect local gas supply and demand dynamics, while in Asia-Pacific, trade is dominated by long-term contracts that are often linked to the price of oil. Gas trade in continental Europe was also governed by long-term oil-indexed contracts in the past, but is increasingly gravitating towards arrangements which allow prices to be set by gas-to-gas competition, which account for around half of European gas trade today.

In *WEO-2015*, gas price spreads between regions persist, but gradually come to levels that are more consistent with the costs of moving gas between the markets. This convergence comes about because of greater availability of liquefied natural gas (LNG) on a flexible basis, with a portion of LNG sellers free to seek out the best available price in the various import markets. A degree of segmentation between markets remains, because of the effect (including a large legacy effect) of long-term contracts that retain more restrictive price or destination requirements. The high costs and long-lead times of developing gas infrastructure also create strong inertia within the system – and the high gas transportation costs rule out the prospect of a single global gas price; but the overall effect is that markets become more interconnected and that price changes in one market are reflected more quickly in others. Differences between the price levels in the Current Policies, New Policies and 450 Scenarios are largely explained by the variations in global and regional demand; different oil price trajectories also play a strong role in price-setting in some regions.

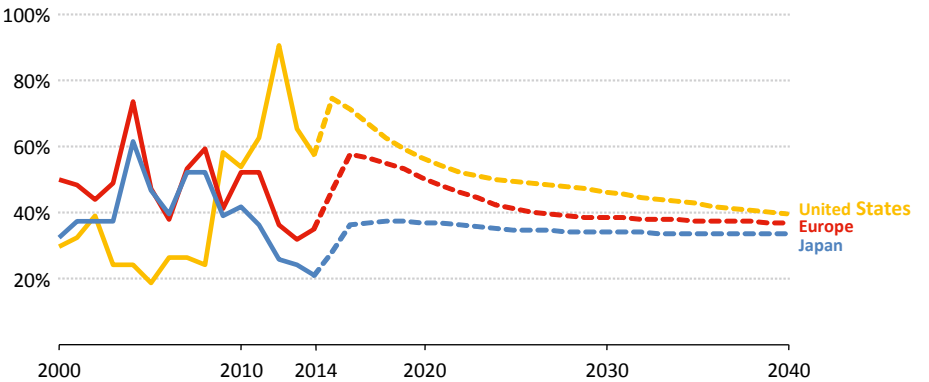
Of the three main regional gas markets, North American prices remain the lowest in each of the scenarios, but they do rise over time in line with the rising breakeven costs of gas supply, reaching $7.5 per million British thermal units (MBtu) in 2040 in the New Policies Scenario. Average import prices vary across the Asia-Pacific region. In Japan, prices have already come down from their post-Fukushima highs and the re-commissioning of nuclear plants over the coming years relieves much of the exceptional demand for imported gas. Average import prices rise steadily over the longer term to reach $14/MBtu in 2040. China, whose options for supply are more varied and include domestic production as well as various pipeline and LNG import options, has a lower average import price than Japan (as do many other Asia-Pacific markets). It rises to $12/MBtu in 2040 in the New Policies Scenario, a similar level to that in Europe.

The Low Oil Price Scenario presents an interesting variation on the price outlook for gas. Importers with oil-indexed contracts generally stand to benefit, but this scenario also accelerates the de-linking of the two prices, as otherwise gas prices would be too low to bring forward the supply necessary to meet gas demand. Overall, Japan and Europe see prices that are 12% and 8% lower, respectively, than in the New Policies Scenario. In the United States, by contrast, prices – and the commercial case for natural gas production – do not change much in the Low Oil Price Scenario: producers tend to benefit from lower upstream costs for services and supplies, but the economics of gas production are worsened by the lower value that they receive for NGLs.

Coal prices

The global coal market consists of a number of regional sub-markets that are typically separated by geography, coal quality and infrastructure constraints. As a result, coal prices vary markedly between regions and even within a country (Figure 1.6). Around one-fifth of global steam coal production is traded inter-regionally, with the remainder used close to where it is mined. Nevertheless, the price of coal on the international market acts as a useful barometer of the dynamics within the market itself.

Figure 1.6 ▷ Coal price relative to gas price by region in the New Policies Scenario (in energy equivalent terms)



The downward pressure on prices in recent years can be attributed to two primary causes. On the supply side, a period of surging demand between 2007 and 2011 triggered a large increase in mining investments in Australia, Colombia, Indonesia and South Africa. These mines have come online at a period of dampened demand growth in China, where local air pollution concerns have led to a shift away from coal towards gas and renewables in the power sector and, to a lesser extent, in the United States, where cheap shale gas has led to some coal being displaced.

The outlook for coal prices differs by scenario: prices are a function of the demand growth and the cost of the production to meet it. In all of the scenarios, the international coal market returns to balance by 2020, after which prices are fundamentally determined by the marginal cost of supply. In the New Policies and Current Policies Scenarios growing demand and trade put upward pressure on prices and increase the call on supply from mines that are currently operating at a loss. More rigorous climate action after this period is reflected in lower demand in the New Policies Scenario compared with the Current Policies Scenario to 2040, and as a result, there is a significant price divergence, with the OECD steam coal import price reaching $108/tonne in the New Policies Scenario compared with $123/tonne in the Current Policies Scenario. In the 450 Scenario, more stringent climate policies slash long-term global coal demand, but the effects are already noticeable in the medium term. Loss-making mines are shut while those with favourable costs stay in business and support a coal price that is kept flat at current levels.