International Energy Agency

WORLD ENERGY OUTLOOK 2012

ENERGY EFFICIENCY EXCERPT

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Robert Priddle carried editorial responsibility.

The study benefited from input provided by numerous IEA experts. In particular, the Energy Efficiency and Environment Division, including Philippe Benoit, Robert Tromop, Lisa Ryan, Grayson Heffner, Sara Pasquier, Vida Rozite, Aurelien Saussay, Yamina Saheb and Nora Selmet, provided input to the efficiency analysis. Other IEA colleagues who also made significant contributions to different aspects of the report include Carlos Fernandez Alvarez, Manuel Baritaud, Paolo Frankl, Cristina Hood, Alexander Koerner, Christopher Segar, Cecilia Tam, Johannes Truby, Nathalie Trudeau, Laszlo Varro and Hirohisa Yamada. Experts from the OECD also contributed to the report, particularly Jean Chateau, Bertrand Magné, Rob Dellink and Marie-Christine Tremblay. Thanks also go to the IEA's Communication and Information Office for their help in producing the final report, to Bertrand Sadin and Anne Mayne for graphics and to Debra Justus for proofreading the text.

The special focus on Iraq would not have been possible without the close co-operation received from the federal government of Iraq, the regional and provincial governments and officials across many government bodies in Iraq. We are particularly grateful to H.E. Dr. Hussain Al-Shahristani, Iraq's Deputy Prime Minister for Energy, for his strong support from the inception of this study through to its conclusion. H.E. Thamir Ghadhban, Chair of the Prime Minister's Advisory Commission in Iraq, provided indispensable input as keynote speaker and chair of our high-level workshop in Istanbul.

We are indebted to many Iraqi senior officials and experts for their time and assistance. Special thanks are due to the leadership and staff of the Ministry of Oil and, in particular, to Fayadh Hassan Neema, Director of the Technical Directorate at the Ministry of Oil, who was an invaluable interlocutor throughout, and to Falah Alamri, Director General of the State Oil Marketing Organization. H.E. Dr. Ashti Hawrami, Minister of Natural Resources in the Kurdistan Regional Government, provided valuable support and insights to the IEA team during their visit to Erbil. We greatly appreciated the welcome afforded the team in Basrah by Ahmed Al-Hassani, Deputy Governor of Basrah Governorate, and by the Provincial Council.

Ambassador Fareed Yasseen, Iraq's Ambassador to France, and his staff provided unstinting assistance to the completion of this study and the team's visits to Iraq, as did Dr. Usama Karim, Senior Advisor to Iraq's Deputy Prime Minister for Energy. Sincere thanks also to Tariq Shafiq, Managing Director of Petrolog and Associates and one of the founding fathers of Iraq's petroleum industry, for his expert counsel.

Maria Argiri, Janusz Cofala (International Institute for Applied System Analysis), Xiaoli Liu (Energy Research Institute), Michael McNeil (Lawrence Berkeley National Laboratory), Trevor Morgan (Menecon Consulting) and Paul Waide (Waide Strategic Efficiency) provided valuable input to the analysis.

The work could not have been achieved without the substantial support and co-operation provided by many government bodies, organisations and energy companies worldwide, notably: American Iron and Steel Institute; Department of Resources, Energy and Tourism, Australia; Booz & Company; Cement Sustainability Initiative of the World Business Council for Sustainable Development; Daimler; Ministry of Climate, Energy and Building, Denmark; Enel; Eni; Institute for Industrial Productivity; The Global Building Performance Network; Ministry of Foreign Affairs, Italy; Iron and Steel Federation, Japan; The Institute of Energy Economics, Japan; Ministry of Economy, Trade and Industry, Japan; Ministry of Energy, Mexico; Ministry of Economic Affairs, the Netherlands; Ministry of Foreign Affairs, Norway; Ministry of Petroleum and Energy, Norway; Norwegian Agency for Development Cooperation; Parsons Brinckerhoff; Peabody Energy; Petrobras; Ministry of Economy, Poland; Schlumberger; Schneider Electric; Shell; Siemens; Energy Market Authority, Singapore; Statoil; Toyota; Ministry of Energy and Natural Resources, Turkey; Department for International Development, United Kingdom; Foreign and Commonwealth Office, United Kingdom; Executive Office of the Secretary-General, United Nations; Department of Energy, United States; Department of State, United States; and Vattenfall.

Workshops

Many international experts participated in a number of workshops that were held to gather input to this study, resulting in valuable new insights, feedback and data:

- Golden Rules for a Golden Age of Gas: Warsaw, 7 March 2012
- Iraq Energy Outlook: Istanbul, 4 May 2012
- Fuelling the Future with Energy Efficiency: Tokyo, 10 May 2012
- Measuring Progress Towards Universal Energy Access: Paris, 25 May 2012

More information at *www.worldenergyoutlook.org/aboutweo/workshops.*

IEA Energy Business Council

Special thanks go to the companies that participated in meetings of the IEA Energy Business Council (EBC) during 2012, which provided significant insights to this study. The EBC brings together many of the world's largest companies in terms of energy exploration, production and use, ranging from commodities companies, automobile manufacturers, wind and solar producers and financial institutions. Further details may be found at *www.iea.org/energybusinesscouncil.*

Peer reviewers

Many international experts provided input, commented on the underlying analytical work and reviewed early drafts of each chapter. Their comments and suggestions were of great value. They include:

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The individuals and organisations that contributed to this study are not responsible for any opinions or judgements contained in this study. All errors and omissions are solely the responsibility of the IEA.

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PART B
FOCUS ON ENERGY EFFICIENCY

PREFACE

Part B of this *WEO* (Chapters 9-12) analyses in depth the outlook for energy efficiency in final uses and in energy production and transformation activities.

Chapter 9 reviews recent energy efficiency trends – whether global energy use is, or is not, becoming more efficient per unit of output – and the changes that have taken place recently on the policy front. It discusses key barriers to change, an essential precursor to discussing how energy efficiency might be improved in the future. Energy efficiency gains in the New Policies Scenario are then presented, together with their implications and the level of investment in energy efficiency needed to attain those gains.

Chapters 10-12 break new ground, presenting an Efficient World Scenario. The scenario makes no bold assumptions about technical breakthroughs, but instead shows the extent of benefits that could be achieved if known best technologies and practices to improve energy efficiency were systematically adopted. Technologies implemented in the Efficient World Scenario are subject to a stringent test of their economic viability, expressed as the acceptable payback period for each class of investment. Necessary policies to realise the scenario are discussed in the context of categories of energy use and government actions needed to eliminate barriers presently obstructing the uptake of energy efficiency. Chapter 10 presents quantitative analysis of the Efficient World Scenario for the global energy economy and examines its implications. Chapter 11 looks at the scenario sector-by-sector. Mainly through figures and tables, Chapter 12 presents results for the world and five key regions and countries.

Energy efficiency: the current state of play

Are we putting enough energy into improving efficiency?

Highlights

- Energy efficiency curbs demand growth, reduces energy imports and mitigates pollution. In the last year, all major energy-consuming countries introduced new legislation on energy efficiency, making provisions for a 16% reduction in energy intensity by 2015 in China, new fuel-economy standards in the United States and a cut of 20% in energy demand in the European Union in 2020. Japan also aims to achieve a 10% reduction in electricity demand by 2030 in its new energy strategy.

- Implementation of those policies and of those under discussion in many other countries, at the level assumed in our New Policies Scenario, would result in annual improvements in energy intensity of 1.8% over 2010-2035, a very significant increase compared with 1.0% per year achieved over 1980-2010. In the absence of those gains, global energy demand in 2010 would have been 35% higher, almost equivalent to the combined energy use of the United States and China.

- In the New Policies Scenario, efficiency accounts for about 70% of the reduction in projected global energy demand in 2035, compared with the Current Policies Scenario. China, the United States, the European Union and Japan account for more than half of the savings, reflecting their dominance in global energy use and the emphasis placed on energy efficiency in these regions. Additional investment of $3.8 trillion to improve energy efficiency in end-use sectors is needed over 2012-2035, an average of $158 billion per year. Energy efficiency measures in the New Policies Scenario account for 68% of the cumulative global savings in CO_2 emissions relative to the Current Policies Scenario.

- The payback periods of the efficiency measures included in the New Policies Scenario are short, ranging from as low as two years for electrical equipment to eight years for space and water heating; but non-technical barriers remain a major obstacle. Monetising those barriers significantly increases payback periods and renders energy efficiency investments less attractive, especially for the buildings sector. These are the barriers governments have to tackle.

- Despite the vital role that energy efficiency plays in cutting demand in the New Policies Scenario, only a small part of its economic potential is exploited. Over the projection period, four-fifths of the potential in the buildings sector and more than half in industry still remain untapped. Much stronger policies could realise the full potential of energy efficiency and deliver significant economic, environmental and energy security gains.

Introduction

Policy makers confronted with the twin challenges of ensuring reliable and affordable energy supplies and dealing with climate change have consistently identified energy efficiency as an essential means of moving to a more sustainable energy future. Energy and economic analyses, including in previous editions of the *World Energy Outlook*, point to the same conclusion: improving energy efficiency in energy-importing countries reduces import needs or slows their growth; measures can be implemented quickly compared with often lengthy projects to expand production; it is among the cheapest of the large-scale carbon dioxide (CO_2) abatement options; and it can play a role in spurring economic growth and reducing energy bills, both of particular importance during this period of economic uncertainty and persistently high energy prices.

Box 9.1 ▻ What are we including when measuring energy efficiency?

Improving energy efficiency can be defined as using less energy to provide the same level of service. For example, when a compact florescent light (CFL) uses less electricity than an incandescent bulb to produce the same amount of light, the CFL is considered to be more energy efficient. But energy savings can arise from more than just switching to more energy-efficient technology. Fuel switching can also reduce primary energy needs. For example, switching away from a gas boiler for space heating to the use of heat pumps can substantially reduce energy needs per unit of heat produced. Energy consumption is also dependent on behavioural factors, such as the chosen level of thermal comfort or the preference to use a private car for personal mobility. In many cases, savings that arise from behavioural changes are classified as energy conservation, rather than energy efficiency. The main difference between the two is that reducing the absolute level of energy demand is the primary goal of energy conservation, if necessary, at the expense of personal comfort or satisfaction, while improved energy efficiency aims to reduce the energy consumed in delivering a given energy service (IEA, 2012a).

In this *Outlook*, we measure energy efficiency improvements as the savings that arise exclusively from improvements in technology (without a change of fuel). We separately quantify changes in energy demand arising from fuel switching (including changes in technology) and from price-driven behavioural changes. This decomposition approach allows us to understand the relative importance each factor is set to play in curbing future energy demand.

While energy efficiency clearly has many merits, it is challenging to measure: unlike primary fuels, it does not appear in national energy balances, and it is neither traded nor priced, except in a few countries. Energy efficiency can be measured at a micro-level, for example, by quantifying the reduction in the volume of fuel needed to drive a certain distance if a particular efficiency measure is adopted. Far more challenging is to understand the contribution made by a multitude of energy efficiency improvements to aggregate energy savings at a national level. Often the challenge relates to calculating what might have been used, under the same conditions without improved technology and practices. Many associated effects need to be disaggregated before the specific energy efficiency effect on energy consumption can be estimated. The detailed country-by-country data needed to separate out these effects are available only for a small number of OECD countries (IEA, 2011a).

For the purpose of this *Outlook*, in order to analyse the role energy efficiency is set to play in the future, we use decomposition analysis. This decomposes changes in energy demand into changes in efficiency, fuel and technology switching, and activity (Box 9.4). To compare the role energy efficiency has played historically in tempering growth in energy demand, we use energy intensity as the best available proxy, as in most cases the data that would be needed to disaggregate the savings into their various contributing factors – including efficiency – are not available. The shortcoming of energy intensity as an indicator of energy efficiency nonetheless needs to be recognised, as it fails to distinguish the effects of factors such as changes in the structure of a country's economy or its climate. For example, service-oriented and temperate countries typically have lower energy intensities than manufacturing-based and colder countries, regardless of their energy efficiency. Moreover, countries with a high proportion of energy-intensive industries, such as Korea, may be extremely efficient in the way they use energy, but still have high energy intensities.

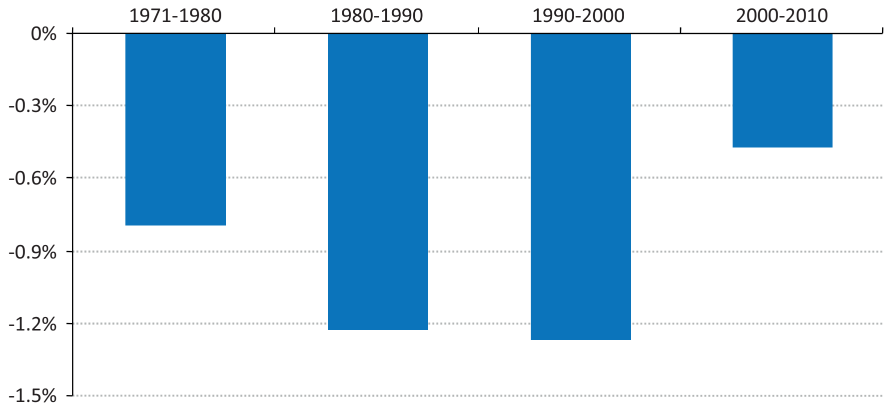
The current status of energy efficiency

Global energy intensity, expressed as the amount of energy used to produce a unit of gross domestic product (GDP),[1] has fallen over the last several decades, primarily as a result of efficiency improvements in the power and end-use sectors and a transition away from energy-intensive industries. But the rate of decline in energy intensity has slowed considerably: from 1.2% per year on average between 1980 and 2000, to only 0.5% per year between 2000 and 2010 (Figure 9.1). This slowdown can largely be explained by an ongoing shift of global economic activity towards countries in developing Asia which have relatively high energy intensities due to their heavy reliance on energy-intensive industries and on coal-fired power generation, which is typically less efficient than other power generation options. In 2009 and 2010, global energy intensity actually increased – bucking the long-term downward trend – due to colder or hotter than average weather in some

1. Energy intensity is measured using GDP at market exchange rate (MER). It can be measured also with GDP expressed in terms of purchasing power parity (PPP), which enables differences in price levels among countries to be taken into account. However, it is misleading to do so when comparing long-term projections of energy intensity. This is because the PPP factors are likely to change in the future as countries become richer or poorer relative to the world average. Thus, using PPP-adjusted GDP projections tends to overstate the future relative importance of emerging economies, as it is likely that their PPP factors will be adjusted down in the future as they become richer (though it is possible that the applicable currency exchange rates may also rise, offsetting this effect to some degree). Therefore, we use GDP at market exchange rates in order to provide a coherent set of information for past and future trends.

regions, lower energy prices and economic contraction in 2009.[2] Preliminary data point to a slight improvement in energy intensity in 2011 of 0.6%, meaning that the long-running trend has been restored after the outliers of 2009 and 2010.

Figure 9.1 ▷ Global energy intensity average annual growth rates, 1971-2010



Note: Energy intensity is measured using GDP at market exchange rate (MER) in year-2011 dollars.

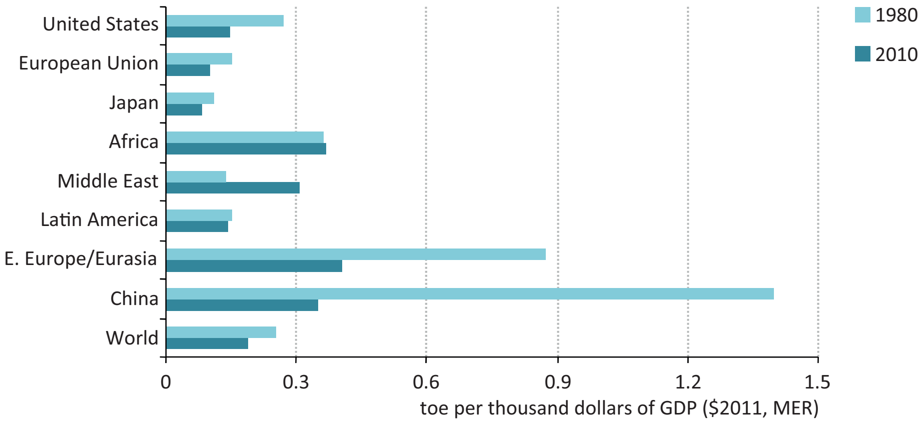
Global energy demand grew from 7 234 million tonnes of oil equivalent (Mtoe) in 1980 to 12 730 Mtoe in 2010, a 76% increase. Over this same period, global GDP expanded by 137%. Without the improvements in energy intensity that were realised over the period, global energy demand in 2010 would have been 35% higher. Energy prices have an important influence on energy intensity, a lesson learned in the 1970s when oil price spikes spurred a wave of energy efficiency and conservation measures that contributed to significant savings in energy demand in the 1980s. Energy intensity improvements in the 1990s cut growth in energy demand over the decade by more than 50%, while in the 2000s they resulted in savings of almost 20%.

Energy intensities tend to be much higher in developing countries than in the OECD, although there has been progressive convergence over the past three decades: the ratio among the highest and lowest values has declined from an average factor of nine in the 1980s to just under five currently (Figure 9.2). This has arisen primarily from globalisation, which has made similar technologies available at similar costs in different parts of the world, and from countries sharing best practices in energy efficiency policy and management techniques. Although energy efficiency is now getting more policy attention than in the past in some parts of the Middle East, the region's energy intensity has been increasing since the 1980s, in large part driven by artificially low energy prices that discourage the deployment of energy-efficient technologies (Figure 9.3). Africa's economic development drove energy

2. Running an industrial facility below full capacity increases its energy intensity. This is because energy consumption declines by a smaller amount than economic output, as a result of an element of fixed energy consumption that is independent from the output level, *e.g.* space heating, ventilation and lighting.

intensity up until around 1995, but it has since been on a downward path, with incremental energy demand (mainly for traditional biomass for cooking) growing at a slower rate than GDP. Latin America as a whole has seen economic output per unit of energy input remain relatively flat, with energy-producing countries' relatively high level of energy intensity offsetting less energy-intensive use in importing economies. High energy prices, energy efficiency measures, CO_2 abatement policies, the move towards more service activities, increasing productivity and, in some countries, a switch away from traditional biomass explain the declining trends in other regions.

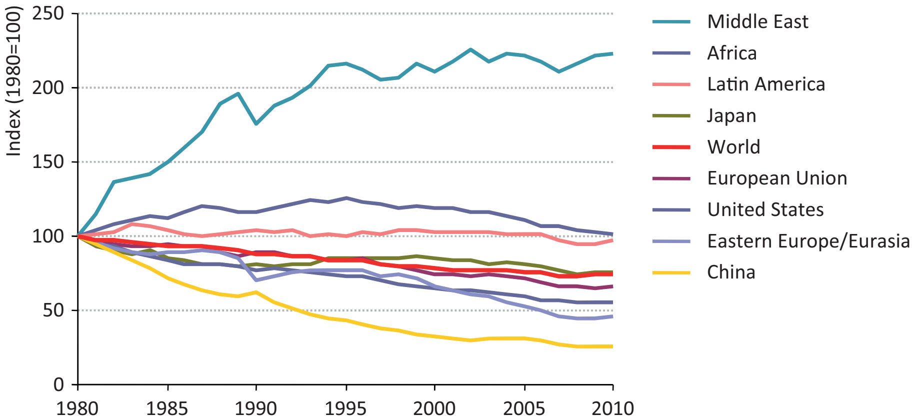
Figure 9.2 ▷ Energy intensities by regions, 1980 and 2010



Among OECD countries, the United States has achieved the biggest improvement in energy intensity in recent decades, albeit from relatively high levels. Its energy intensity declined at an average rate of 2% per year from 1980 to 2010. In recent years, policy efforts to further improve energy efficiency have been reinforced. The 2009 economic stimulus package in the United States included new energy efficiency initiatives and substantial additional funding for existing programmes, while, in 2011, fuel-economy standards were introduced for heavy-duty vehicles, alongside a tightening of standards for light-duty vehicles.

Japan and the European Union are the regions with the lowest energy intensity. This reflects a high general level of technical efficiency, spurred by relatively high energy prices and policies to raise awareness among citizens and companies, and to promote energy-efficient technologies. Japan experienced an average improvement of 0.9% per year from 1980 through 2010; while the European Union achieved 1.4% per year, benefiting from the significant potential in some member countries to further improve efficiency.

Figure 9.3 ▷ **Energy intensity trends by region, 1980-2010**



Existing policies

An increasing number of countries have made energy efficiency a key pillar of their energy strategies, viewing it as a means of realising gains in multiple areas of public policy. The European Union is in the process of adopting an energy efficiency directive – to complement its carbon and renewables policies – that envisages a 20% reduction in energy demand by 2020 against a business-as-usual approach.[3] Even though Japan is already a leader in energy efficiency, in September 2012 the government released the Innovative Strategy for Energy and the Environment, which calls for a greater focus on improving energy efficiency and includes a target to cut electricity demand by 10% in 2030, compared with 2010 (Box 9.2). The United States extended the US Corporate Average Fuel Economy standards to 2025, one element in an emerging trend towards much lower oil-import needs (see Chapter 2). Among the emerging economies, China has adopted ambitious energy intensity targets in its 11th and 12th Five-Year Plans, underpinned by a broad set of policies, including policies that aim to facilitate structural changes in the economy. In India, continuing the persistent efforts of the past few years, preparatory work for the 12th national plan identifies energy efficiency as an important cornerstone of a secure energy future. The range of policies being adopted by governments to improve energy efficiency is wide: regulations, market-based instruments, financial instruments, and information and awareness measures all feature, often brought together in an overarching strategy or framework (Table 9.1).

Cross-sectoral policies typically form the framework for energy efficiency measures across individual sectors. They often include targets, in terms of energy efficiency, energy intensity improvements or energy savings. In the European Union, for example, the Energy Efficiency

3. The European Parliament and Council reached an agreement in June 2012 on the text of the Energy Efficiency Directive, which specifies that primary energy demand should not exceed 1 474 Mtoe, or final energy demand exceed 1 078 Mtoe in 2020. The European Parliament voted in favour of the Directive in September 2012, and it will be submitted to Council vote before the end of the year.

Directive requires member states by April 2013 to set national targets for primary energy savings for 2020 and to achieve end-use energy savings of 1.5% per year; member states are required to report on these targets and develop National Energy Efficiency Action Plans. Other important instruments with wide application include energy price and tax policies, as well as financial mechanisms to incentivise and facilitate investment in energy efficiency. For example, China has provided $21 billion of tax incentives for industrial energy efficiency investments. Australia has recently introduced a carbon price that will incentivise investment in energy efficiency through increased electricity prices, as well as the Energy Efficiency Opportunities programme, which seeks to induce all large energy-users to improve their energy efficiency. Many countries have provided grants and tax incentives for energy efficiency investments and are now increasingly developing longer-term financial mechanisms to catalyse private sector investments in energy efficiency. However, subsidies to consumer prices for energy still remain a major barrier to improving energy efficiency, limiting the incentive for consumers to reduce their energy use (see Chapter 2).

Countries are increasingly introducing policies to improve the energy performance of buildings, which made up one-third of global final energy demand in 2010. Most OECD countries have mandatory energy codes for new and existing buildings, albeit with different levels of stringency and enforcement. In non-OECD countries, where new buildings represent a much higher share of the stock, energy efficiency codes for buildings are increasingly being introduced (including in China), although sufficient attention is not always being given to enforcement. Some countries, such as Germany, have introduced financing options to encourage private investors to improve energy efficiency in buildings. Energy labelling is an important way of informing consumers of the energy use of buildings, equipment and appliances at the time of purchase or rental. It is now mandatory for buildings and some appliances in a growing number of regions, including across the European Union. Some countries have set targets for passive or zero-energy buildings.[4]

In the transport sector, fuel economy policies are increasingly being implemented: most of the major car markets in the world – which collectively accounted for two-thirds of global passenger vehicle oil demand in 2010 – now have fuel-economy standards in place. An area which is only recently starting to attract more attention is freight transport – though it accounted for around one-third of road transport oil demand in 2010, fuel-economy standards for the freight fleet are in force or under discussion in only a few countries. Fuel economy labelling and related fiscal measures are also widely used for passenger vehicles, but less so for trucks. They are important especially in countries without the technical capacity to introduce (or enforce) fuel economy regulations (IEA, 2012b). Aside from improving the fuel economy of road vehicles, policies to reduce private vehicle use by improving public transport and land-use planning are also becoming more widespread.

4. Buildings that have net zero-energy consumption, achieved with extremely efficient building shells and heating/cooling systems combined with energy producing technologies, like solar (BPIE, 2011).

Table 9.1 ▷ Overview of key energy efficiency policies that are currently in place by country/region and sector

	United States	Japan	European Union
Cross-sectoral			
Energy efficiency strategy or target	None	None	EU Energy Efficiency Directive agreed; National Energy Efficiency Action Plans required; EU-level target to reduce primary energy consumption by 20% in 2020; EU ETS.
Buildings, appliances, equipment and lighting			
Building energy performance requirements	Mandatory energy requirements in building codes in some states.[5]	Voluntary guidelines in place.	Building energy performance requirements for new buildings (zero-energy buildings by 2021) and for existing buildings when extensively renovated; 3% renovation rate of central government buildings.
Energy labelling	Voluntary buildings labelling; mandatory and voluntary labelling for some appliances and equipment.	Voluntary buildings labelling; national voluntary equipment labelling programmes.	Labelling mandatory for sale or rental of all buildings and some appliances, lighting and equipment.
Equipment energy performance requirements	45 products covered.	Top Runner: 23 products covered.	15 product groups in EcoDesign Directive, further product groups planned end-2012; phase-out of incandescent light bulbs.
Transport			
Fuel-economy and GHG standards	PLDV: 34.5 mpg by 2016 (6.8 l/100 km), 54.5 mpg by 2025 (4.3 l/100 km); trucks: starting MY 2014.	PLDV: 16.8 km/l by 2015 (5.95 l/100 km); trucks: 12.2% target by MY 2015.	PLDV: 130 g CO_2 /km by 2015 (5.2 l/100 km); 95 g CO_2/km (3.8 l/100 km) planned by 2020; LCV: 147 g CO_2/km (5.9 l/100 km) by 2020; no trucks yet.
Fuel economy labelling	PLDV: yes; trucks: none.	PLDV: yes; trucks: yes.	PLDV: yes; trucks: none.
Fiscal incentives	Gas guzzler tax; EV tax credit; rebates in many states for EVs.	Registration taxes by CO_2 emissions and fuel economy.	Taxes are lower for vehicles with low average CO_2 emissions in most countries.
Industry			
Energy management programmes	Voluntary energy management programme for the implementation of ISO-50001.	Periodic energy audits and nationally certified energy managers for large industries.	Voluntary agreements in place or planned in many countries.
MEPs for electric motors	Premium efficiency (IE3) MEPs for 3-phase induction motors.	Adding 3-phase induction MEPs to Top Runner programme.	IE3 for 3-phase induction motors < 7.5 kW by 2015; all IE3 (IE2 + variable speed drive) in 2017.

5. For residential buildings in 18 states, based on 2009 code, and in 24 states for public and commercial buildings, based on 2007 code. One state adopted 2012 code for residential and 2010 for commercial buildings.

Table 9.1 ▷ Overview of key energy efficiency policies that are currently in place by country/region and sector (continued)

Russia	China	India	Brazil
Cross-sectoral			
2009 Federal Law No. 261-FZ on energy saving and improving energy efficiency; reduce energy intensity by 40% by 2020.	12th Five Year Plan (2011-2015): target to reduce energy intensity by 16% by 2015.	11th Five-Year plan (2007-2012): target to improve energy efficiency by 20%; 12th Five-Year plan forthcoming.	2011 National Energy Efficiency Plan; reduce projected power consumption by 10% by 2030.
Buildings, appliances, equipment and lighting			
Mandatory building codes (but not yet fully implemented).	Mandatory codes for all new large residential buildings in big cities.	Energy Conservation Building Code (2007), with voluntary requirements for commercial and residential buildings.	Voluntary guidelines in place.
Information on energy efficiency classes for appliances required since January 2011.	Labelling mandatory for new, large commercial and governmental buildings in big cities.	Voluntary Star Ratings for office buildings.	Voluntary for residential and commercial buildings.
Phase-out of incandescent >100 Watt light bulbs.	46 products covered by labelling schemes.	Mandatory S&L for room air conditioners and refrigerators, voluntary for 5 other products.	13 products covered by voluntary labels.
Transport			
PLDV: none; trucks: none.	PLDV: 6.9l/100 km by 2015, 5.0 l/100 km by 2020; trucks: proposed MY 2015.	PLDV: under development; trucks: none.	None
PLDV: none; trucks: none.	PLDV: yes; trucks: none.	PLDV: none; trucks: none.	None
None	Acquisition tax based on engine size.	Registration taxes by vehicle and engine size, sales incentives for advanced vehicles.	None
Industry			
Periodic energy audits required for some industries.	Top 10 000 programme setting energy savings targets by 2015 for the largest 10 000 industrial consumers.	PAT (Perform, Achieve, Trade) in force since 2011. Audits mandated for designated consumers.	None
None	High-efficiency (IE2) MEPs for 3-phase induction motors in place.	None	High-efficiency (IE2) MEPs for 3-phase induction motors in place.

Notes: ETS = emissions trading system; PLDV = passenger light-duty vehicle; trucks = road freight trucks > 3.5 tonnes; EV = electric vehicle; LCV = light commercial vehicle; mpg = miles per gallon; MY = model year; l/100 km = litres per 100 kilometres; g CO_2/km = grammes of CO_2 per kilometre; MEPs = minimum energy performance standards; IE = international efficiency classes for motors (IE1 = standard efficiency; IE2 = high efficiency; IE3 = premium efficiency); S&L = standards and labels.

Box 9.2 ▷ Lessons from Japan's energy-saving "Setsuden" campaign

Following the devastating earthquake and resulting tsunami that hit Japan in March 2011, many power plants were shut down or damaged, leading to a substantial loss of generating capacity. For example, Tokyo Electric Power (TEPCO), which was supplying 42 million people and entities responsible for 40% of Japan's GDP, lost 40% of its capacity (METI, 2011a). Steps were quickly taken to restore supplies, including by repairing damaged plants, bringing emergency generators into service, purchasing power from independent and private producers and using pumped-storage power stations.

Despite these efforts, major power shortages were anticipated, prompting the government to launch Japan's energy-saving "Setsuden" campaign. In May 2011, a target was set to reduce peak power demand in the east of the country by 15% (METI, 2011b). Mandatory demand restrictions were applied, for the first time since 1974, to all large businesses, while small businesses were encouraged to take voluntary measures. Industries reduced or changed their working hours. Diesel generators were installed. In some cases, production lines were moved to factories in west Japan or overseas. In the public sector, lights were removed, dimmed or switched off, air-conditioning temperatures were raised, and trains and metros ran less frequently. Households were encouraged to use electric fans instead of air conditioners, to use blinds to reduce heat from sunlight and to disconnect electric appliances not in use.

As a result of the Setsuden campaign, and thanks to a fairly mild summer, summer peak power demand in east Japan was cut by over 15% (equal to one-fifth of the output from nuclear plants in 2010) and unplanned blackouts were avoided (METI, 2011c). This success can be attributed to the collective efforts of the Japanese people and the government's leadership in identifying the efficiency potential by sector and providing advice about how it might be achieved. But not all of the measures applied would be appropriate during ordinary times. Workers cannot routinely be asked to shift working hours or delay or bring forward their holidays. Some industrial processes cannot abruptly cut demand without prejudicing their competitiveness. Saving power is an important aim, but not at the expense of damaging economic performance.

Based on experience gained from the Setsuden campaign, Japan plans to further improve its energy efficiency, even though it is already a global leader in the field. Steps being taken include amending the energy conservation regulations to favour measures to reduce peak demand and adding building materials to the existing energy efficiency target programme.

Since the 1970s, countries have introduced numerous policies and measures to promote energy efficiency in the industry sector, with varying levels of success. The most common measures include incentives (in the form of subsidies or energy taxes), emissions trading schemes, equipment performance standards, energy management programmes and funding of research and technology development. However, while most countries have some type of energy efficiency policies targeting industry, progress in integrating energy efficiency consideration into business decision making has been limited. This may be due, in part, to a lack of measures such as support for capacity building and training, and facilitating access to energy efficiency service providers and financing; but it is also due to the fact that energy consumption makes up only a small part of costs in most industries (UNIDO, 2011). The introduction of energy efficiency policies is just the first step in ensuring that energy savings materialise; of equal importance is monitoring their implementation (Box 9.3).

Box 9.3 ▷ The importance of effective implementation

To support governments in their implementation of energy efficiency, the IEA recommended to the G-8 summits in 2006, 2007 and 2008 the adoption of specific energy efficiency policy measures. The consolidated set of recommendations covers 25 fields of action across seven priority areas: cross-sectoral activity, buildings, appliances, lighting, transport, industry and energy utilities (IEA, 2009). These recommendations were updated and endorsed by IEA member countries in 2011. However, while proposing or putting in place a set of policies is a necessary requirement to tap energy efficiency potential, it is not sufficient to deliver the intended savings. Verification of effective implementation is essential. Evaluations of member countries in 2009 and 2011 revealed mixed progress in implementation of the IEA 25 Energy Efficiency Policy Recommendations (IEA, 2009, 2011a, 2011b and 2012c). In 2011, only 40% of them were either fully or substantially implemented (IEA, 2012c).

Three key issues need to be addressed to increase effective implementation:

- *Market surveillance and enforcement.* Non-compliance with minimum energy performance standards (MEPS) for equipment can be as high as 20-50% in the absence of enforcement regimes (IEA, 2010). For example, although building codes apply in theory in many countries, their enforcement remains a challenge in both OECD and non-OECD countries. Without a credible enforcement strategy, mandatory regulations or standards lose much of their force, representing a significant policy and economic failure for the implementing country.
- *Institutional arrangements*. Agencies tasked with establishing and delivering energy efficiency policies must co-ordinate a number of very diverse tasks, ranging from policy analysis, through project design and management, marketing, programme evaluation and many other elements. Ensuring effective co-ordination horizontally (within a single level of government, for example between national-level institutions) and vertically (between different levels of government, for example national to regional) is essential to effective delivery of energy efficiency policy outcomes.
- *Energy efficiency data.* Monitoring progress in energy efficiency requires detailed end-use sectoral data on energy consumption at regular intervals, which means adequate resources must be dedicated to this effort. Only a few OECD countries include energy efficiency data in their energy sector statistics.

Barriers to energy efficiency deployment

While investment in many energy-efficient technologies and practices appear to make good economic sense, the level of their deployment is often much lower than expected. This is due to the existence of a number of barriers that discourage decision makers, such as households and firms, from making the best economic choices (Table 9.2).

Table 9.2 ▷ Key barriers and remedial policy tools

	Barrier	Effect	Remedial policy tools
Visibility	Energy efficiency is not measured.	Opportunity not known to exist and so not acted upon.	Test procedures/measurement protocols/efficiency metrics.
	Efficiency is measured but not made visible to decision makers.	Opportunity not visible to decision makers and so not acted upon.	Ratings/labels/disclosure/benchmarking/audits/real-time measurement and reporting.
Priority	Low awareness of the value of efficiency.	Energy efficiency is undervalued.	Awareness raising and communication efforts.
	Efficiency investments are bundled with all other investment decisions.	Efficiency investments can appear to be a low priority.	Regulation, mechanisms to decouple efficiency actions from other concerns.
Economy	Split incentives.[6]	Costs and benefits are not taken into account fully and energy efficiency is undervalued.	Regulation, financing mechanisms that incentivise investment in efficiency.
	Insufficient finance available or competing needs.	Under-investment in efficiency.	Stimulation of capital supply for efficiency investments, support of new efficiency business and financing models.
	Energy consumption subsidies.	Market conditions do not encourage efficiency.	Removal of subsidies.
	Unfavourable perception or treatment of risks.	Financing cost of efficiency projects is inflated, or energy price risk is under-estimated.	Better information on project and energy price risks, mechanisms to reduce efficiency project risk.
Capacity	Limited know-how on implementing energy efficiency measures.	Energy efficiency implementation is constrained.	Capacity building programmes.
	Limited government resources to support implementation.	Barriers addressed more slowly.	Shift government resources toward efficiency goals.
Fragmentation	Energy consumption is split among diverse range of end-uses and users.	Efficiency is more difficult to implement collectively.	Targeting regulations and other policies toward high-impact groups.
	Business models focused on either energy supply or energy demand.	Energy supply often favoured over energy service.	Regulations that reward overall energy service provision rather than just energy supply.
	Fragmented and under-developed supply chains.	Efficiency opportunities are more limited and more difficult to implement.	Programmes aimed at better market integration and overall economies.

6. A split incentive, sometimes referred to as a principal-agent problem, refers to the potential difficulties in motivating one party to act in the best interests of another when they may have different goals and/or different levels of information.

A major barrier to greater deployment of energy-efficient technologies and practices is a lack of awareness, or "visibility", by a decision maker. This may either be because the energy efficiency opportunity has not been measured, and therefore is not even known to exist, or because a decision maker has not been made aware of the fact that it exists. In both cases, it means that the decision maker is taking an investment decision based on imperfect information.

Another significant barrier is the fact that the costs and benefits of an energy efficiency investment decision can often fall on different actors. This is sometimes referred to as "split incentives". These split incentives can occur in many ways, such as:

- Between landlords and tenants, where building owners have little incentive to invest in improving energy efficiency because they do not pay the energy bill (the tenant does).
- Between buyers and operators, where the person in a firm that is responsible for purchasing a piece of capital equipment is not the person responsible for its operation and maintenance budget. In this case, the equipment with the lowest purchase cost may be chosen even if higher running costs mean it is more expensive over its operational life.
- Where the payback period[7] for investing in an energy efficiency improvement is longer than the length of time the buyer intends to own the asset (or thinks they might own it). This is a particularly serious concern for long-lived assets, such as buildings, where the payback period on an investment may be longer, but can also apply to relatively short-lived energy-using equipment, such as appliances.
- Where the benefits of improved energy efficiency are valued by a collective group, or society as a whole, rather than by the individual making their own investment decision.

The barriers to energy efficiency deployment can be compounded by the fact that energy consumption is divided across a multitude of diverse end-uses and users, suppliers and business models (fragmentation). This fragmentation complicates the design and adoption of widely-applicable solutions, increasing the complexity and cost of developing effective energy efficiency intervention programmes.

Whenever money is paid to overcome these barriers there is a direct transaction cost and, even when no money is paid directly, there may be considerable implicit costs, such as the time spent searching for information. These costs need to be factored into any energy efficiency investment decision. One technique that is used to value implicit transaction costs is to apply a monetary value to the time spent in overcoming the barrier, *e.g.* by assigning a value for time equal to the average hourly wage.

When transaction costs are included, the average payback period of an energy efficiency measure can increase to the point that some potential investments become unattractive. Studies suggest that the transaction costs for energy efficiency projects undertaken by industry can increase costs by between 9% and 40%, with smaller projects typically

7. The payback period is the length of time required to recover the initial cost of an investment. In this *Outlook*, the payback period is measured in years.

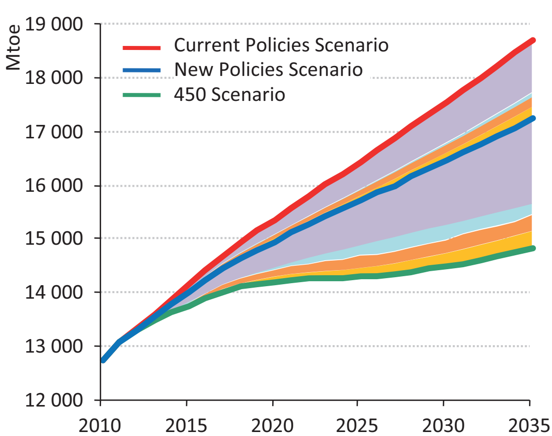
experiencing the largest increase (Mundaca and Neij, 2006). Transaction costs for households are often higher still (Joskow and Marron, 1992; EBRD, 2011), as obstacles to behavioural change, and the costs associated with finding or acquiring relevant information can be higher than for firms (Sathaye and Murtishaw, 2004).

It is important to recognise that there are a variety of energy efficiency policy instruments that are capable of removing most of the barriers and the associated transaction costs. Government action to develop and implement energy efficiency policies and programmes is crucial to ensure that they are overcome. For example, there is an important role to simply help raise awareness about the costs and benefits of potential investment decisions. Split incentives can be tackled through a mix of regulation and by devising business and financial solutions that share benefits equitably between different parties. Capacity and fragmentation barriers can often be reduced through stronger governance and resource allocations, regulation and capacity building efforts. Experience suggests that policy measures which target the removal of barriers affecting a concentrated and influential set of actors, such as specific energy-intensive industries, often produce the fastest results at the lowest cost.

The outlook for energy efficiency

Energy efficiency delivers the single largest share of energy savings in achieving the New Policies Scenario and in moving beyond it, reflecting the large amount of cost-effective potential that exists. Efficiency accounts for about 70%, or 1 060 Mtoe, of the reduction in projected global energy demand in 2035 in the New Policies Scenario, compared with the Current Policies Scenario (Figure 9.4). Energy demand in the New Policies Scenario still grows by 35% in the period 2010-2035, but without the implementation of the assumed efficiency measures the growth would be 43%. As a result, global energy intensity in the New Policies Scenario declines at 1.9% per year on average over the period 2011-2035, a significant improvement on the trend over the past decade.

Figure 9.4 ▹ Change in global primary energy demand by measure and by scenario



Energy savings in 2035	CPS to NPS	NPS to 450
Efficiency in end-uses	67%	66%
Efficiency in energy supply	5%	8%
Fuel and technology switching	12%	12%
Activity	16%	14%
Total (Mtoe)	**1 479**	**2 404**

Note: CPS = Current Policies Scenario; NPS = New Policies Scenario; 450 = 450 Scenario.

Box 9.4 ▷ Decomposing the role of energy efficiency in curbing energy demand

To analyse the role energy efficiency is set to play in the future, this *Outlook* uses a decomposition technique, which quantifies the relative importance of the different factors shaping future energy demand.[8] This has enabled us to attribute differences in projected energy demand across the *WEO-2012* scenarios to: efficiency effects; fuel and technology switching effects; or activity effects:

- *Efficiency effects.* Without changing the fuel used, the same level of energy service can be achieved with a lower level of energy use. Energy efficiency can be improved, for example, by changing from a conventional to a condensing boiler, by using a light-emitting diodes (LEDs) lamp instead of an incandescent one, or through better energy management of industrial processes.
- *Fuel and technology switching effects.* The same energy service can be provided by different fuels and technologies. For example, an oil-fired boiler or a heat pump can provide space heating in buildings; an electric arc furnace or a basic oxygen furnace can produce steel; and a car with an internal combustion engine or an electric motor can provide a transport service from one place to another. In each case, both technologies serve the same energy service demand, but with different associated levels of energy efficiency. This effect captures more than pure fuel switching as it also includes technology switching.
- *Activity effects*. Demand for energy services is influenced by a variety of factors, including economic and population growth and the level of end-user prices. As we assume the same GDP and population growth rates across our main scenarios, the primary reason for changes in activity between them is change in end-user prices.

We have applied this decomposition technique to all energy sectors – transport, residential, commercial, industry and power – using the best available information on sectoral energy demand, energy consumption and technologies (see Chapter 10, Figure 10.1). As we have focussed on changes in energy demand between scenarios, the results are not influenced by other factors – such as economic structure, non-price related changes in human behaviour, capacity utilisation in industry and weather patterns – that will no doubt change over time, but are the same across our scenarios.

Between 2011 and 2035, improvement in energy efficiency in end-use sectors (buildings, transport and industry), accounts for about two-thirds of the reduction in primary energy demand in the New Policies Scenario, compared with the Current Policies Scenario – by far the largest component. Energy efficiency improvements in the power sector, refineries, and transmission and distribution networks play a much smaller, yet still significant, role. The response to end-use energy price increases, through subsidies removal, CO_2 pricing and the relative increase of more expensive electricity producing technologies in the power

8. For the decomposition, we use the Logarithmic Mean Divisia Index I (Ang, Zhang and Choi, 1998; Kesicki, 2012). For more detail, see *www.worldenergyoutlook.org.*

mix, accounts for savings of 16% in 2035. Fuel and technology switching play a similar role in reducing primary energy demand in 2035.

Energy efficiency is also the largest contributor to energy savings in the 450 Scenario, compared with the New Policies Scenario, representing almost three-quarters, or around 1 800 Mtoe, of the reduction in energy use in 2035. In the 450 Scenario, energy savings due to improved efficiency on the supply side is more pronounced, as the power sector becomes more efficient under the impact of more widespread and higher CO_2 prices. In the 450 Scenario, energy prices to final consumers are significantly higher than in the New Policies Scenario, in some regions because of the introduction of CO_2 pricing, in others because of further reductions to fossil-fuel subsidies. Higher prices provide additional incentives to improve energy efficiency, while also encouraging energy conservation.

Trends by region

Energy efficiency policies in the European Union, China, the United States and Japan account for 53% of the reduction in global energy demand in the New Policies Scenario, compared with the Current Policies Scenario. This result reflects the sheer size of their energy markets and the emphasis these countries are placing on energy efficiency in their policies (Table 9.3).

The European Union has established a comprehensive energy efficiency policy framework with targets for 2020, notably a 20% reduction in energy demand in 2020 *vis-à-vis* their baseline. A key regulation of the EU energy efficiency directive focuses on engaging energy providers to help consumers – industry and household – to increase their investment in energy efficiency. The EU target is missed in the New Policies Scenario, with energy savings reaching just 14% in 2020 on the assumption of implementation delays in some member countries. However, necessary policies are fully implemented over time, a key factor in our projection that EU energy demand in 2035 is 2.5% lower than in 2010 and almost 90 Mtoe less than in the Current Policies Scenario (Figure 9.5). Without implementing the assumed efficiency measures, EU energy demand in 2035 would be 3% higher compared with 2010.

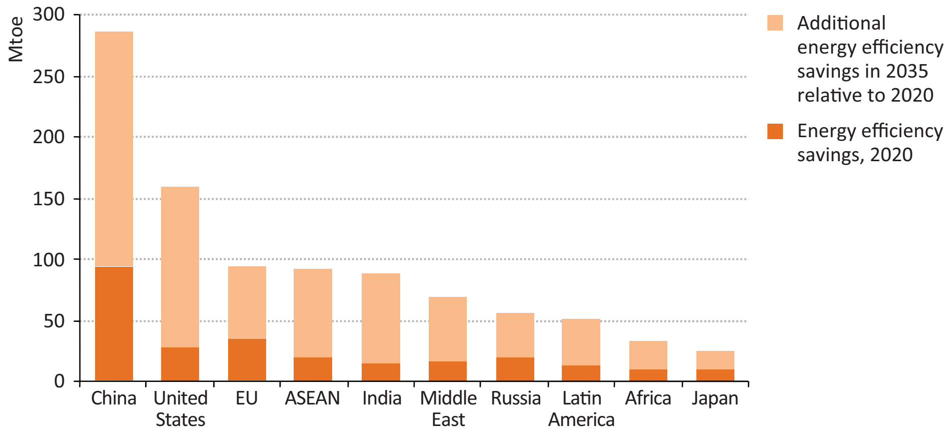
China has established a comprehensive framework to improve energy efficiency, with an overall goal of reducing energy intensity by 16% between 2011 and 2015. A key pillar of its efforts is an ongoing restructuring of its economy, which is expected to bring about significant savings in energy consumption per unit of GDP. Other key elements include innovation and energy savings in companies identified by the government in a list of "ten thousand energy-saving and low-carbon industrial enterprises", which collectively make up 37% of the targeted energy savings by 2015. The longer-term impact of the policies that China is pursuing, coupled with greater availability of natural gas, promises to change the country's energy landscape, drastically cutting coal demand growth post-2015. In the New Policies Scenario, China's energy demand grows by 60% over 2010-2035, however, without the implementation of the assumed efficiency measures, growth would be 72%. In our projections, China successfully meets its 2015 target for energy intensity.

Table 9.3 ▷ Key energy efficiency assumptions in major countries/regions in the New Policies and 450 Scenarios

	New Policies Scenario	450 Scenario
United States	Fuel-economy standards for new PLDVs at 54.5 mpg (4.3 l/100 km) in 2025. Fuel-economy standards for new trucks (up to 21% by 2017/2018, depending on type). Increased state and utility budgets for energy efficiency.	Fuel-economy standards for new PLDVs at 67 mpg (3.5 l/100 km) in 2035. Fuel economy improvement for new trucks up to 45% by 2035 (depending on type). Mandatory building codes; zero-energy buildings initiative. Extension of grants for energy efficiency.
European Union	Partial implementation of the Energy Efficiency Directive. Fuel-economy standards for PLDVs at 95 g CO_2/km in 2020 (3.8 l/100 km); LCV at 147 g CO_2/km (5.9 l/100 km) in 2020.	Full implementation of the Energy Efficiency Directive. Fuel-economy standards for PLDVs at 80 g CO_2/km in 2035 (3.2 l/100 km)*; LCV at 100 g CO_2/km (4.0 l/100 km). Zero-energy buildings in new construction by 2020. Ecodesign.
Japan	Fuel-economy standards for PLDVs at 20.3 km/l (4.9 l/100 km) in 2020. Measures to contain electricity demand growth.	Fuel-economy standards for PLDVs at 32 km/l (3.1 l/100 km) in 2035. More stringent measures to contain electricity demand growth.
China	Strategies to meet the target in the 12th Five-Year Plan (2011-2015) to cut energy intensity by 16% including: - structural changes to the economy. - top 10 000 companies. - innovation. Fuel-economy standards for PLDVs at 5.0 l/100 km in 2020.	Fuel-economy standards for PLDVs 3.1 l/100 km in 2035. Introduction of zero-energy buildings for all new construction, starting 2025.
India	Full implementation and extension of the National Mission on Enhanced Energy Efficiency. Fuel-economy standards for PLDVs: assumed annual improvement of 1.3% between 2010 and 2020. Compact florescent lamps financed through CDM. Average annual improvement of PLDVs fuel economy by 1.3% until 2020.	Minimum performance standards for new coal plants (38% in 2035). Reduction in transmission and distribution losses. Mandatory standards for appliances and increased penetration of energy-efficient lighting. Fuel-economy standards for PLDVs at 3.0 l/100 km.
Middle East		Fossil-fuel subsidy rates decline to a maximum of 20% by 2035.

* Fuel-economy standards in the 450 Scenario that are presented in g CO_2/km are related only to improvements in efficiency. Additional reductions in average g CO_2/km can occur through the use of alternative fuels such as biofuels, electricity or natural gas. All fuel-economy standards refer to test-cycle fuel consumption.

Figure 9.5 ▷ Savings in primary energy due to energy efficiency in the New Policies Scenario compared with the Current Policies Scenario by region, 2035



Note: EU = European Union.

The United States is in the process of revising its minimum energy performance standards (MEPS) for appliances and equipment, a policy area in which the country has been very active since 1978. Twenty-four states have adopted long-term energy savings targets, which are driving utility investments in energy efficiency. State budgets for electricity efficiency programmes increased to $4.5 billion in 2010 from $3.4 billion in 2009 (ACEEE, 2011). While the United States does not have an economy-wide energy efficiency target, it is focusing increasingly on improving energy efficiency in road transport, long recognised as having significant potential for improvement at low cost. The new 2025 fuel economy target for passenger cars of 54 miles per gallon (mpg), compared with around 35 mpg today, would exploit much of the known technical potential of conventional vehicles, assuming there is no significant change in the average size and power of the fleet over the period. In the New Policies Scenario, this policy alone allows the United States to cut oil consumption by some 2.1 mb/d of oil by 2035, with significant economic benefits due to reduced spending on imports. In terms of total demand, efficiency gains result in a 1% decline in energy demand by 2035, compared with current levels, versus 6% growth in the absence of the fuel-economy measures.

Japan's new Innovative Strategy for Energy and the Environment, released in September 2012, includes a major focus on energy efficiency. One target is to reduce electricity demand in 2030 by 10%, compared with 2010 levels. This is expected to be backed-up by measures to incentivise the introduction of more efficient technologies in the residential sector and, to a lesser extent, the industrial sector. In the New Policies Scenario, the new measures temper electricity demand growth significantly; though by 2030 it is still 6% higher than in 2010. Japan's primary energy demand is projected, in the New Policies Scenario, to be 10% lower in 2035 than in 2010, with the bulk of the reduction coming from efficiency measures. In the absence of these measures, we estimate demand in 2035 would still be lower than in 2010, but only by 5%.

The centrepiece of India's efforts to save energy is its innovative Perform, Achieve and Trade (PAT) mechanism for energy efficiency, which is aimed at large energy-intensive industries. Other countries in developing Asia, particularly in the ASEAN region, have been identified as having large potential to improve energy efficiency in industry (IEA, 2011c). In the New Policies Scenario, we assume that governments facilitate the introduction of energy service companies (ESCOs) and tap a portion of this new market. In the New Policies Scenario, energy demand in developing Asia, excluding China, increases by 95% between 2010 and 2035; but in the absence of the assumed efficiency measures, the rise would be 109%.

Due to plentiful energy resources and low energy prices, improving energy efficiency has historically not been a key priority throughout much of the Middle East. With the exception of a few countries, subsidised prices have significantly hampered the uptake of efficient technologies in the power sector, road transport and buildings. For example, the average efficiency of fossil fuel power generation in the region is currently just 33%, nine percentage points below the OECD average. In the New Policies Scenario, very few measures specifically targeted at improving energy efficiency are assumed to be implemented in the region. Nonetheless, efficiency gains cut projected Middle Eastern energy demand by 7% in 2035, compared with the Current Policies Scenario. This can largely be attributed to the spill-over effect as the implementation of energy efficiency policies in other parts of the world makes more efficient industrial and transport capital stock available in the international market.

In much of Africa, with the exception of South Africa and a few countries in North Africa, providing access to basic energy services and increasing the availability of energy to underpin economic growth have been given considerably more attention by policy makers than energy efficiency. While improving energy access is fundamental to fulfilling development aspirations, integrating energy efficiency strategies at the very start of such programmes could enable access to be provided to more people in a shorter timeframe (see Chapter 18). During the projection period, efficiency measures make up 78%, or over 360 Mtoe, of the 2% reduction in energy demand in Africa in the New Policies Scenario, compared with the Current Policies Scenario. The bulk of the savings are made in South Africa. Elsewhere in the continent savings stem from the more widespread use of improved biomass cook stoves. As is the case in the Middle East, spill-over effects from the improved efficiency of energy-using equipment traded in the world markets play an important role in raising efficiency levels in Africa.

Trends by sector

In comparing the New Policies Scenario with the Current Policies Scenario, 44% of the final energy savings that result from efficiency improvements come from the industry sector, as rising energy prices strengthen the economic case for making energy efficiency investments in energy-intensive industries (Table 9.4). The share of energy in total industry input costs in large developing countries has been estimated at 10% for chemicals and basic metals, and 6.5% for non-metallic minerals (UNIDO, 2011). These shares tend to be higher in small developing countries, where access to technology and capital is often limited, and lower in OECD countries. In the New Policies Scenario, an increasing share of industrial output comes from emerging economies, where most of the new capacity is added. The uptake of more efficient technologies is strong in OECD countries and China, because of the introduction of minimum energy performance standards and increased energy prices, due to the introduction of CO_2 prices.

Table 9.4 ▷ Energy demand and savings due to efficiency measures in the New Policies Scenario compared with the Current Policies Scenario by end-use sector (Mtoe)

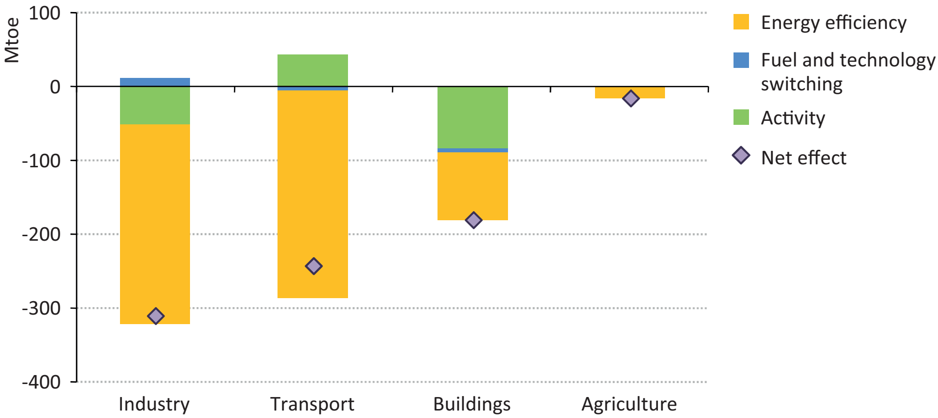
	Energy demand in the New Policies Scenario			Cumulative energy savings due to energy efficiency
	2010	2020	2035	2011-2035
Industry	2 421	3 035	3 497	3 221
Transport	2 377	2 778	3 272	2 510
Buildings	2 910	3 302	3 748	1 138
Other	970	1 107	1 232	465
Total	**8 678**	**10 223**	**11 750**	**7 334**

Note: Other includes agriculture and non-energy use.

In the New Policies Scenario, increasingly stringent regulation delivers substantial energy savings in the transport sector, making it the second-largest contributor to the reduction in energy demand over the projection period due to efficiency measures. Several countries are discussing the introduction of ambitious fuel-economy standards, often in a bid to slow or cut oil imports or to reduce local pollution. Tighter standards are expected to increase the rate of innovation in the automotive industry, which will have spill-over effects for efficiency levels globally. As energy prices are lower in the New Policies Scenario than in the Current Policies Scenario, some of the energy efficiency savings are offset by the rebound effect, *i.e.* the increase in the demand for energy services that occurs when their overall cost declines (included in Figure 9.6 under activity).

In the New Policies Scenario, energy savings in the buildings sector are relatively small, compared with other sectors, because of the high transaction costs. Most of the energy efficiency savings occur in commercial buildings, where regulation is easier to apply. Some demand reduction also occurs in the residential sector thanks to the assumed reduction in fossil-fuel subsidies in some countries, including India, Russia and parts of the Caspian region.

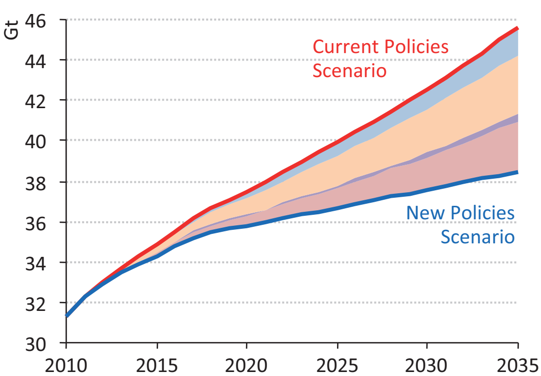
Figure 9.6 ▷ Decomposition of the change in final energy consumption in the New Policies Scenario compared with the Current Policies Scenario by sector in 2035



Role in reducing CO_2 emissions

Energy efficiency measures in the New Policies Scenario reduce CO_2 emissions by 4.6 gigatonnes (Gt) in 2035, compared with the Current Policies Scenario. This saving accounts for 65% of total savings in 2035 (Figure 9.7). The share of energy efficiency in total savings declines over time, as energy efficiency is cheaper than other abatement options and is among the first options used. Lower electricity demand from more efficient appliances, industrial motors and buildings reduces fuel input to the power sector and is the largest factor in CO_2 reduction through efficiency measures (2.9 Gt of savings in 2035). Fuel savings achieved through more efficient vehicles, industrial processes and heating applications save an additional 1.3 Gt CO_2 in 2035. Higher power generation efficiency accounts for an additional 0.3 Gt of savings in the New Policies Scenario, less significant than the contribution from increased renewables (1.6 Gt) or nuclear (0.4 Gt).

Figure 9.7 ▷ Contribution of change in CO_2 emissions by policies in the New Policies Scenario compared with the Current Policies Scenario

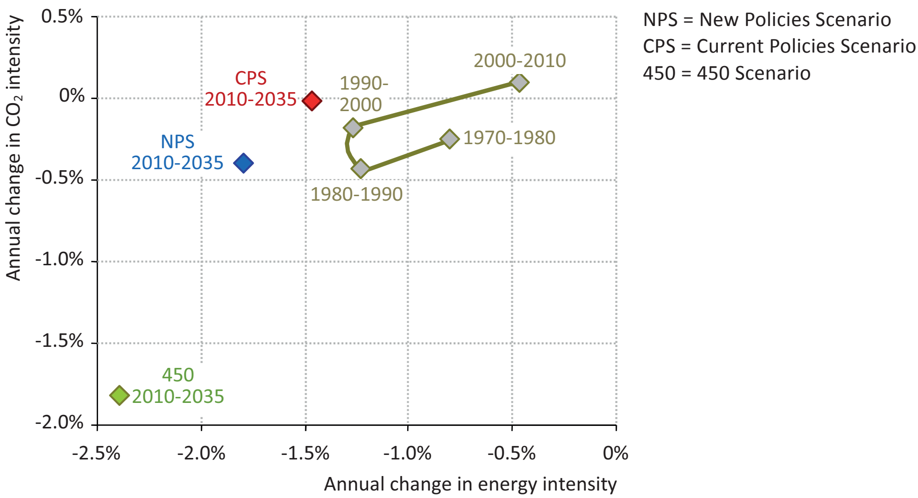


Abatement	2020	2035
Efficiency	71%	65%
End-use fuels	19%	18%
Electricity savings	47%	42%
Power plant	5%	5%
Other	29%	35%
Total (Gt CO_2)	**1.7**	**7.1**

9

The policies that we assume to be implemented, particularly subsidies to renewable energy, the introduction of carbon pricing and coal to gas switching in the power sector, underpin a decline in carbon intensity[9] of 0.4% per year on average (Figure 9.8). This trend would represent a shift with respect to the last decade, when global carbon intensity remained flat. Nonetheless, the declining energy and carbon intensities in the New Policies Scenario are not enough to limit the long-term increase in the global mean temperature to two degrees Celsius: the 450 Scenario requires annual average improvements of 2.4% in energy intensity and 1.8% in carbon intensity (Chapter 8).

Figure 9.8 ▷ Trends in energy and CO_2 intensity by scenario, 2010-2035



Untapped economically viable potential in the New Policies Scenario

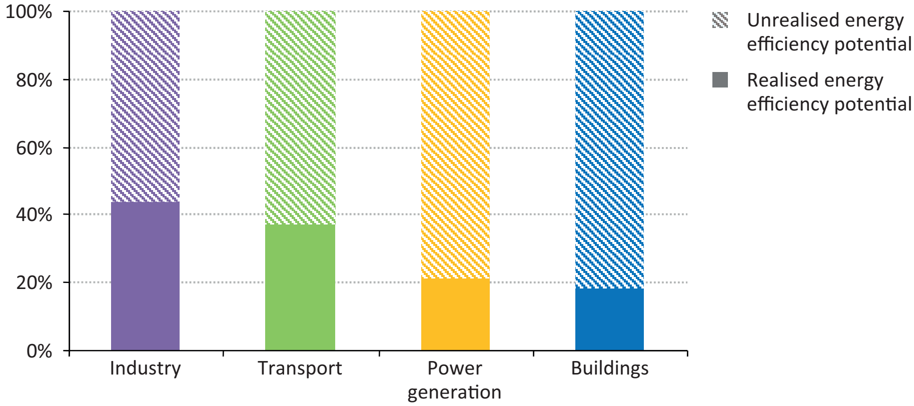
While the New Policies Scenario represents a significant improvement over current trends, our detailed sector-by-sector analysis shows that it leaves significant potential for energy efficiency untapped. The Efficient World Scenario, presented in Chapter 10, examines the implications of realising this full economic potential. Comparing the results of the two scenarios demonstrates that the share of economic potential realised in the New Policies Scenario ranges from less than 20% in buildings to up to 44% in industry (Figure 9.9).

In the New Policies Scenario, regions including the European Union, the United States and China introduce fuel-economy standards. Globally, these measures capture 37% of the full potential for energy efficiency improvements in the transport sector. The assumed fuel-economy standards for passenger light-duty vehicles, coupled with end-user pricing policy, lead to wider deployment of hybrids and very efficient internal combustion engines (ICEs) (IEA, 2011c). Driven mostly by higher energy prices, targets and incentives, the use of more efficient technologies in energy-intensive industries in non-OECD countries (where

9. In this context, carbon intensity is the amount of CO_2 emissions per unit of primary energy consumed.

almost all new additions occur) exploits around 44% of the global efficiency potential in the industrial sector.[10]

Figure 9.9 ▷ Utilised long-term energy efficiency economic potential in the New Policies Scenario, 2011-2035



Thus far, energy efficiency policies in buildings have received less attention from policy makers, as they are in general more difficult to implement, enforce and verify, and are sometimes more costly. For these reasons, the buildings sector only achieves one-fifth of the economically available potential in the New Policies Scenario (See Chapter 10). Buildings and their associated energy technologies may have very different time scales. For example, a building shell may be in place for a structure's entire life and, if it is inefficient when first constructed, it will impose a high energy load over its full lifetime, unless it is retrofitted. Energy retrofits are usually economically justified when included in routine technical renovation, provided that the associated costs can be amortised over the remaining life of the building. However, the case may be less compelling when the owner is not the occupier and is not responsible to pay the energy bill (a case of split incentives); or if the tenure of the owner-occupiers is not known and may be shorter than the remaining life of the building. There are few commercial solutions to these market barriers. This, in addition to the absence of long-term incentive schemes for retrofitting in most countries creates a significant lock-in effect that, unless overcome through very strong policy intervention, will continue to deter improvement of the energy performance of existing buildings. Few countries are considering such incentives.

The potential for raising the average efficiency of thermal power plants depends largely on the relative price of fossil fuels and their competitiveness, policies in place to stimulate or reduce the deployment of specific technologies and the overall level of electricity demand. Moreover, the absence of a widespread price on carbon provides little incentive to increase the efficiency of such plants. Lower electricity demand requires fewer new

10. A study undertaken in Australia found that 40% of the potential to improve energy efficiency in the industrial sector (compared with the efficiency that could be achieved through implementing the policies under consideration) had been realised (ClimateWorks, 2012).

additions to the power system, therefore limiting the scope for increasing the weighted-average efficiency of all fossil fuel plants. This is one of the underlying factors for why power plant average efficiency in the New Policies Scenario is sometimes only marginally higher than in the Current Policies Scenario. More generally, it is often cheaper to refurbish an old, inefficient plant, than to invest in a new very efficient one, and this may be decisive where uncertainties about policies affecting future operations persist. For these reasons, the power sector achieves no more than 21% of the energy efficiency potential in the New Policies Scenario.

S P O T L I G H T

Do energy efficiency measures "undermine" carbon markets?

As most energy efficiency measures are less costly than other climate change mitigation measures, they should be among the first steps taken by countries seeking to rein in CO_2 emissions. While energy prices that include value for carbon externalities provide an additional economic incentive for energy efficiency investment, some barriers to their uptake reflect market failures that are not addressed by a carbon price by definition (IEA, 2011d).

Where carbon pricing does provide an additional incentive for efficiency improvements, the converse is also true – specific energy efficiency measures are also needed to complement CO_2 prices to ensure that cost-effective potential energy savings are realised. Energy efficiency and carbon-pricing policies interact and need to be aligned. Superposing energy efficiency measures on existing carbon-pricing systems may reduce the CO_2 price to a level at which there is insufficient incentive to undertake long-term low-carbon investments, locking in more carbon-intensive infrastructure and causing higher mitigation costs in the future. For example, energy efficiency measures tend to reduce electricity demand and therefore wholesale electricity prices. This means that technologies such as renewables need greater support per unit of capacity installed. An appropriate level of carbon pricing, which increases wholesale prices, would render renewables more competitive.

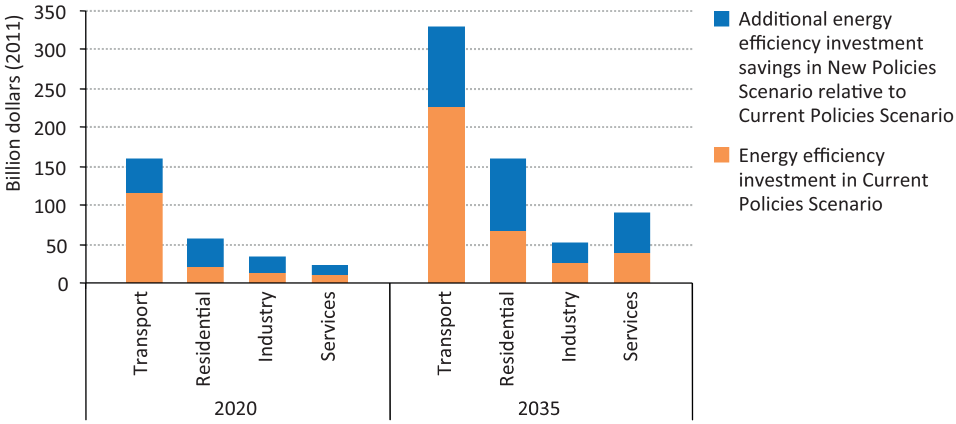
Investment in energy efficiency

To achieve the ongoing efficiency gains projected in the New Policies Scenario, investment in energy efficiency (beyond that in the Current Policies Scenario) needs to increase steadily from $117 billion in 2020 to $290 billion in 2035 (Figure 9.10).[11] This includes additional investment in each of the end-use sectors: transport, residential, industry and services.

11. Energy efficiency investment is used to denote expenditure on a physical good or service which leads to future energy savings, compared with the energy demand expected otherwise. This section focuses on energy efficiency investment in end-use sectors – transport, residential, industry and services – as this is where most of the savings and additional investment occur. Over the *Outlook* period, power sector investment is reduced by $0.5 trillion, due to lower electricity demand, while the additional energy efficiency investment in the power sector is $350 billion in total.

Over the *Outlook* period, cumulative additional investment in the New Policies Scenario amounts to $3.8 trillion.[12]

Figure 9.10 ▷ Average annual increase in energy efficiency investment in the New Policies Scenario compared with the Current Policies Scenario



Investment in transport increases by $1.6 trillion, 41% of the total additional investment for all sectors worldwide. OECD countries account for two-thirds of the incremental transport investment. This high share is a function of the higher cost of increasing fuel economy in the OECD countries on one hand, as they already tend to be at higher levels, and, on the other, the fact that most OECD countries have adopted fuel economy policy targets, while only China has adopted such measures among non-OECD countries. Fuel economy improvements are achieved in road transport through improvements in internal combustion engine technology, such as changes to the thermodynamic cycle or reducing engine friction, as well as weight reductions and improvements to auxiliary systems. In addition, energy savings result from greater use of hybrid cars and alternative fuel vehicles and more rapid market penetration of light weight materials. Such technological advances come at a cost: in 2035, the average additional cost per vehicle is $550 in non-OECD countries and around $1 400 in OECD countries, compared with the Current Policies Scenario. In the United States and Europe, the additional costs are around $1 600 per vehicle, given the stringency of fuel-economy standards, while in China the additional cost is around $810 per vehicle. But this adds only a few percent to the price of a vehicle. Improving vehicle efficiency is, of course, generally cheaper in countries with a larger share of inefficient vehicles in the existing fleet.

12. The estimates of capital costs for end-use technology used in this analysis are based on the results of work carried out in co-operation with a number of organisations, including the Cement Sustainability Initiative, and Global Buildings Performance Network, and have been verified with a number of industrial sources for the iron and steel sector, petrochemicals, cement, road and freight vehicles, buildings and energy management systems. Several independent sources were used to check consistency.

About one-third of the additional investment in residential and services sector buildings is in improving the efficiency of electrical equipment (appliances and lighting), totalling $745 billion over the *Outlook* period. Building energy management, often a cheap option per unit of energy saved, is assumed not to be widespread in the residential sector but is increasingly used in commercial and public buildings.[13] In the New Policies Scenario, improvements to insulation and heating systems are mostly achieved in new buildings. Such investments often do not increase property value and have payback periods that exceed the average length of ownership, creating substantial barriers to their being undertaken without a revised policy framework. Investment in retrofits, insulation and thermal efficiency total $1.0 trillion over the *Outlook* period.

In the New Policies Scenario, additional investment in improving energy efficiency in industry amounts to $450 billion between 2011 and 2035, compared with the Current Policies Scenario. Average annual investment increases over time as cheaper options are tapped in the early years and the number of projects undertaken to increase efficiency increases. About two-thirds of the additional investment in industry is in improving the efficiency of heat systems, where much unrealised potential exists (GEA, 2012). The remainder of the investment is in electrical equipment, mostly industrial motors. Improved motor systems have been available on the market for some years, but their uptake has been slow, especially in developing countries (UNIDO, 2011). This is one of the most striking examples that, even when energy efficiency investments are economic and pay back very quickly, other barriers can be serious impediments. In the New Policies Scenario, increasing electricity prices make the economic case stronger.

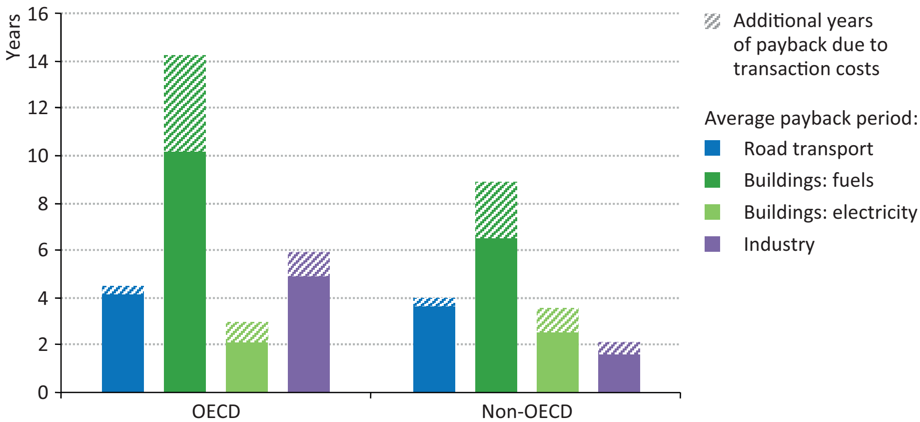
The payback periods of the energy efficiency measures that are assumed to be adopted in the New Policies Scenario are short, with the exception of buildings in OECD countries where retrofits are being implemented.[14] In road transport, for example, fuel standards adopted in OECD countries pay back in around four years, even allowing for transaction costs. For cars and trucks such transaction costs are in fact small, as fuel economy is one of the main parameters taken into consideration when making the investment. Additionally, information on vehicle fuel economy is readily available to consumers in most OECD countries. Energy efficiency measures in industry in OECD countries have a payback of less than five years (two-and-a-half years for motors), while the payback period for investment in industry in non-OECD countries is below two years (Figure 9.11). Including transaction costs averaging 20% of the investment cost does not greatly change the payback period.

13. Buildings energy management, or active control, comprises measures that through automation and control ensure that equipment works in an optimised way, *i.e.* only when needed and not more. Automation ensures turning off devices when not needed and regulating motors or heating at the optimised level.

14. To calculate the payback period of energy efficiency measures we have associated the additional investment in each year to the savings in fuel expenditures that such investment will entail over the lifetime of the capital stock. Savings in fuel expenditures are a function of the energy savings resulting from the mix of the efficiency measures taken and end-use fuel prices. The payback is calculated as an average for the investment occurring over the *Outlook* period, accounting for savings that occur even beyond the period.

The average payback period of efficiency measures undertaken in buildings in OECD countries is relatively long as building retrofits, the most expensive measure in this sector, are undertaken in some countries. Including transaction costs more significantly increases the average payback period for investment in space heating and cooling, and water heating efficiency measures in the residential sector. In OECD countries the payback period increases to over fourteen years and in non-OECD it reaches almost nine years, almost bordering the lifetime of some of the capital stock for which the investment is made.

Figure 9.11 ▻ Average payback periods for energy efficiency measures in the New Policies Scenario by sector including and excluding transaction costs



Note: Transaction costs are assumed to be equivalent to 9% of the investment cost of the energy efficiency measure for transport, 20% for industry and 40% for buildings.

Measures to address some of the barriers to energy efficiency implementation are adopted in the Current Policies Scenario, though the effort falls far short of what is needed to remove them. More is done in the New Policies Scenario but, even here, the level of policy intervention aimed at addressing energy efficiency barriers is such that large transaction costs remain. The Efficient World Scenario, presented in Chapters 10-12, offers a much more robust policy framework that largely eliminates the implicit transaction costs.

Box 9.5 ▻ How much money is currently flowing into energy efficiency?

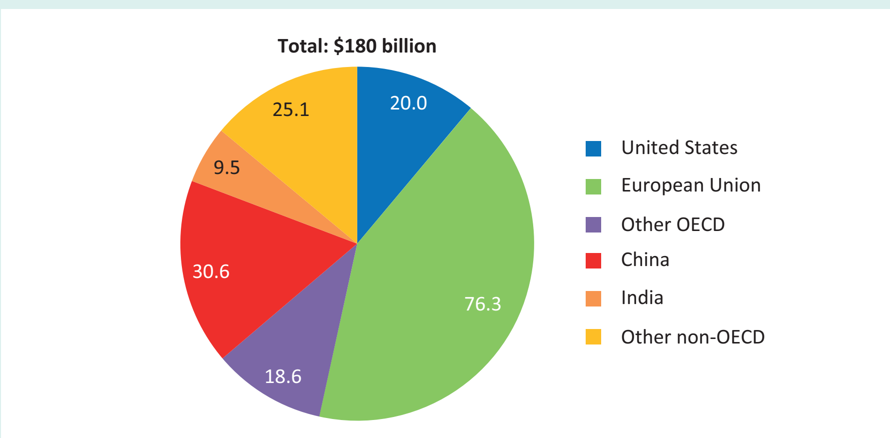
Despite the increasing interest of policy makers, financial institutions and other stakeholders, investments in energy efficiency are seldom tracked systematically and no comprehensive estimate is available of current global investment in energy efficiency. This is due to the fact that energy efficiency investments are undertaken by a multitude of agents, households and firms, often using their own funds. Moreover, there is no standard definition for what constitutes an energy efficiency investment.

To overcome this information gap, for this *Outlook* we have made a first attempt to estimate energy efficiency investment through a country-by-country survey. We have found that many countries track investment in improving energy efficiency in buildings and industry, but data for the transport and power sectors are more difficult to obtain or estimate. Given these limitations, we have used the following approach:

- Use country sources and estimates, wherever available. This proved possible for larger countries.
- Infer energy efficiency investment from data from multilateral development banks and other sources which detail public funding invested in energy efficiency projects to which a multiplier is applied, based on the economic circumstances and practices of the individual country (AGF, 2010).

Using this methodology, we estimate that global investment in projects aimed principally at improving energy efficiency amounted to $180 billion in 2011 (Figure 9.12). This is significantly lower than the investment in expanding or maintaining fossil fuel supply (nearly $600 billion). About two-thirds of the estimated investment in energy efficiency in 2011 was undertaken in OECD countries. Investment in the European Union reached approximately $76 billion, while investment in the United States reached $20 billion (Capital E, 2012). Investment in China reached $31 billion, 85% of it undertaken by companies (CPI, 2012). There is increasing activity in energy efficiency in India as a result of government programmes to promote energy efficiency through regulation and capacity building, estimated to have amounted to $9.5 billion, split between the buildings and industrial sectors (HSBC, 2011). There is also significant energy efficiency investment in Russia by the government and also by the European Bank for Reconstruction and Development; in total we estimate it reached $5.7 billion in 2011.

Figure 9.12 ▷ Investment in energy efficiency by country and region, 2011



A blueprint for an energy-efficient world

Six steps toward a hat-trick of energy goals

Highlights

- The Efficient World Scenario offers a blueprint to realise the economically viable potential of energy efficiency. We set out the policies that governments need to enact to lower market barriers, thereby minimising transaction costs and enabling the necessary energy efficiency investments. Those investments pay back well before the end of the lifetime of the energy capital stock and result in huge gains for the economy, energy security and the environment.

- The Efficient World Scenario results in a more efficient allocation of resources, boosting cumulative economic output through 2035 by $18 trillion – equivalent to the current size of the economies of the United States, Canada, Mexico and Chile combined. GDP gains in 2035 are greatest in India (3.0%), China (2.1%), the United States (1.7%) and OECD Europe (1.1%). Additional investment of $11.8 trillion in more efficient end-use technologies is needed, but is more than offset by a $17.5 trillion reduction in fuel expenditures and $5.9 trillion lower supply-side investment.

- Growth in global primary energy demand over 2010-2035 is halved, relative to the New Policies Scenario, and energy intensity improves at 2.6 times the rate of the last 25 years. Oil demand peaks at 91 mb/d before 2020 and declines to 87 mb/d in 2035. Coal demand is lower in 2035 than today, while natural gas demand still rises. We estimate that the rebound effect (increased energy demand due to higher GDP and lower prices) approaches 10% of the cumulative savings from efficiency improvements, but this can be cut by more than half with end-user pricing policies.

- Oil demand is reduced by 12.7 mb/d in 2035, compared with the New Policies Scenario, equal to the current production of Russia and Norway combined. This eases pressure for new discoveries and developments. Oil-import bills in the five largest importers are cut by 25%. Though Middle East oil-export revenues are lower than in the New Policies Scenario, they still increase significantly relative to today.

- Energy-related CO_2 emissions peak before 2020 and decline to 30.5 Gt in 2035, pointing to a temperature increase of 3 °C; in addition to energy efficiency, low-carbon technologies will be needed to achieve the 2 °C goal. Emissions of local pollutants are cut sharply, bringing benefits to China and India, in particular.

- We propose six categories of policy action, which, if widely implemented, can turn the Efficient World Scenario into reality. Key steps include: strengthening the measurement and disclosure of energy efficiency, to make the gains more visible to consumers; regulations to prevent the sale of inefficient technologies; and financing instruments.

The Efficient World Scenario

Introduction

Energy efficiency policies already in place and many of those currently under discussion are set to accelerate the rate of efficiency improvement in the global energy economy. These improvements are reflected, respectively, in the Current Policies Scenario and the New Policies Scenario. Yet those scenarios see the exploitation of only a small portion of the available energy efficiency potential, as many barriers still exist to the implementation of the necessary measures, even when they are fully viable in economic terms.

In the following three chapters, we present an Efficient World Scenario. This quantifies the implications of dismantling the impediments, so that a wave of investment is released for measures to improve energy efficiency. All of these investments satisfy stringent tests in terms of their payback period. The objective is to understand the transformation such measures would achieve – how far they would take us towards a sustainable energy economy – and how the change might be achieved. Our analysis is based on detailed scrutiny of the known opportunities for action to realise this economic potential and of the policies required to do so. The Efficient World Scenario provides a comprehensive global picture – region-by-region and sector-by-sector.

The chapter starts by defining the approach and key assumptions that underpin the Efficient World Scenario and shows how its realisation would represent a triple win, cutting energy demand, improving the global economy and delivering environmental benefits. While the primary goal of energy efficiency policy is to realize energy savings, it is important to take these associated benefits into account, as they can be very significant, bolstering the case for policy intervention. Some of them can readily be given a monetary value, but for others this is much more difficult. At the end of the chapter, we summarise the government action that would be needed to obtain these benefits.

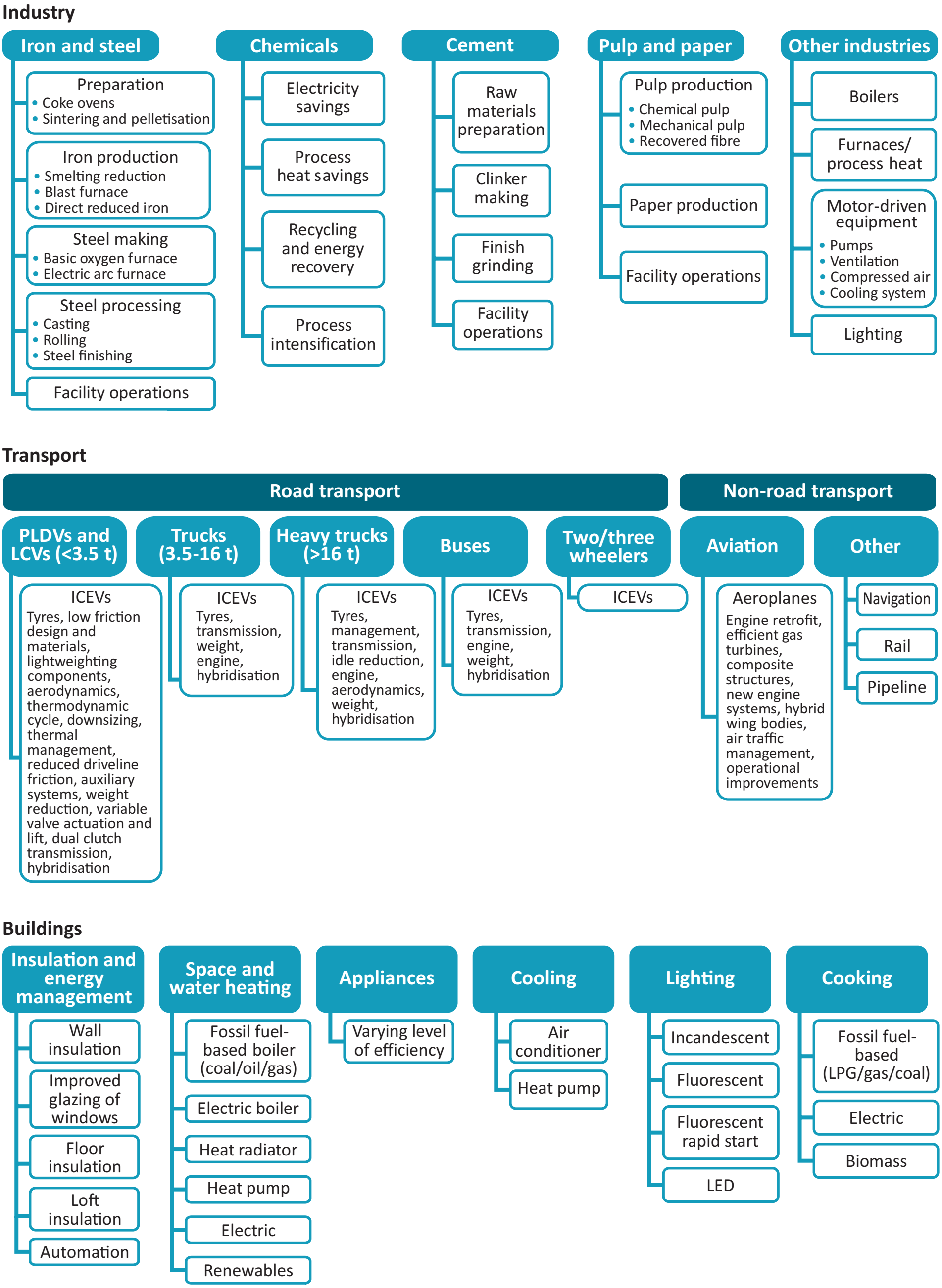
Methodology and assumptions

The core assumption in the Efficient World Scenario is that policies are put in place to allow the market to realise the potential of all known energy efficiency measures which are economically viable. To calculate the economic potential, which varies by sector and by region, two key steps were undertaken.

First, the technical potentials were determined, identifying key technologies and measures to improve energy efficiency by sector, in the period through to 2035. This process involved analysis, over a number of sub-sectors and technologies, of a huge amount of data and information from varied sources (Figure 10.1). For the industry, power and transport sectors, we undertook detailed surveys of companies, with operations across the world, to ascertain the efficiencies of the best technologies and practices available now and how these are likely to evolve based on the efficiency and costs of technologies that are in the process of being developed and demonstrated. For the buildings sector[1], we consulted

1. The buildings sector comprises energy demand from residential and services and, hence, includes energy consumed by appliances as well as lighting.

Figure 10.1 ▷ **Representation of energy efficiency by end-use sector* in the World Energy Model as considered in the Efficient World Scenario**



* In the power sector, twelve fossil fuel-based efficiency opportunities were considered. For details, see *www.worldenergyoutlook.org/weomodel/*. Note: PLDV = passenger light-duty vehicles; LCV = light commercial vehicle; ICEV = internal combustion engine vehicle; t = tonnes.

10

with a large number of companies, experts and research institutions at national and international levels. We also conducted an extensive literature search to catalogue the technologies that are now in use in different parts of the world and judge their probable evolution. The Efficient World Scenario assumes neither major or unexpected technological breakthroughs, nor more holistic concepts (such as prioritising energy efficiency at all levels of urban planning), nor changes in consumer behaviour (except where induced by lower energy prices). While such measures might well be cost-effective, measuring their cost and impact at global level is speculative, in that they represent a significant departure from current practices and, therefore, data for the quantification of their potential are limited. If adopted at scale, however, they could achieve reductions of energy demand beyond what is achieved in the Efficient World Scenario. The scenario is, rather, based on a bottom-up analysis of currently available technologies and practices, and considers incremental changes to the level of energy efficiency deployed.

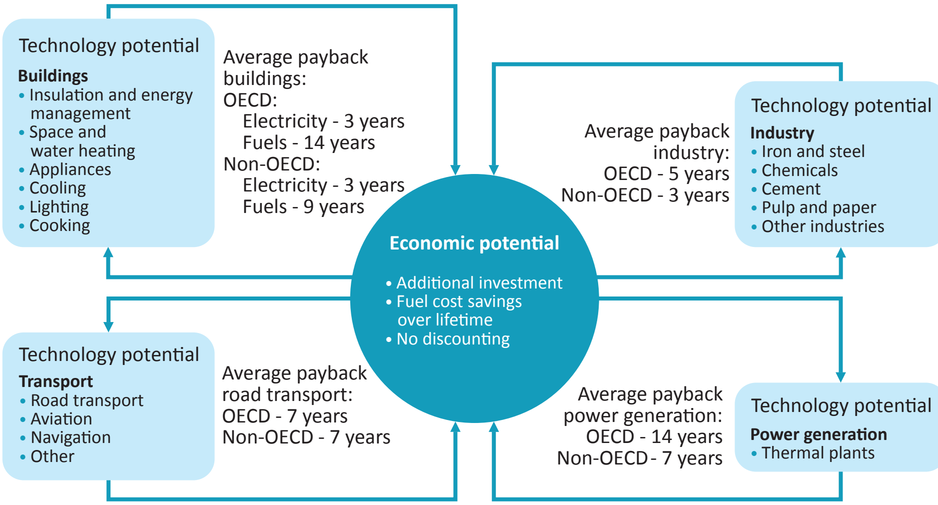
In a second step, we identified those energy efficiency measures which are economically viable. All practicable measures of what is economically viable are imperfect, not least because of data difficulties and the challenge of arriving at an acceptable average discount rate across many different communities or circumstances. The criterion we adopted was the amount of time an investor might be reasonably willing to wait to recover the cost of an energy efficiency investment (or the additional cost, where appropriate) through the value of undiscounted fuel savings (Figure 10.2).[2] Acceptable payback periods were calculated as averages over the *Outlook* period and take account of regional and sector-specific considerations. For example, the payback period adopted in relation to non-OECD industry is shorter than for the OECD, since energy efficiency investments are generally considered attractive outside the OECD only if the investments can be recovered quickly, whereas within the OECD there is more pressure on industry to demonstrate action to improve energy efficiency, so that a longer acceptable payback period is allowed.[3]

The payback periods that result are, in some cases, longer than what is required today by some lending institutions, households or firms; but they are always considerably shorter than the technical lifetime of the individual assets. The periods chosen are in line with prevailing judgements in the literature and have been deemed acceptable under the policy assumptions of the Efficient World Scenario by stakeholders who have been consulted in the course of the work.

2. Using a 5% social discount rate as a typical proxy for a societal perspective would have increased payback periods of building fuels (21 years in OECD, 12 years in non-OECD countries), power generation (22 years in OECD, 9 years in non-OECD countries) and transport (9 years). All of these payback periods are still within an acceptable limit from the perspective of asset lifetimes, but they require specific policies in some cases directed at overcoming initial deployment hurdles.

3. Payback periods can be much longer, *e.g.* in the case of the closure of small industrial facilities in China. These are, though, exceptions and have little impact on the average payback periods as there are many energy efficiency options with very short payback periods in non-OECD countries.

Figure 10.2 ▹ **Efficient World Scenario methodology**



Notes: Payback periods are specified by region and sub-sector. They refer to investment additional to the New Policies Scenario over 2012-2035, but savings are also accounted for beyond the projection period when the lifetime of the capital stock exceeds the *Outlook* period.

The payback periods adopted do not take into account the transaction costs associated with overcoming the present barriers to investment (see Chapter 9). The Efficient World Scenario is posited on the basis that these barriers will be overcome by a bundle of targeted policy measures, so eliminating or, at least, minimising, transaction costs (see end of this chapter for a discussion of such policy measures). Of course, action of this kind will entail a cost; for example, the cost of enforcement of minimum required standards. Estimating this cost is fraught with difficulties; but it can confidently be stated that it is much less than the economic benefits which will ensue (see later section on implications for the global economy).

Moreover, the payback calculation does not take into account the co-benefits to society associated with energy efficiency.[4] These benefits are reported separately in our analysis in order to leave decision makers free to assign weights to them in accordance with their national standards and priorities. The use of relatively straightforward payback periods is widespread among investors and lending institutions, and so will be a familiar methodology to those taking investment decisions in the market place today.

Policies in areas other than efficiency are assumed to be the same as in the New Policies Scenario. In the case of renewables, one consequence could be lower deployment in regions where policy targets are expressed as a share of total generation or total fuel consumption (as in the case of biofuels-blending mandates). In countries with carbon

4. Other metrics such as the global cost method, life-cycle costs analysis and benefits calculations take co-benefits into account and are also adopted in policy making, for example in the European Union.

pricing, carbon dioxide (CO_2) prices are lower than in the New Policies Scenario, as energy efficiency measures contribute to targeted emissions reductions. Fossil-fuel subsidies are phased out by 2035 at the latest in all regions except the Middle East, where they are reduced to a maximum rate of 20% by 2035.

Energy markets in the Efficient World Scenario

In the Efficient World Scenario, the implementation of energy efficiency measures in both energy transformation and consumption reduces the growth in primary energy demand significantly (Table 10.1). World primary energy demand reaches over 14 800 million tonnes of oil equivalent (Mtoe) in 2035 – a reduction of 14% relative to the New Policies Scenario (equivalent to 18% of global energy use in 2010) and 21% relative to the Current Policies Scenario.[5] Global energy demand still grows, but at an average annual rate of 0.6%, compared with 1.2% in the New Policies Scenario. The energy savings are less marked in the period to 2020, due to the relatively low capital stock turnover in the energy sector in this period, but they are far from negligible: in 2020, demand is 6% lower than in the New Policies Scenario.

Table 10.1 ▷ World primary energy demand in the Efficient World Scenario by fuel (Mtoe)

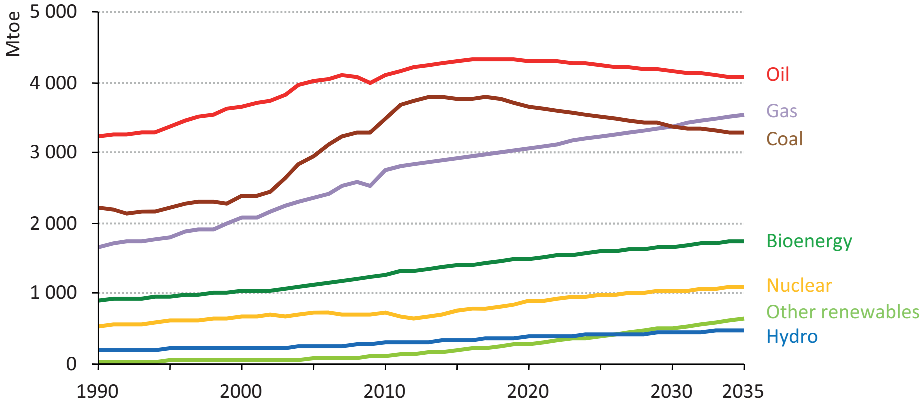
	Total primary energy demand			Change versus NPS		CAAGR*
	2010	2020	2035	2020	2035	2010-2035
Coal	3 474	3 648	3 274	-11%	-22%	-0.2%
Oil	4 113	4 311	4 061	-3%	-13%	-0.1%
Gas	2 740	3 070	3 541	-6%	-14%	1.0%
Nuclear	719	887	1 094	-1%	-4%	1.7%
Hydro	295	382	476	-2%	-3%	1.9%
Bioenergy	1 277	1 502	1 749	-2%	-7%	1.3%
Other renewables	112	293	650	-2%	-8%	7.3%
Total	**12 730**	**14 093**	**14 845**	**-6%**	**-14%**	**0.6%**

* Compound average annual growth rate. Note: NPS = New Policies Scenario.

The Efficient World Scenario sees the adoption of more efficient equipment and processes in industry, improvements in building shells, windows, insulation, lighting and appliances, the use of more efficient vehicles and aeroplanes, and improvements in efficiency in power generation and grids. The use of all fuels is affected, fossil and non-fossil, though the reduction is greatest for fossil fuels (in both absolute and relative terms), as reducing their consumption is the target of most efficiency measures. Their share of primary energy consumption falls from 81% in 2010 to 74% in 2035, as demand for both oil and coal peaks before 2020 and then declines through 2035 (Figure 10.3).

5. In the course of this chapter, the Efficient World Scenario is generally compared against the New Policies Scenario, the central scenario of this year's *Outlook*.

Figure 10.3 ▷ **World primary energy demand in the Efficient World Scenario by fuel** (Mtoe)



All of the growth in global energy demand in the Efficient World Scenario takes place in non-OECD countries. Collectively, their demand grows at an average annual rate of 1.3% between 2010 and 2035, reaching close to 9 600 Mtoe by 2035, which is 14% lower than in the New Policies Scenario. Energy demand peaks around 2015 in the OECD and then gradually declines to about 4 900 Mtoe in 2035, which is 13% lower than in the New Policies Scenario and 10% lower than in 2010. China, the United States and India, currently the world's three largest energy-consuming countries, combined account for 50% of the energy savings in 2035, compared with the New Policies Scenario. The largest reduction in energy demand in percentage terms occurs in the Middle East, where the combination of energy efficiency policies and the phase-out of fossil-fuel subsidies leads to a 19% reduction in primary energy demand in 2035, compared with the New Policies Scenario.

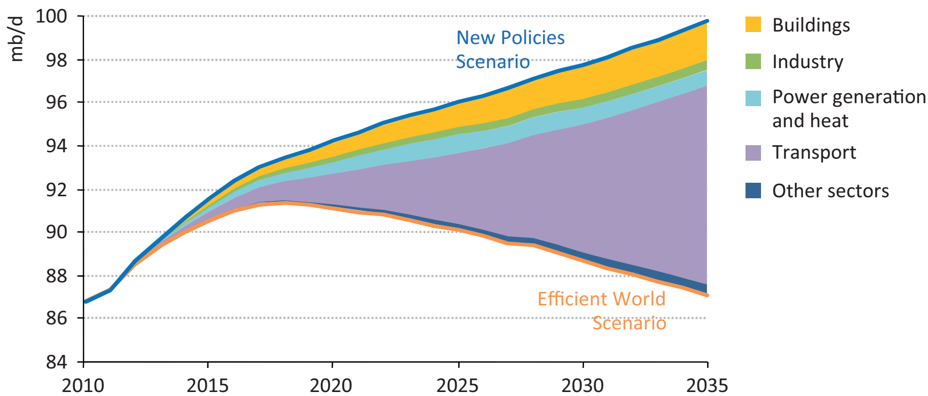
10

Trends by fuel

In the Efficient World Scenario, oil demand peaks at 91 million barrels per day (mb/d) before 2020 and then declines to 87.1 mb/d in 2035 (Figure 10.4). The reduction of 12.7 mb/d in 2035, compared with the New Policies Scenario, is comparable to the total oil production today of Russia and Norway combined. The transport sector makes the biggest contribution to this reduction, accounting for more than 60% of the cumulative savings over the *Outlook* period. This is thanks to increased efficiency across all sub-sectors and the phase-out of fossil-fuel subsidies, notably in the Middle East and Africa (see Chapter 11 for trends at the sectoral level in the Efficient World Scenario). Improved efficiency for space and water heating in the buildings sector is responsible for some 16% of cumulative oil savings, while the remainder arises through improvements in efficiency in industrial and transformation processes, as well as in power generation.

Non-OECD countries realise two-thirds (or 8.4 mb/d) of the 12.7 mb/d reduction in oil demand in 2035, compared with the New Policies Scenario. China sees the largest savings in absolute terms, with a reduction of 2.1 mb/d, followed by the Middle East (2.0 mb/d), and India (1.0 mb/d). Oil demand in OECD countries is lower by 3.4 mb/d in 2035, with the biggest reductions occurring in OECD Europe (1.3 mb/d) and the United States (1.0 mb/d). Savings in OECD countries would be much greater but for the savings already projected in the New Policies Scenario. The remaining savings are from international bunkers.

Figure 10.4 ▷ Reduction in global oil demand in the Efficient World Scenario compared with the New Policies Scenario (mb/d)



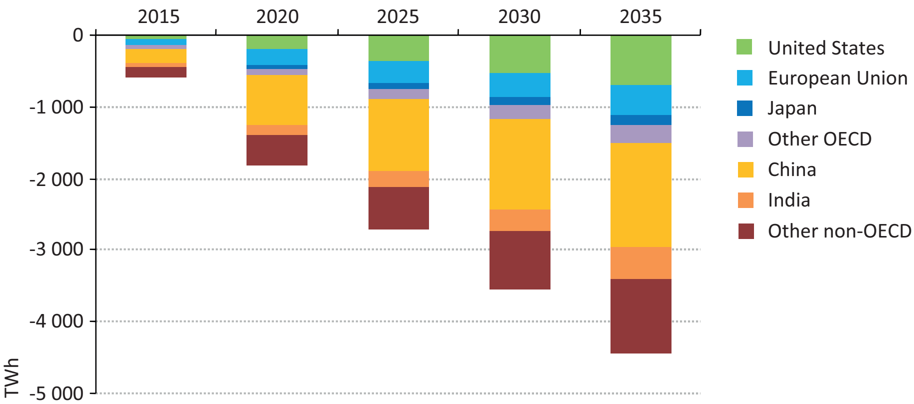
Prospects for coal and gas, currently the dominant fuels in the power sector, are closely linked to electricity demand, which increases at just 1.6% per year on average between 2010 and 2035 in the Efficient World Scenario, compared with 2.2% in the New Policies Scenario (Figure 10.5). Electricity demand growth slows in both OECD and non-OECD regions, reflecting the significant potential that currently exists worldwide to deploy more energy-efficient lighting, appliances, air-conditioning and motor systems, or to use them more intelligently through the use of automation, *i.e.* through active controls. The deployment of such equipment could significantly temper near-term demand growth, as their relatively short operating lifetimes allows for a quick replacement of existing inefficient stock, and as they can be brought into service at significant volumes quickly. This is particularly the case in developing countries, where ownership levels are still low but growing very quickly.[6]

Lower electricity demand growth diminishes the need to expand power generation capacity. Coal is the fuel that is most affected, partly because a large share of the savings arises in countries that are heavily dependent on coal for electricity generation. The faster deployment of more efficient coal-fired power plants, as well as more efficient processes in industry, further reduces coal use. Global coal demand peaks before 2020, at around 5 400 million tonnes of coal equivalent (Mtce), before dropping to about 4 700 Mtce in 2035, which is 22% lower than in the New Policies Scenario (Figure 10.6). China drives this global trend, with some 21% lower coal demand at the end of the *Outlook* period compared

6. The widespread application of technologies that could imply a countervailing trend, such as a large-scale deployment of electric vehicles, is largely beyond the policy framework adopted in the Efficient World Scenario.

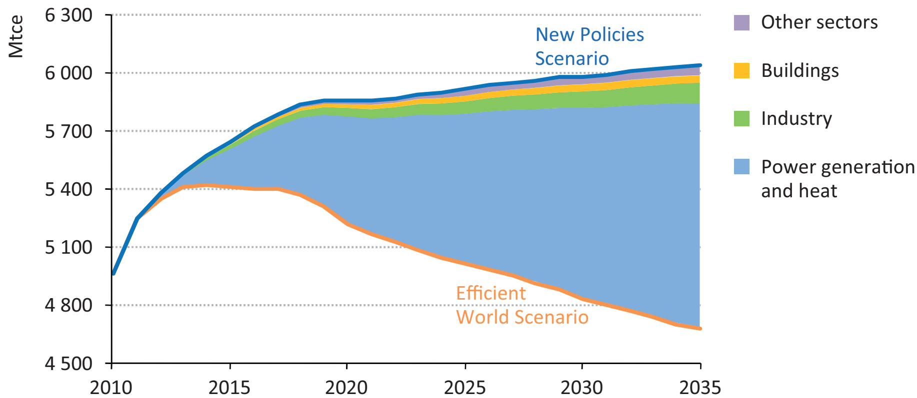
with the New Policies Scenario. Demand in India still increases throughout the period, but is 29% lower in 2035 than in the New Policies Scenario. OECD coal demand declines at an average annual rate of 2.3%, reaching 870 Mtce in 2035, or 26% lower than in the New Policies Scenario. The United States is responsible for more than 50% of the cumulative reduction in OECD coal demand, with Europe accounting for a further 33%. Global coal-fired power capacity additions are 35 gigawatts (GW) per year on average between 2012 and 2035, 23% lower than in the New Policies Scenario.

Figure 10.5 ▷ Reduction in electricity demand by region in the Efficient World Scenario compared with the New Policies Scenario



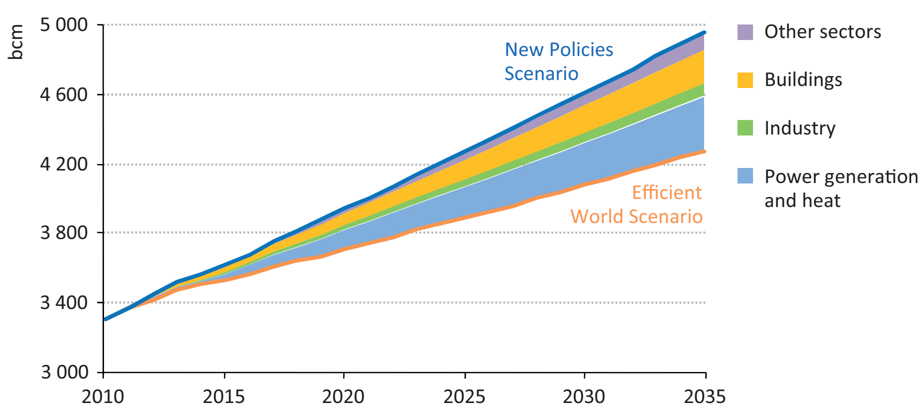
Unlike for the other fossil fuels, global demand for natural gas still increases in the Efficient World Scenario, as it remains an important fuel in the power, industry and buildings sectors. Total demand reaches 3 700 billion cubic metres (bcm) in 2020 and almost 4 300 bcm in 2035 (Figure 10.7). Nonetheless, demand is 14% (or 680 bcm) lower in 2035 than in the New Policies Scenario, which is roughly equivalent to US natural gas demand in 2010. Global demand grows at an average annual rate of 1.0%, compared with 1.6% in the New Policies Scenario, and gas overtakes coal in the early 2030s to become the second most important fuel in the energy mix after oil. Around 30% of the cumulative savings occur in the buildings sector, where gas is used much more efficiently. Gas remains an important fuel for residential space and water heating, as well as cooking. In power generation, which contributes almost 50% of cumulative savings, gas demand in 2035 is 16% lower than in the New Policies Scenario, mostly due to lower electricity demand, but also higher-efficiency plants. Average additions of gas-fired power capacity are 50 GW per year between 2012 and 2035, 13% lower than in the New Policies Scenario. Non-OECD countries account for almost 60% of the difference in global gas demand in 2035, relative to the New Policies Scenario. The Middle East sees the biggest reduction in demand, at 115 bcm, driven by reduced electricity demand and increased efficiency in the power and buildings sectors. The second-largest reduction in 2035 in non-OECD countries occurs in Russia, at 60 bcm, followed by China, at around 40 bcm. In OECD countries, the bulk of the savings arise in the buildings sector, through buildings renovation and the uptake of more energy-efficient space and water heating equipment, and in power generation.

Figure 10.6 ▷ Reduction in global coal demand in the Efficient World Scenario compared with the New Policies Scenario



The outlook for non-fossil fuels in the Efficient World Scenario is closely linked to that of electricity demand, as policy assumptions related to subsidies for renewables are unchanged from the New Policies Scenario. With global electricity demand 14% lower in 2035 in the Efficient World Scenario, as a result of demand-side efficiency measures, there is a reduction in electricity generation from other renewables (-9%), bioenergy (-9%), nuclear (-4%) and hydro (-3%). The share of all non-fossil fuels in the generation mix still increases from 33% in 2010 to 48% in 2035 in the Efficient World Scenario. Average additions of renewables and nuclear generating capacity are 129 GW per year between 2012 and 2035, 7% lower than in the New Policies Scenario, with wind power accounting for almost 40% of the reduction.

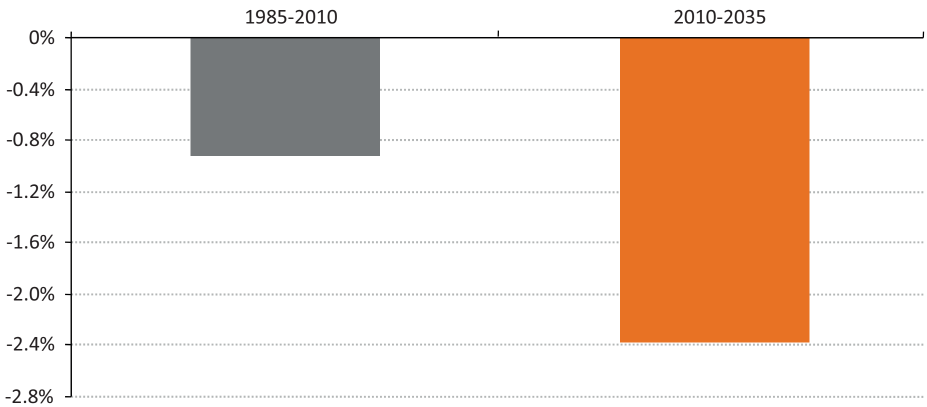
Figure 10.7 ▷ Reduction in global natural gas demand in the Efficient World Scenario compared with the New Policies Scenario



Energy intensity

Global energy intensity – the amount of energy used to produce a unit of gross domestic product (GDP) – declines at an average annual rate of 2.4% in the Efficient World Scenario over the *Outlook* period, representing a dramatic improvement on past trends (Figure 10.8). By 2035 global energy intensity is 45% lower than in 2010. In OECD countries, energy intensity falls by 2.4% per year (almost twice as much as over the past 25 years) and is 45% lower in 2035 than in 2010. The decline is led by the United States, where energy intensity falls at an average annual rate of 3.0%. Japan's energy intensity falls at a slower rate than the OECD average, as it is already among the lowest in the world and there is less scope for improvement, but it is still around 40% lower in 2035 than in 2010. In non-OECD regions, energy intensity falls at an average annual rate of 3.2%, compared with 1.7% over the last 25 years, reducing the intensity by more than half over the *Outlook* period. China is the country that changes most, with an average annual improvement of 4.2%, followed by India at 3.7% and Russia at 3.0%.

Figure 10.8 ▷ Average annual change in global energy intensity in the Efficient World Scenario



Energy prices

The policy measures that drive efficiency improvements in the Efficient World Scenario have important repercussions on energy prices, both domestically and on international markets. In real terms, the IEA crude oil import price needed to balance supply and demand reaches $116/barrel (in year-2011 dollars) in 2020 and declines to $109/barrel in 2035. The oil price in 2035 is $16/barrel lower than in the New Policies Scenario. Likewise, coal and natural gas prices are lower in the Efficient World Scenario (Table 10.2). These new equilibrium prices lead to a "rebound effect" – *i.e.* part of the savings in energy consumption that would be achieved (but only part) is offset as consumers respond to lower prices by using more energy (Box 10.2).

Table 10.2 ▹ Fossil-fuel import prices in the Efficient World Scenario (year-2011 dollars per unit)

	Unit	2011	2020	2035	Change from NPS in 2035
IEA crude oil imports	barrel	108	116	109	-13%
Natural gas					
United States	MBtu	4.1	5.4	7.7	-4%
Europe imports	MBtu	9.6	11.1	10.6	-15%
Japan imports	MBtu	14.8	13.8	13.0	-12%
OECD steam coal imports	tonne	123	106	100	-13%

Note: NPS = New Policies Scenario; MBtu = million British thermal units.

Energy trade

The introduction of more efficient capital stock in energy production and consumption has implications for energy bills and trade. Energy-importing countries import less oil, natural gas and coal, compared with the New Policies Scenario. However, certain importing countries that are also producers experience a lower reduction in import needs in absolute terms than their demand savings. This is because lower international prices alter supply too, cutting production disproportionately in regions with higher production costs.

Although oil demand peaks and then declines in the Efficient World Scenario, oil trade (between *WEO* regions) still increases by 5% over the level of 2011, due to a mismatch of the locations of demand and supply. The growth in international trade is, nevertheless, about three-quarters lower than in the New Policies Scenario. Oil imports in OECD countries drop sharply over the *Outlook* period, but they continue to rise in other oil-importing regions. Imports in developing Asia rise from 10.6 mb/d in 2011 to 22.0 mb/d in 2035, a reduction of 3.5 mb/d, compared with the New Policies Scenario. Energy efficiency policies in China and India, mostly directed at their fast-expanding car and truck fleets, reduce imports by 2.0 mb/d and 1.0 mb/d respectively in 2035, compared with the New Policies Scenario. Between OECD regions, Europe sees the biggest savings in 2035, compared with the New Policies Scenario. Imports into the European Union drop from 9.8 mb/d in 2011 to 7.0 mb/d in 2035, a reduction of 1.1 mb/d in 2035, compared with the New Policies Scenario. All other OECD importing countries also see big drops in their oil-import requirements, compared with 2011 levels. US imports in 2035 are 0.5 mb/d (or 14%) lower than in the New Policies Scenario, as the additional reduction in US demand that takes place in the Efficient World Scenario is partly offset by lower domestic oil production, due to lower international oil prices. The United States is already projected to cut its oil demand significantly in the New Policies Scenario, due to recent changes in policy, thereby limiting the scope for further reductions in the Efficient World Scenario (Chapter 3).

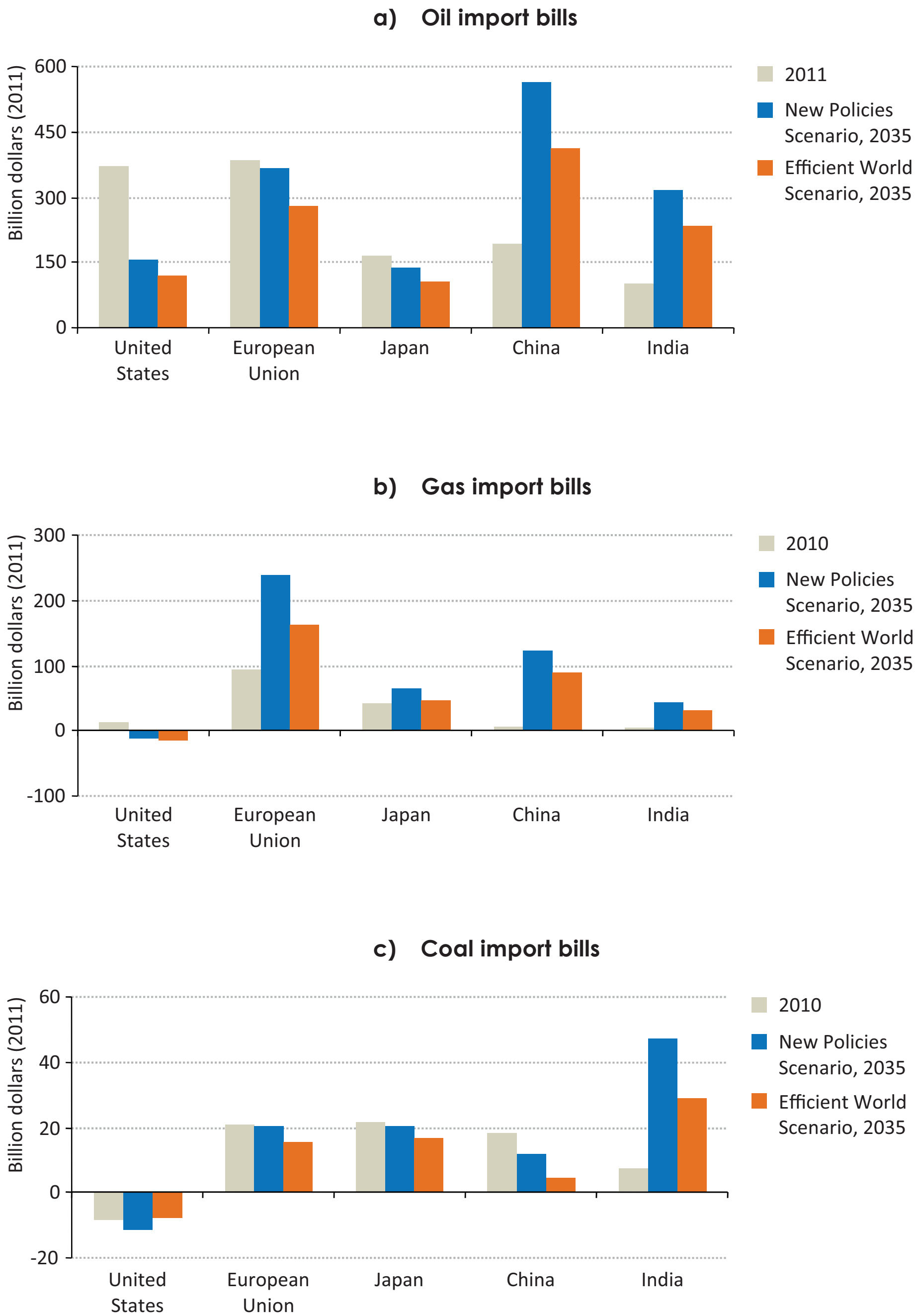
Natural gas trade (between *WEO* regions) grows substantially over the projection period, from 675 bcm in 2010 to almost 990 bcm in 2035, but this is a reduction of almost 20% compared with the New Policies Scenario. EU imports grow from 335 bcm in 2010 to about 420 bcm in 2035, a reduction of over 100 bcm, compared with the New Policies Scenario. Japan's imports remain at close to the levels of 2010, compared with an increase of more than 20% in the New Policies Scenario. Import requirements in China and India grow over time, but at a slower pace. On the supply side, exports from Russia and the Middle East are reduced significantly, compared with the New Policies Scenario.

Trade in hard coal (coking and steam coal) between *WEO* regions mirrors the demand trends, peaking soon after 2015, at around 970 Mtce, and declining slightly thereafter. India, the largest importer of coal in 2035, remains a net importer throughout the *Outlook* period, but imports are cut by almost one-third in 2035, compared with the New Policies Scenario. By 2035, Japan and the European Union also see their imports of coal reduced, reaching a level of around 120 Mtce (26% lower than in 2010) and almost 110 Mtce (31% lower than in 2010) respectively. China, which is expected to become the world's largest coal importing country in 2012, also imports much less. Exports from Indonesia and Australia are significantly curtailed relative to the New Policies Scenario, due to the lower demand in the Asia-Pacific region. In the United States, production is reduced, in response to lower prices and lower domestic demand. It remains a net exporter, though the level is about 20% lower in 2035 than in the New Policies Scenario.

As a result of reduced import needs and lower international fossil fuel prices, importing countries see their spending on energy imports reduced significantly. The energy efficiency measures implemented cut aggregate oil, gas and coal import bills in 2035 for the major importing regions by almost $570 billion, compared with the New Policies Scenario (Figure 10.9). Almost 70% of these savings accrue from lower oil import bills. The United States, the European Union and Japan all spend less on oil imports in 2035 than today and less than projected in the New Policies Scenario. Spending by China and India increases, compared with current levels, but remains significantly lower than in the New Policies Scenario. The oil-import bills of the five largest importers are cut by 25%. Spending on natural gas imports increases over current levels in all major importing countries, with the exception of Japan.

Oil and gas revenues earned by producers in the Middle East increase to $930 billion in 2035. Although this represents a 26% reduction on their revenues compared with the New Policies Scenario, there are other offsetting economic benefits, as the assumed partial phase-out of fossil fuel subsidies slows the increase in domestic energy consumption, thereby increasing the availability of oil and gas for export over the longer term, to earn vital state revenue streams (Spotlight).

Figure 10.9 ⊳ Fuel import bills in selected countries by fuel and scenario



Note: Negative numbers refer to export revenues.

SPOTLIGHT

Will improved energy efficiency be good for the oil-exporting countries?

Historically, energy efficiency has not been a focus of attention in many of the oil-rich countries in the Middle East: unlike all the other regions in the world, energy intensity in the Middle East has actually increased since the 1980s (see Chapter 9). But the attention of policy makers in the region is increasingly shifting towards more efficient uses of energy, in particular in Gulf countries. Saudi Arabia established an energy efficiency centre in 2012, while the United Arab Emirates has launched a national energy efficiency and conservation programme, with the aim of improving efficiency in buildings.

A number of factors have led to this shift in policy focus: around 70% of electricity consumption in most Gulf states comes from the use of air-conditioning and ventilation devices, boosting peak electricity demand and affecting network stability. Significant losses in transmission and distribution networks often add to the problem, while the use of fuel oil and the direct combustion of crude oil for generating electricity have led to the region having an extremely low average power plant efficiency of 33%, much lower than typical thermal efficiencies in OECD countries. In the transport sector, a key area of concern is the much higher average fuel consumption of passenger cars, which is around 70% higher than the OECD average. The consequences of this low efficiency in domestic energy use are sharp domestic demand growth in the short term and reduced availability of oil for export in the longer term (Chapter 3, Box 3.1).

The main barrier to the adoption of more energy-efficient technologies in the Middle East lies in the subsidies to fossil fuels and electricity, which undermine the economic incentive for consumers to invest in energy-efficient technologies and encourage wasteful consumption. For example, due to extremely low petrol prices in Saudi Arabia, the payback period for a car which consumes half the petrol per 100 kilometres than the average car today is close to 20 years (compared with five years in the United States or seven years in China). This is far too long to incentivise any such investment. Similarly, subsidised electricity prices decrease the individual's incentive to consider more efficient air-conditioning and encourages wasteful use.

If the Middle East makes additional investments in energy efficiency of about $500 billion, compared with the New Policies Scenario, the reduction of domestic demand achieved increases the scope for Middle East countries to export. In 2035, an additional 2 mb/d of oil and 115 bcm of gas could be exported with cumulative revenues of $1.6 trillion over the *Outlook* period, if global demand was the same as in the New Policies Scenario.

Investment and fuel savings[7]

In the Efficient World Scenario, the implementation of policies to overcome barriers to the deployment of energy efficiency drives a steady stream of additional energy efficiency investments in the end-use sectors, compared with the New Policies Scenario. In the case of buildings, these additional investments rise from around $165 billion (in year-2011 dollars) in 2020 to more than $330 billion in 2035, amounting to a cumulative addition of $4.6 trillion over the *Outlook* period. However, this is more than offset by total fuel bill savings of $7.6 trillion over the same period (Table 10.3). The cumulative additional investments in industry reach $1.1 trillion by 2035, giving rise to $3.3 trillion in energy bill savings over the same time frame. For transport (excluding international bunkers), additional annual investment rises from about $90 billion in 2020 to around $575 billion in 2035, making a cumulative total of $4.8 trillion.[8] Once again, this investment is more than outweighed by global fuel cost savings, in this case of $5.7 trillion over the period to 2035, compared with the New Policies Scenario. The lifetime of the capital stock extends beyond the projection period in all sectors, so additional fuel cost savings accrue post 2035.

Table 10.3 ▷ Investment in energy efficiency, energy savings and fuel cost savings by end-use sector in the Efficient World Scenario compared with the New Policies Scenario, 2012-2035

	OECD			Non-OECD		
	Additional investment ($ trillion)	Energy savings (Mtoe)	Fuel cost savings ($ trillion)	Additional investment ($ trillion)	Energy savings (Mtoe)	Fuel cost savings ($ trillion)
Industry	0.4	668	1.2	0.7	3 482	2.2
Transport	1.6	1 121	3.0	3.2	2 731	2.7
Buildings	3.2	3 478	5.9	1.4	3 704	1.7
Total	**5.3**	**5 267**	**10.0**	**5.2**	**9 917**	**6.6**

Note: Early retirement of industrial facilities before the end of the technical lifetime by five years is assumed in the Efficient World Scenario and is included in the investment figures.

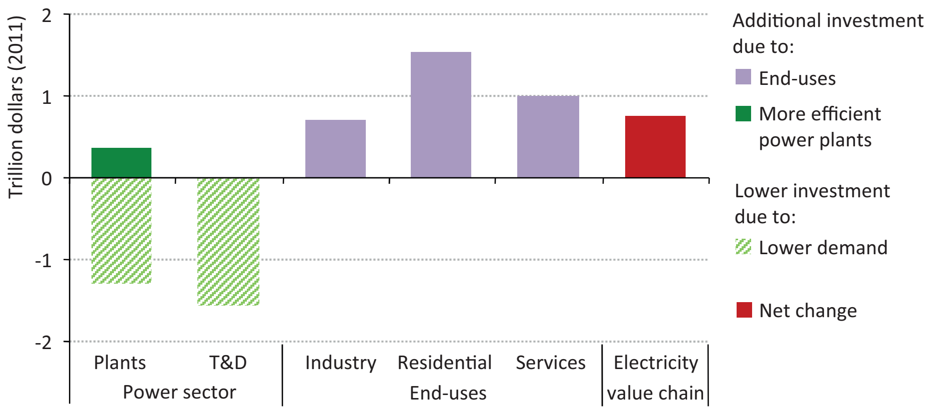
Global primary energy demand in the Efficient World Scenario is a cumulative 28 000 Mtoe lower than in the New Policies Scenario between 2010 and 2035, and electricity demand falls by a cumulative 56 000 terawatt-hours (TWh), or 8%. This reduces the need for investment in energy supply infrastructure along the entire value chain (Figure 10.10). Investment in energy supply in the Efficient World Scenario, including coal, oil and gas extraction and transportation, biofuels production and electricity generation, transmission and distribution (T&D), drops by a cumulative total of $5.9 trillion from 2012 to 2035, or 16%, compared with the New Policies Scenario. This sum offsets half of the additional investment on the demand side. Investment in the supply of fossil fuels falls by $3.4 trillion

7. Detailed analysis of the Efficient World Scenario at the sectoral level is presented in Chapter 11.

8. Additional investment occurs in international aviation and marine bunkers and amounts to an additional $1.3 trillion.

and investment in the power sector by $2.5 trillion across the whole electricity supply value chain, as average annual capacity additions are 28 GW lower than in the New Policies Scenario. This reduces cumulative investment requirements in new power generation capacity by $1.3 trillion, compared with the New Policies Scenario, and more than offsets the additional cumulative investment of $350 billion required for more efficient power plants. Investment in T&D in the power sector is reduced by $1.6 trillion, due to lower electricity demand and reduced losses.

Figure 10.10 ▹ Change in investment across the electricity value chain in the Efficient World Scenario, compared with the New Policies Scenario, 2012-2035



Implications for the global economy

Achieving the Efficient World Scenario would give a boost to the global economy of $18 trillion over the *Outlook* period, with a 0.4% higher global GDP in 2035 than in the New Policies Scenario (Box 10.1). This reflects a gradual reorientation of the global economy, as the production and consumption of less energy-intensive goods and services frees up resources to be allocated more efficiently. The reduction in energy use and the resulting savings in energy expenditures increase disposable income and encourage additional spending elsewhere in the economy.

While the global economy benefits overall, the impact differs across countries (Figure 10.11). In OECD countries, household consumption tends to account for a large share of GDP and means that the policies of the Efficient World Scenario are seen most clearly in increased household demand for more energy efficient goods and services. In 2035, the economy of the United States is 1.7% larger in the Efficient World Scenario, with $450 billion more economic output, most of it in the form of services. Europe's GDP is more than 1% larger, and, in addition to services, Europe sees a notable increase in domestic production and purchase of more energy-efficient road vehicles.

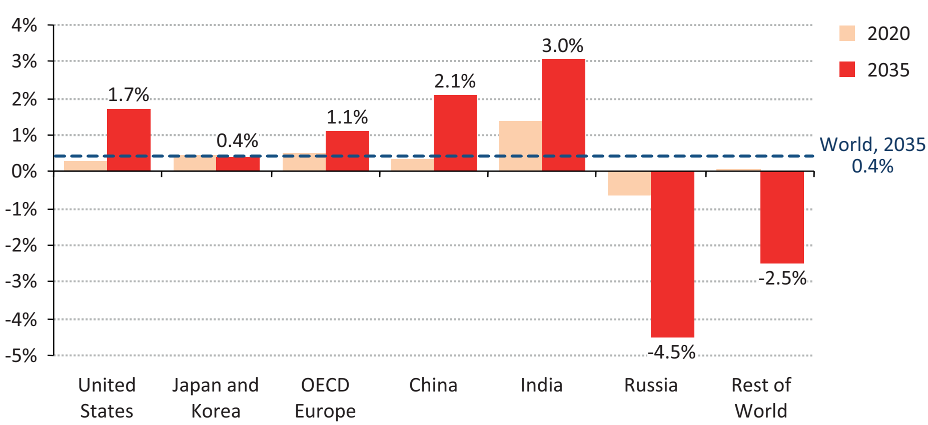
Box 10.1 ▻ Assessing the impact of the Efficient World Scenario on global economic growth

As well as the direct impact of energy efficiency policies on energy demand and energy-related investment, it is important to assess their broader impact on the global economy. Our analysis seeks to do this by linking the IEA's World Energy Model (WEM), a partial equilibrium model designed to replicate how energy markets function, to the OECD ENV-Linkages general equilibrium model, an economic model that describes how economic activities are linked to each other across sectors and regions (OECD, 2008). Specifically, the ENV-Linkages model was calibrated using the outputs of the WEM for energy demand, investment in energy consuming and producing equipment and fuel savings (OECD, 2012).

Our analysis shows that the economic impact of the Efficient World Scenario would feed through a number of channels. In general, the policies included in the Efficient World Scenario would encourage firms and households to shift their spending patterns towards more energy-efficient capital goods, which, in turn, reduces their expenditure on energy consumption. This change in the balance of spending, and therefore supply and demand, has a cascade effect on the relative price of all goods and factors of production in the economy.

Firms producing less energy-intensive goods and services are faced with increased demand and react by trying to maximise profits. By contrast, demand for more energy-intensive goods and services declines. At a household level, the move towards less energy-intensive goods and services results in a reduction in energy expenditure, which boosts disposable income and increases spending elsewhere. In addition, trade flows between countries respond to changes in relative prices between regions. For instance, if steel becomes relatively cheaper to produce in China because of increased energy efficiency, Chinese firms gain market share.

Figure 10.11 ▻ Change in real GDP in the Efficient World Scenario compared with the New Policies Scenario



In many non-OECD countries, investment and exports play a larger role in the economy, relative to household consumption. This means that, in addition to the shift toward consumption of domestically produced goods and services, there is a more significant impact observed in manufacturing, construction and energy-intensive industries. India and China receive the largest relative and absolute boost in the Efficient World Scenario, with their economies being 3% and 2.1% larger respectively. In contrast to most other countries, the economies of the largest oil and gas exporters, such as Russia, experience lower levels of economic growth, mainly as a result of lower growth in oil and gas export revenues (due to reduced demand and prices).

The services sector ($700 billion) and transport services sector ($320 billion) experience the largest net growth of value-added in the Efficient World Scenario in 2035 (Figure 10.12), relative to the New Policies Scenario. Service-related sectors experience particularly strong growth in nearly all countries, especially the United States and European countries. The transport sector, which includes freight and public transportation, sees particularly strong growth in Europe driven, in part, by the enforcement of stringent fuel-economy standards and the rapid uptake of energy-efficient vehicles. Manufacturing grows more than in the New Policies Scenario in most countries and is focused on more energy efficient products, such as more efficient cars and electrical appliances. Overall, the construction sector sees slightly increased activity in the Efficient World Scenario, as inefficient buildings are refurbished and new buildings are required to comply with stringent energy efficiency standards. Globally, energy-intensive industries experience sizeable interregional reallocations of production but the net effect on the value-added is virtually zero. The chemical industry in the United States and the iron, steel and cement sectors in China gain most market shares.

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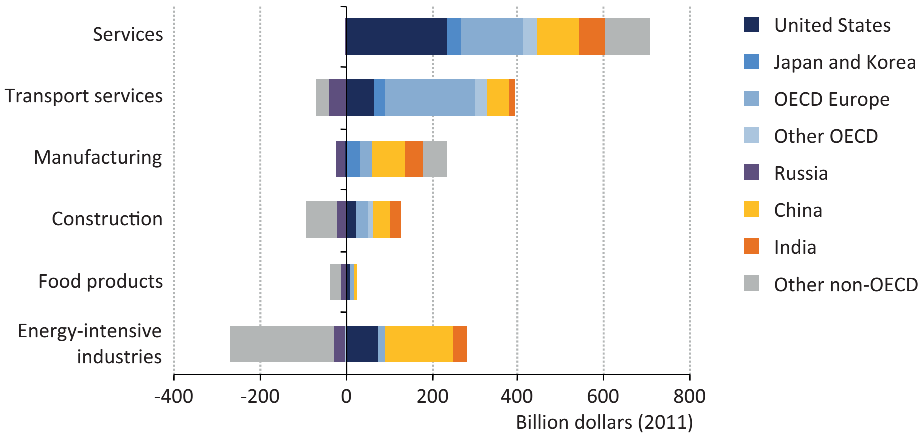
Figure 10.12 ▻ Changes in value-added by sector and region in the Efficient World Scenario compared with the New Policies Scenario in 2035



Note: In the OECD ENV-Linkages model, the manufacturing sector includes the manufacture of electronic devices and machinery, motor vehicles and trailers, transport equipment and clothing products.

While the global economy is larger in 2035, global trade is actually more than 2% lower in the Efficient World Scenario, equivalent to $0.5 trillion in goods and services (Figure 10.13). This stems from a move to less energy-intensive goods and services, which implies that a greater proportion of all goods and services are being produced and consumed domestically. Indeed, service-related sectors in OECD countries are strongly stimulated by the Efficient World Policy and capture two-thirds of additional investments. Additionally, fewer cargoes of heavily traded commodities and energy-intensive goods are transported around the world. As a result, many regions, such as Europe, China and India, improve their trade balance.

Box 10.2 ▹ How large is the rebound effect?

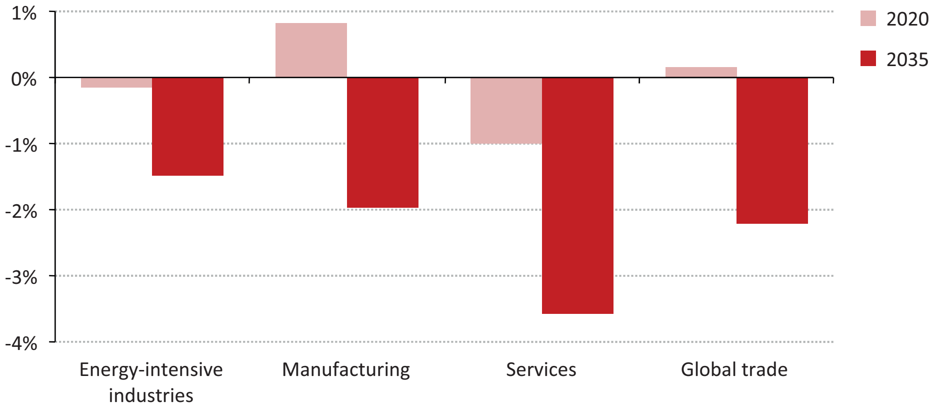
Increased energy efficiency does not always deliver the full energy savings predicted by engineering analysis. The undesirable side-effects are commonly referred to as the "rebound effect".

Where does the rebound effect originate? Increased efficiency of a product or facility, saving operating costs, may lead to increased use, such as when the owner of a more efficient car starts driving it more often. This is usually referred to as a direct rebound effect. An indirect effect also occurs, as a result of the increase of disposable income due to reduced energy expenditures by households and firms, which may lead to spending the available money on other energy-consuming products. This pushes up energy demand, particularly in developing countries (Bergh, 2011). Lower energy prices as a result of lower energy demand have a similar effect.

How significant is the rebound effect? Despite increased attention to the problem and extensive academic debate, large uncertainties remain about the actual size of the rebound effect and its various components (Sorrell, 2007). More recently, even the definition and methodology of calculating the rebound effect has come under scrutiny (Turner, 2012). Since the rebound effect is related to income levels and to the degree of energy service saturation in a particular country, every assessment is usually country-specific. Generalising, it can be said that, depending on the country or the consumption sector at stake, the direct rebound effect is generally small, ranging from 0-10% (see Nadel, 2012 for a discussion of the case of the United States). Estimates of the indirect rebound effect range from small to very large, with some studies suggesting 100% or more. Those figures are highly controversial.

Our estimate of the overall rebound effect is 9% of the savings that are achieved in the Efficient World Scenario, compared with the New Policies Scenario. A significant portion of this could be avoided by appropriate pricing policy. Keeping end-user prices at the same level as in the New Policies Scenario, for example, would reduce the rebound effect by more than 50%.

Figure 10.13 ▷ **Change in global trade flows for selected sectors in the Efficient World Scenario compared with the New Policies Scenario in 2035**



Source: IEA-OECD analysis using OECD ENV-Linkages model.

Environmental implications

Energy-related CO_2 emissions

Energy-related CO_2 emissions in the Efficient World Scenario peak before 2020, at 32.4 gigatonnes (Gt), and decline steadily from then on, to 30.5 Gt in 2035. Due to the faster deployment of energy-efficient technologies, emissions in 2035 are 6.5 Gt lower than in the New Policies Scenario (Figure 10.14). Energy efficiency, including end-use efficiency, electricity savings and efficiency gains in power plants, is responsible for 95% of the reduction in CO_2 emissions in the Efficient World Scenario, compared with the New Policies Scenario in 2035. The remainder comes from technology and fuel switching in the end-use sectors, mainly higher use of natural gas and heat pumps.

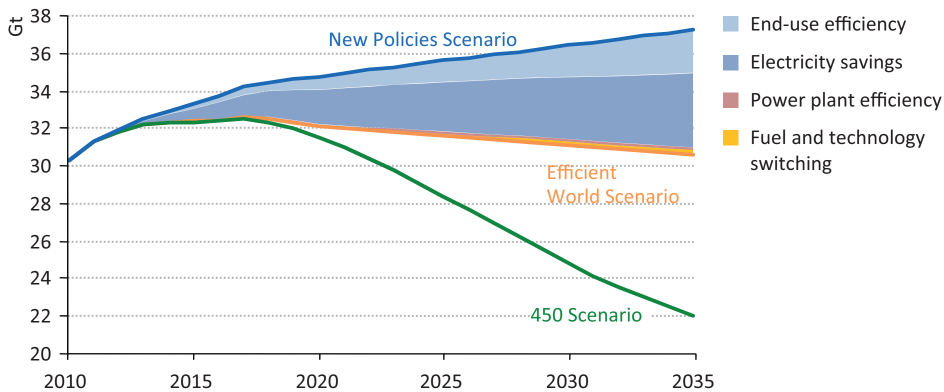
The reduction due to energy efficiency can be separated into direct and indirect savings. Direct emission savings arise from the use of less fossil fuel for the same unit of energy service provided. The transport sector is responsible for 45% of the cumulative energy efficiency-related direct CO_2 savings, followed by industry with 30%, buildings with 17% and the power sector with 7%.

Indirect emissions savings from energy efficiency arise from avoided emissions in power generation due to lower electricity and heat demand in the end-use sectors. These savings result from reduced demand in the buildings sector and in the industry sector.[9] Appliances account for roughly 40% of the electricity savings in residential buildings, with lighting and space heating contributing additional savings in OECD countries and space cooling in

9. In the New Policies Scenario, electricity contributes less than 2% to energy demand in the global transport sector in 2035. Hence, the potential for indirect emission savings in this sector is very small.

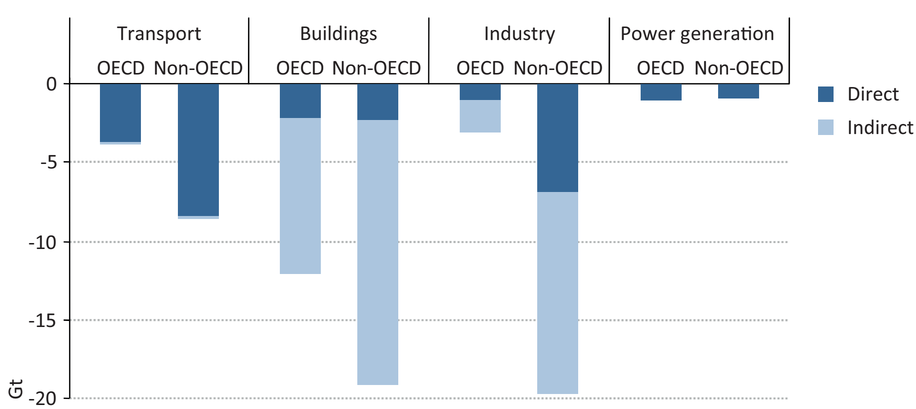
non-OECD countries. A key factor in reducing electricity-related emissions in industry is the deployment of more efficient motor systems (see Chapter 11).

Figure 10.14 ▷ Energy-related CO_2 emissions by scenario and abatement measures



Indirect savings account for more than 60% of the total CO_2 emissions savings from energy efficiency achieved in the Efficient World Scenario, relative to the New Policies Scenario (Figure 10.15). Non-OECD countries are responsible for almost three-quarters of indirect savings as a result of their more carbon-intensive electricity generation on the one hand, with a higher share of fossil fuels and lower average efficiency levels. On the other hand, the potential to improve the efficiency of the use of electricity is higher in non-OECD countries, in particular in industry, as their average efficiency levels are comparatively low at present and as they represent the bulk of the growth in energy demand.

Figure 10.15 ▷ Cumulative efficiency-related CO_2 emissions savings in the Efficient World Scenario relative to New Policies Scenario by sector and region



The Efficient World Scenario puts CO_2 emissions on a long-term trajectory consistent with stabilising the atmospheric concentration of greenhouse-gas emissions at around 550 parts per million. This trajectory is consistent with a 50% probability of staying below a 3 degrees Celsius (°C) temperature increase above pre-industrial levels in the long term, compared with 3.6 °C in the New Policies Scenario. This emphasises that, while energy efficiency is an indispensable element of any decarbonisation pathway, additional measures would be needed to achieve the international goal of limiting the temperature increase to 2 °C. Compared with the 450 Scenario, energy-related CO_2 emissions are 8.5 Gt higher in 2035, despite a similar level of energy consumption (see Chapter 8 for a discussion of the implications of the Efficient World Scenario on the level of emissions locked-in over time).

Local pollution

More than two million people die each year from indoor and outdoor air pollution (WHO, 2011). The rapid deployment of energy-efficient technologies that is assumed in the Efficient World Scenario would not only reduce energy consumption and CO_2 emissions, but could also save thousands of lives every year. China and India are responsible for almost half of global sulphur dioxide (SO_2) emissions, the main source of acid rain. In China, SO_2 emissions decreased over the last decade because of the installation of desulphurisation units on power plants, while India's emissions increased, in the absence of strict emission limits. In the Efficient World Scenario, China reduces its SO_2 emissions by 37% over the *Outlook* period, which results in SO_2 emissions being 12% lower in 2035 compared with the New Policies Scenario. In India, annual growth in SO_2 emissions slows from 2.6% in the New Policies Scenario to 1.4% in the Efficient World Scenario. On a wider level, SO_2 emissions are reduced by slightly more than 11% in OECD countries and almost 15% in non-OECD countries in 2035 in the Efficient World Scenario, compared with the New Policies Scenario, thanks to higher efficiency levels in power generation and industry (Table 10.4).

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The largest sources of nitrogen oxides (NO_x) emissions are road transport and power generation, even though there have been major reductions in NO_x emissions from road transport in OECD countries over the past few years. NO_x emissions and particulate matter ($PM_{2.5}$) are the primary causes of smog in urban areas and can significantly damage the human respiratory system. While NO_x emissions are reduced over the *Outlook* period in the New Policies Scenario, in the Efficient World Scenario they are cut by a further 13% in 2035 in the OECD and 16% in non-OECD regions respectively, due to air pollution controls in vehicles and more efficient processes in power generation and industry. $PM_{2.5}$ emissions cause a range of health problems, including asthma and lung cancer, and are responsible for a significant number of premature deaths. Burning of traditional biomass and industrial processes cause the majority of $PM_{2.5}$ emissions in developing countries. Such emissions are reduced in the Efficient World Scenario through partial replacement of traditional biomass by more efficient cooking equipment. Compared with the New Policies Scenario, the largest reduction in $PM_{2.5}$ emissions in absolute terms is achieved in China and India, which are responsible for two-thirds of the global reduction in $PM_{2.5}$ emissions by 2035.

Table 10.4 ▷ Air pollution by region and sector (million tonnes)

	2005	2010	Efficient World Scenario 2020	Efficient World Scenario 2035	Change in EWS vs NPS 2020	Change in EWS vs NPS 2035
Sulphur dioxide (SO_2)						
OECD countries	**29.2**	**18.5**	**12.8**	**10.3**	**-5.4%**	**-11.3%**
Power generation	18.2	9.4	4.3	2.2	-11.6%	-30.5%
Buildings	1.4	1.2	0.9	0.7	-9.3%	-18.1%
Industry*	8.6	7.5	7.2	7.2	-0.9%	-2.1%
Road transport	0.3	0.1	0.0	0.0	-2.0%	-13.8%
Other**	0.8	0.5	0.4	0.2	-2.5%	-10.6%
Non-OECD countries	**68.1**	**67.7**	**56.9**	**51.8**	**-7.6%**	**-14.9%**
Power generation	38.0	33.5	24.0	18.8	-13.5%	-26.3%
Buildings	4.4	4.7	4.5	3.4	-6.1%	-16.3%
Industry*	23.6	28.0	26.9	28.0	-2.3%	-4.8%
Road transport	0.9	0.4	0.3	0.4	-1.7%	-14.9%
Other**	1.2	1.1	1.2	1.1	-3.5%	-12.5%
Nitrogen oxides (NO_x)						
OECD countries	**38.4**	**29.5**	**18.7**	**13.9**	**-4.6%**	**-12.7%**
Power generation	9.8	7.2	4.3	3.0	-9.4%	-21.3%
Buildings	2.0	1.9	1.8	1.6	-8.0%	-20.1%
Industry*	5.4	5.0	5.1	5.1	-1.5%	-3.4%
Road transport	15.0	10.3	3.7	1.7	-2.3%	-13.2%
Other mobile sources	6.1	4.9	3.7	2.4	-3.9%	-13.6%
Other**	0.1	0.1	0.1	0.1	0.0%	0.0%
Non-OECD countries	**48.9**	**55.2**	**54.7**	**56.0**	**-5.9%**	**-15.8%**
Power generation	12.7	14.8	14.3	13.8	-13.2%	-24.5%
Buildings	3.0	3.2	3.3	3.1	-3.4%	-8.9%
Industry*	9.8	12.4	13.6	14.5	-2.2%	-4.7%
Road transport	14.5	15.0	13.2	13.4	-3.6%	-19.6%
Other mobile sources	8.5	9.3	9.8	10.7	-3.2%	-14.0%
Other**	0.6	0.5	0.6	0.6	0.0%	0.0%
Particulate matter ($PM_{2.5}$)						
OECD countries	**4.5**	**4.2**	**3.8**	**3.6**	**-3.2%**	**-6.0%**
Power generation	0.3	0.2	0.2	0.1	-12.5%	-30.7%
Buildings	1.3	1.3	1.3	1.3	-6.3%	-9.7%
Industry*	0.9	0.8	0.8	0.9	-0.3%	-0.7%
Road transport	0.6	0.4	0.2	0.2	-2.1%	-12.8%
Other mobile sources	0.4	0.4	0.2	0.2	-3.8%	-12.8%
Other**	1.0	1.0	1.1	1.1	0.0%	0.0%
Non-OECD countries	**36.2**	**38.6**	**37.5**	**35.3**	**-2.2%**	**-5.6%**
Power generation	2.0	2.3	2.5	2.3	-14.8%	-27.4%
Buildings	16.1	17.1	16.8	14.7	-1.7%	-5.0%
Industry*	11.1	12.2	11.2	10.8	-0.5%	-1.2%
Road transport	1.0	0.9	0.6	0.7	-3.4%	-18.9%
Other mobile sources	0.7	0.8	0.8	0.9	-3.4%	-14.5%
Other**	5.2	5.4	5.7	5.9	0.0%	0.0%

* Includes industrial processes. ** Other includes waste management, agriculture, other mobile sources (if not separately shown) and fuel extraction. Note: NPS = New Policies Scenario; EWS = Efficient World Scenario.

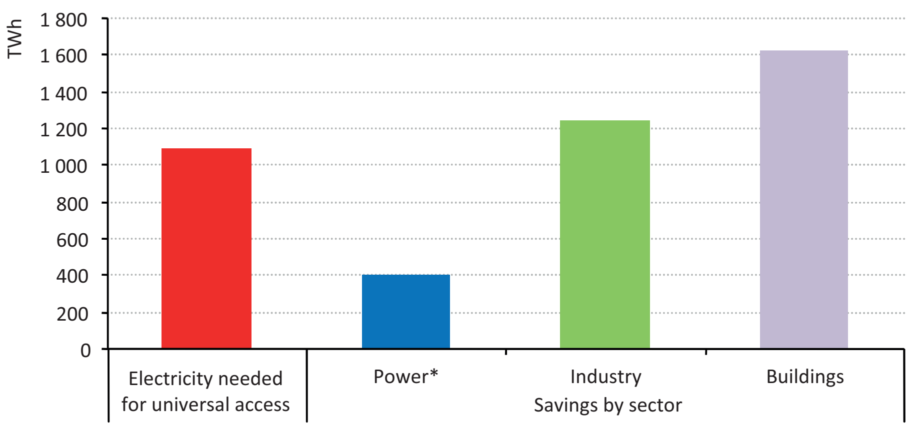
Source: IIASA (2012).

The role of energy efficiency in increasing energy access

Access to adequate energy services is fundamental to pulling communities out of poverty, as it is a vital input for social and economic development. Currently 1.3 billion people do not have access to electricity worldwide and 2.6 billion people rely on biomass as their primary source of fuel for cooking. Despite the action being undertaken, such as the efforts recently announced under the umbrella of the UN Sustainable Energy for All initiative, these numbers are not reduced significantly by 2035 in the *Outlook* (see Chapter 18).

Countries with low levels of access to modern energy services rarely concentrate on energy efficiency, as they face other, more pressing, challenges. Energy efficiency policies also demand a high level of sophisticated co-ordination between government agencies, which is difficult to achieve even in OECD countries. Governments with limited energy resources often first look to improve the efficiency of the supply side, in order to extend their capacity to provide energy to households. The next step is often to address technical losses in generation and distribution systems and then to seek to cut demand in end-uses, in order to free up additional resources for use by others. By improving energy affordability, energy efficiency can make it easier for lower income households to pay energy bills, freeing up funds for other priorities.

Figure 10.16 ▷ Additional electricity needed to achieve energy for all in India compared with savings in the Efficient World Scenario, 2011-2030



*Efficiency improvements in fossil-fuel power plants and system grids.

A number of developing countries have already identified the important role that energy efficiency can play in improving energy access. India, for example, announced the National Mission for Enhanced Energy Efficiency, which identifies increased electricity access and improved reliability as important co-benefits of improved efficiency. Our analysis shows that in certain countries, including India, the energy saved in the Efficient World Scenario is more than enough to provide the additional electricity needed over the level of the New

Policies Scenario to serve basic energy needs of the entire population by 2030.[10] Although, the challenges associated with grid extension and the development of off-grid solutions would also need to be met (Figure 10.16). In other cases, while the savings are not by themselves sufficient to satisfy the basic needs universally, they could enable electrification programmes to expand at a much faster rate by freeing up financial resources to be devoted to this purpose.

Building the Efficient World Scenario: a blueprint for savings

The discussion on barriers to energy efficiency in Chapter 9 makes it plain: the energy savings identified in the Efficient World Scenario will not happen if market actors are left to their own devices. To seize the opportunity, the Efficient World Scenario rests on the foundation of a raft of concrete, forceful and complementary policy measures taken to overcome these barriers. These stimulate private and public sector actions that generate the energy savings and co-benefits of the Efficient World Scenario. As the nature of the barriers to energy efficiency are manifold and divergent, depending on the circumstances of the end-use and economy considered, a portfolio of measures is needed. But, whatever the specifics of the sector or economy being addressed, certain key principles need to be adhered to. Implementation of the Efficient World Scenario envisages the prior adoption of policy measures in line with the public policy framework, or blueprint, which follows. While much can be achieved by individual countries or regions, full realisation of the benefits of the blueprint is likely to depend on a formal global commitment, to raise energy efficiency and report results regularly, using mutually agreed verification mechanisms.

Make it visible

The energy performance of each energy end-use and service needs to be made visible to the market. Under the Efficient World Scenario, it is envisaged that governments take the lead, in partnership with private sector agents, to ensure that the energy performance of all major energy services and end-uses is measured and reported to consumers, clients and statistical authorities in a consistent, accessible, timely and reliable manner. Governments need to frame the market for energy services in this manner so as to ensure that energy efficiency options can compete on a level playing field with energy supply options. A key element of this is to ensure that the relative energy efficiency of different products and services is visible in the market place. Policy makers need to ensure that, beyond the basic measurement of consumption per unit of output, common, agreed measurement test procedures and/or protocols are developed to measure energy efficiency. They need to ensure also that the resulting information is routinely available, in a readily comprehensible form, to all those considering the procurement of energy using assets or equipment or the

10. This timeframe is chosen to be consistent with meeting the UN goal of full electrification by 2030, which we analyse in detail in Chapter 18 in the Energy for All Case.

optimisation of an existing system.[11] Such increased visibility lowers information costs, an important element of transaction costs.

Make it a priority

The profile and importance of energy efficiency needs to be raised. Visibility stimulates market actors to consider energy efficiency, but is often not enough to motivate them to demand it. Government needs to take additional steps to ensure the full value of higher energy efficiency is clear to the individual and to society at large. Available measures include: regulatory requirements, such as the obligations China and Japan place on industry to implement energy efficiency measures, and those some European and North American regulators place on utilities; market transformation programmes; measures to obligate companies to address questions of energy performance at board level, such as corporate social responsibility reporting requirements; and awareness raising and promotional activities.

Make it affordable

Create and support business models, financing vehicles and incentives to ensure investors in energy efficiency reap an appropriate share of the rewards. Tailored financing instruments are needed to address the various split incentive barriers to energy efficiency; for example, where the asset ownership period is shorter than the payback period, such as for the retrofit in buildings. These mechanisms may need to be structured to encourage the redeployment of long-term capital, ordinarily targeting energy supply-side investments, into investments aimed at energy-demand reduction through efficiency. In any case, they need to remove the risks to asset owners of potential asset sale before the return on investment is accrued. Examples of these instruments include utility-operated or funded energy efficiency finance schemes, typically tied to demand-side management or utility energy efficiency obligation schemes; pay-as-you-save schemes; and supportive frameworks for the energy services industry. Other instruments can be deployed to help increase the attractiveness of energy efficiency investments when they are competing for capital with alternative investment opportunities that are perceived to have a higher rate of return. These include soft loans, grants, credit lines, loan guarantees, and special funds. Equally, when appropriate, fiscal and financial incentives can help increase the attractiveness of energy efficiency investment. Such incentives can often be temporary, designed to bridge the initial cost gap. They allow market volumes to grow and the cost gap to reduce, due to economy of scale effects.

11. Examples of policy instruments used to address the measurement of energy efficiency are: energy performance test procedures, energy efficiency measurement metrics; energy system and sub-system metering and energy auditing. Examples of policy instruments used to ensure that energy efficiency is reported to end-users and procurers are: energy labelling, rating and energy performance disclosure schemes, energy performance benchmarking, smart metering and performance feedback systems, such as continuous commissioning (*i.e.* constant monitoring and tuning of building equipment to ensure it is operating optimally without wasting energy).

Perceptions of financial risk are another barrier to energy efficiency investment. They can be tackled by measures to lower the risk premiums applied to lending for energy efficiency projects, combined with measures to alert end-users to the value of energy efficiency investment because of the potential volatility of energy prices. These measures include risk guarantees, credit lines, mechanisms to standardise and bundle project types, and awareness and capacity building efforts among the finance community. The type and scale of these instruments, as in the Efficient World Scenario, varies by sector and economy, but needs to be of sufficient scale to address many of the primary affordability barriers to energy efficiency investment by dramatically reducing actual or implicit transaction costs. It is important to note that many of these financing instruments essentially operate to re-deploy supply-side capital investments into demand-side efficiency improvement investments, which has the effect of changing energy supply businesses or financiers into energy service (supply and demand) businesses and financiers. The success of these measures in the Efficient World Scenario helps to lower bills through reducing demand (despite the recycling of a part of these savings to finance the energy efficiency measures that results in a slight increase in energy prices). Overall, however, the reduction in demand lowers both bills and prices and gives rise to a modest rebound effect. This, in turn, is offset in certain economies by the removal of energy subsidies by 2035. The removal of subsidies not only creates a level playing field for energy efficiency investment, helps improve the viability of energy businesses and reduces energy security risks, but is one of the more important direct drivers of savings under the Efficient World Scenario.

Make it normal

Energy efficiency needs to be normalised if it is to endure. Once a high-efficiency technology or service solution has been widely adopted, there is rarely a step backwards: the old less-efficient technology or approach is rapidly forgotten. Usually the cost differentials for higher-efficiency technologies and services decline substantially as adoption rates increase. Accordingly, policies which build the market are helpful and necessary to “normalise” energy efficiency. Under the Efficient World Scenario, a mix of regulations is deployed to prohibit the least-efficient approaches and impose minimum energy performance standards for equipment, vehicles, buildings and power plants. This is, indeed, the single most important category of policy mechanisms in the Efficient World Scenario. In some instances, regulatory requirements are also placed on industry – to develop, implement, monitor and report effective energy saving programmes – and utilities – to finance and implement energy efficiency schemes for their customer base. The scale of this activity lowers the transaction costs. Complementary measures to ensure that the energy-efficient solution becomes the normal solution include efforts to boost the supply of new, higher efficiency technologies and services into the market. Resulting benefits from learning and economies of scale help make the most energy-efficient option the normal solution.

Make it real

Monitoring, verification and enforcement activities are needed to verify claimed energy efficiency. Without such efforts, experience has shown that savings will turn out to be less than expected and the overall policy objectives be undermined. Under the Efficient World Scenario, there is a substantial increase in the scale of such activities. Verification builds confidence in claimed performance and outcomes. Enforcement is necessary to secure compliance (for example, with vehicle efficiency standards or the application of buildings codes). Monitoring provides the principal inputs for evaluation, which is essential to ensure energy efficiency programmes are delivering the expected outcomes and to facilitate any necessary adjustments.

Make it realisable

Achieving the supply and widespread adoption of energy efficient goods and services depends on an adequate body of skilled practitioners in government and industry. The Efficient World Scenario foresees the adoption of systematic programmes to develop and sustain a body of skilled energy efficiency workers. The required skills extend to policy development and implementation, product and service development, monitoring, verification and enforcement, fostering innovative business models and the implementation of quality assurance efforts to ensure there is no loss of service or satisfaction through the adoption of the efficient option. The buildings sector illustrates the scale of the challenge. The diverse nature of the sector (the "fragmentation barrier", see Chapter 9, Table 9.2) requires sustained and extensive capacity building for the necessary skills, once developed, to be widely transferred.

Investment in governance and programme development, and implementation is required on a scale considerably beyond current practice. Governance of energy efficiency is intrinsically more complex than the governance of energy supply, because there are many more energy end-uses and services, which are often major industries in their own right and which have unique characteristics that require targeted policy measures. While a substantial increase in administrative funding is required, the sums involved are a very small fraction of the value of the savings and greater economic efficiency they facilitate. One of the world's best resourced and most successful equipment standards programmes reports that the cost of administering the programme is just $1 for every $650 of the value of the energy savings it produces (US DOE, 2012).

Unlocking energy efficiency at the sectoral level

What is needed and where?

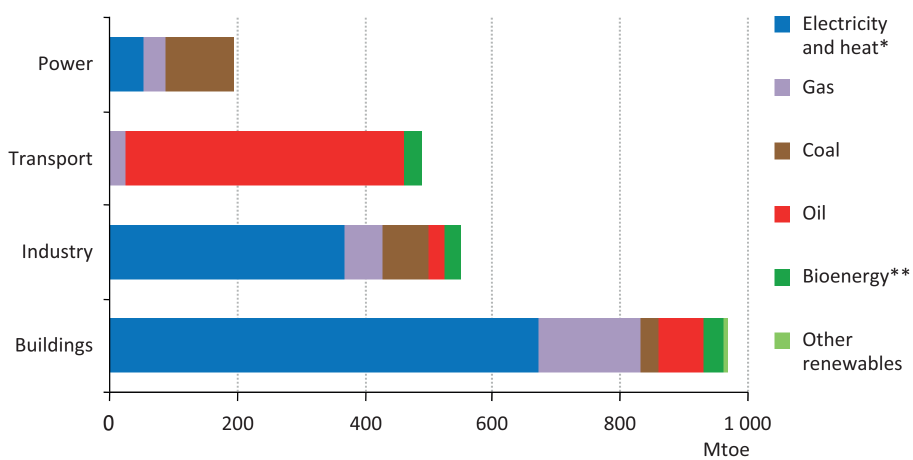
Highlights

- In the Efficient World Scenario, primary energy demand is reduced by 2 350 Mtoe in 2035 compared with the New Policies Scenario, mostly occurring in the power sector. However, 85% of these savings are the result of energy efficiency measures in end-uses. If the savings are attributed to the end-use sectors, buildings account for 41% of the reduction in primary energy demand in 2035, followed by industry (23%), transport (21%) and power (8%).
- Energy used in the buildings sector grows at an average annual rate of 0.4% between 2010 and 2035 in the Efficient World Scenario, a substantially slower rate than the 1% of the New Policies Scenario. The savings are driven by faster uptake of efficient lighting, appliances and equipment in all regions, retrofitting of existing buildings in OECD countries, and more efficient new-build, technology switching and energy price reforms in non-OECD countries.
- Energy demand growth in the industry sector falls to 1.1% per year on average in 2010-2035 in the Efficient World Scenario, from 1.5% in the New Policies Scenario. Despite an increase of 113% in industrial sector activity, energy use increases by only 31% over the period. Savings arise from faster adoption of more efficient technologies, phasing out older facilities, process change and system optimisation, including of electric motor driven systems.
- Efficiency gains in the transport sector reduce oil demand in 2035 by 9.1 mb/d compared with the New Policies Scenario. The global average fuel economy of new sales (test-cycle) for passenger light-duty vehicles reaches 3.5 litres per 100 kilometres (l/100 km) in 2035, down from 7.6 l/100 km in 2010. The on-road global average fuel consumption of heavy trucks in 2035 is around 45% lower than what it was in 2010. Key policy instruments that help to achieve the fuel economy improvements include stringent standards, fuel economy labelling, tax breaks and other incentives.
- Electricity demand growth in 2010-2035 is reduced by one-third, compared with the New Policies Scenario, mainly as a result of higher efficiency in the equipment used in buildings and industry. Almost 200 Mtoe of savings stem from increased efficiency in the power generation sector. The overall efficiency of fossil-fuel power generation rises to 49% in 2035, six percentage points above 2010 levels. This increase is 2.5 percentage points higher than in the New Policies Scenario, and is achieved mainly thanks to efficiency and emission standards that prevent the construction of inefficient plants and the refurbishment of old ones.

The balance of sectoral opportunities

The discussion of the Efficient World Scenario in Chapter 10 illustrated the benefits available from exploiting known opportunities for economic investment in energy efficiency. This chapter concentrates on the opportunities by sector. The measures included on a sectoral level are detailed in Table 11.1. Primary energy demand in 2035 is reduced by some 2 350 million tonnes of oil equivalent (Mtoe), or 14%, compared with the New Policies Scenario, the majority of it in the power sector (1 263 Mtoe). However, 85% of the savings in the power sector are the result of demand-side savings in other sectors, especially buildings and industry. If those savings are attributed to the end-use sectors where the demand reduction occurs, the buildings sector accounts for almost 41% of the savings (Figure 11.1), mostly due to improvements in the energy efficiency of building shells and electrical equipment. In 2035, within industry and the buildings sector, almost two-thirds of the energy savings are in the form of electricity and heat. By contrast, savings in the transport sector are dominated by a reduction in oil demand, mainly driven by improved fuel efficiency in road transport.

Figure 11.1 ▷ Energy savings in 2035 by fuel and sector in the Efficient World Scenario compared to the New Policies Scenario



* Electricity demand savings in end-use sectors are converted into equivalent primary energy savings and attributed to each end-use. The savings allocated to the power sector arise solely from the increased efficiency of the plant, the grid and system management. ** Bioenergy includes waste.

Note: The figure excludes savings in non-energy use, other energy sectors and agriculture, which together account for 152 Mtoe.

Table 11.1 ▷ Summary of key policies by sector in the Efficient World Scenario

Sector	Policy framework in the Efficient World Scenario	Policies beyond the scope of the Efficient World Scenario
Buildings	• Stringent building energy codes for new buildings and those undergoing renovation implemented by 2015 and enhanced by 2020. • Retrofits, beyond the level of the New Policies Scenario, in existing buildings (in OECD countries). • Minimum energy performance standards (MEPS) for all major appliances and equipment, implemented/enhanced by 2015. • Building energy management systems in all new construction in OECD from 2015 and in non-OECD from 2020.	• Changes in urban design (horizontal versus vertical cities). • Architectural improvements, such as reduction in per-capita floor space requirements through better layout design. • Increased access to electricity. • Support for distributed renewable energy generation. • Energy conservation induced by behavioural change beyond that induced by price.
Industry	• All new equipment having efficiency levels matching best available technology by 2015. • Early retirement of inefficient existing facilities by five years. • Process change, when applicable to local conditions. • Implementation of process control and energy management systems. • Adoption of high-efficiency electric motor systems.	• Deployment of carbon capture and storage. • Support for low carbon energy. • Structural changes in the economy beyond those included in the New Policies Scenario.
Transport	• Deployment of the most efficient vehicle options in road transport by 2035, driven by mandatory fuel-economy standards, fuel-economy labelling, tax breaks and incentives. • International sectoral agreement in the aviation and maritime sectors.	• Fuel switch beyond the level of the New Policies Scenario. • Integrated transport and land-use planning. • Modal shift policies. • Demand management strategies (car-pooling, teleworking, etc). • Behavioural changes beyond those induced by price.
Power generation and grids	• Efficiency standards on existing fossil fuel plant, reducing refurbishment and lifetime of inefficient plant. • Efficiency standards on new fossil fuel plants, reducing or prohibiting the construction of coal subcritical or gas steam power plants. • Support for smart grids and efficiency standards for power networks.	• Introduction of CO_2 pricing beyond the countries assumed in the New Policies Scenario. • Enhanced support for renewables. • Stronger support and penetration of CCS technology. • Stronger support for nuclear power plants.

Buildings

Techno-economic potential and policy framework

There is a very large technical potential to improve the energy efficiency of the building stock and the equipment used within it. New buildings can be constructed to use less than 10% of the energy of typical designs and can be net zero-energy or even net positive-energy contributors if on-site distributed generation is used (NREL, 2007).[1] Holistic retrofits can save up to 90% of the thermal energy use in existing buildings (ECEEE, 2011); while the technical savings potential from the use of energy efficient equipment and appliances can range between 5-90%, depending on the end-use.[2] But a range of barriers exist which discourage realisation of these savings. While the New Policies Scenario already includes some measures targeting the buildings sector, these address only part of the economically viable savings potential.

The Efficient World Scenario addresses most of the remaining gaps through the adoption and implementation of a raft of strong policy measures. In buildings, it assumes that all energy efficiency policies now under consideration for the buildings sector are fully implemented, reinforced and strengthened and that their breadth and scope is extended. In particular, stronger measures are adopted to overcome the factors which deter individual building owners and developers from implementing energy efficiency measures which, in themselves, are fully economic. For the building shell and structure these measures include stringent building energy codes that apply to both new and existing buildings and that progress at the fastest rate the local building industry is capable of meeting; more effective code compliance; building energy labelling and performance disclosure; linking the permission to plan and build to attainment of building energy performance objectives; access to financing through mechanisms such as dedicated energy efficiency credit facilities and pay-as-you-save schemes; strong fiscal and financial incentives; capacity building, training and awareness; and research and development. These policy measures are structured to ensure that new buildings advance as rapidly as is realistically achievable towards net zero-energy consumption levels, while also ensuring the rate and depth of energy efficient retrofit of the existing building stock is substantially increased through target-based holistic renovation programmes (especially for OECD countries). However, only energy efficiency investments that are repaid within strictly-defined payback periods are considered under the Efficient World Scenario (see Chapter 10).

For building components, such as windows and insulation, and energy using equipment, a complementary set of policies is applied. This includes mandatory labelling schemes and minimum energy performance standards (MEPS) for all significant energy end-uses and also for energy-related equipment, such as windows, showerheads, faucets and insulation. The stringency of these policies is increased to take better account of the true improvement

1. Such deep reductions are not necessarily achievable for all building types or climate zones, and are often uneconomic for new construction.

2. 90% is for standby power and the 5% is for cooking appliances. All other equipment and appliances have savings potentials in between these two limits (IEA, 2009a).

potential and technology learning curves for energy using and related equipment. Much greater use is also made of supporting policies, such as utility demand-side management (DSM) programmes and incentives to accelerate extensive renovations and the replacement of less efficient technologies by more efficient alternatives. Additionally, policy support is given to energy management systems, like automation, active controls, smart metering and monitoring systems (for consumer feedback). The incentive to adopt higher energy efficiency measures is further enhanced by the assumed partial removal of fossil-fuel subsidies (see Chapter 10).

Of these policies, adoption of progressively more stringent building energy codes and minimum energy performance requirements for all significant energy-using equipment is the key policy for the buildings sector. Equipment efficiency standards can be readily applied in all markets, but building codes are more difficult to implement in markets with a greater share of informal construction and need to be phased in more gradually. Strengthening compliance is essential for policies in both areas to work, and the necessary investment by the authorities in market monitoring, verification and enforcement activities is assumed. For the existing building stock, ambitious programmes need to be implemented, including mandatory annual renovation rates, under the stimulus of appropriate incentives.

Outlook

Energy demand in buildings in the Efficient World Scenario grows at an average annual rate of 0.4% from 2010 to 2035 to reach almost 3 200 Mtoe, or 15% less than in the New Policies Scenario (Table 11.2). There is a substantial reduction in buildings sector energy intensity: the rate of growth in energy use is appreciably slower than growth in building floor area, which increases at an average annual rate of 1.7%. This is attributable to the much wider adoption of measures to improve the thermal performance of the building stock and raise the efficiency of equipment and appliances.

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Table 11.2 ▷ Global buildings energy demand by fuel and energy-related CO_2 emissions in the Efficient World Scenario

	2010	2020	2035	CAAGR* 2010-35	Change versus New Policies	
					2020	2035
Total (Mtoe)	**2 910**	**3 080**	**3 193**	**0.4%**	**-7%**	**-15%**
Coal	124	111	69	-2.3%	-10%	-27%
Oil	329	299	233	-1.4%	-9%	-22%
Gas	616	655	697	0.5%	-8%	-19%
Electricity	831	960	1 161	1.3%	-10%	-17%
Heat	148	150	145	-0.1%	-6%	-15%
Bioenergy	841	866	809	-0.2%	-1%	-4%
Other renewables**	21	39	78	5.5%	-6%	-8%
CO_2 emissions (Gt)	**2.9**	**2.8**	**2.6**	**-0.5%**	**-8%**	**-21%**

*Compound average annual growth rate. ** Includes solar and geothermal.

The use of fossil fuels in the sector reduces gradually, as growth in demand for natural gas is more than offset by a decline in demand for coal and oil. Coal exhibits the largest reduction in demand (27%) in 2035 relative to the New Policies Scenario, followed by oil (22%) and then electricity and gas (both at around 18%). The share of electricity in building energy use continues to grow strongly, as it does in the New Policies Scenario, rising from 29% in 2010 to 36% in 2035. Despite the strong growth in electricity demand in the Efficient World Scenario, the additional savings, compared with the New Policies Scenario, reach more than 240 Mtoe by 2035, largely due to the improved efficiency of appliances and equipment. These electricity savings are expressed in terms of final energy consumption; but if the primary energy needed to produce electricity and heat are factored in the savings amount to about 675 Mtoe in 2035.

Although the cumulative energy savings over the outlook period in buildings, relative to the New Policies Scenario, are almost equally divided between the OECD and non-OECD regions, the reduction comes from very different sets of options. In OECD countries, where new construction activity is estimated to be as low as 1% of the building stock each year and demolitions 0.3-0.5%, the biggest potential savings are made in existing buildings (IEA, 2009b).[3] On the other hand, non-OECD countries generally have much higher new construction activity than OECD countries, especially in emerging economies, where the rate of renewal is estimated to be around 5% of existing stock for residential buildings and 10% for commercial buildings (IEA, 2009b). Consequently, the biggest saving potential in non-OECD countries is in new buildings, through the penetration of more efficient appliances and equipments.

Accordingly, the majority of savings in buildings in the residential and services sectors in the OECD region is attributable to the reduction in energy use for space heating and cooling, due to refurbishment of existing buildings and, especially, to improvements in the insulation of building shells for both. Recent case studies show that the renovation of building shells and openings, combined with installation and appropriate operation of heat control and measuring devices, can improve building energy efficiency by up to 60% (IEA, 2009b). In the Efficient World Scenario, energy demand in OECD buildings declines at 0.15% per year on average. Fossil-fuel consumption declines, while use of modern biomass and other renewables grows. There is a substantial reduction in the use of natural gas and oil, due to improved insulation and operation, and a shift towards heat pumps for space heating. In spite of this shift, the consumption of electricity in buildings is reduced sharply relative to the New Policies Scenario, as a result of the broader implementation of mandatory MEPS and labelling, which stimulate the adoption of more efficient appliances and equipment, and insulation and retrofits in building shells, which lower space heating and cooling service demand. Overall, OECD building electricity consumption falls by 16% in 2035, compared with the New Policies Scenario.

3. Except for Japan, where the demolition rate is much higher.

Energy use in buildings within non-OECD countries rises from 1 658 Mtoe in 2010 to 1 985 Mtoe in 2035 in the Efficient World Scenario: 12% less than in the New Policies Scenario. Most of the major non-OECD countries are considering the introduction of legislation to set mandatory building energy codes for new buildings and MEPS and labelling for appliances, lighting and equipment. In the Efficient World Scenario, these measures are fully implemented and strengthened. They are further complemented by capacity building, training, demonstration projects, awareness campaigns and the provision of financial incentives. The partial removal of fossil-fuel subsidies gives a further stimulus to efficiency improvements and so reduces energy demand.

China has the world's largest building stock, absorbing 16% of global energy consumption in buildings in 2010. The total floor area of all buildings in China is about 48 billion square metres currently and it is expected to reach 60 billion square metres by 2035.[4] This expansion is largely driven by housing demand in urban areas, where per-capita floor space has been increasing by one square metre per year in the recent past (China Daily, 2008). Although significant efforts have been made to implement energy conservation measures, such that most new urban construction now complies with building codes, there is still potential to increase code compliance in rural areas and to improve the energy efficiency of the existing building stock (LBNL, 2010). In the Efficient World Scenario, a wide range of policies and measures are assumed to be adopted in China, producing energy savings in buildings of 18% by 2035, compared with the New Policies Scenario.

Most existing buildings in Russia and Eastern Europe have very high energy intensities, with losses estimated to be up to 40% of supplied energy (IEA, 2009b). There is large potential to reduce thermal energy use through the refurbishment of the building stock and the heat networks which supply it (IEA, 2011a). Although energy efficiency is already becoming a priority in Russia, the policy package adopted within the Efficient World Scenario is much more comprehensive than the policies currently under consideration. It entails the full implementation of legislation providing subsidies for retrofits and energy efficiency technologies and fines for owners of buildings that fail to respect the defined standards. These measures are combined with reform of the heat markets and imposition of more stringent building energy codes and equipment efficiency standards. These measures result in energy savings of 15% in 2035, compared with the New Policies Scenario.

In India, total energy demand in buildings in 2035 is reduced by 14%, compared with the New Policies Scenario. India is expected to construct more buildings in the period 2012-2035 than the total stock existing in 2010. In addition to the broader adoption and enforcement of building energy codes, much of the savings in the near term come from technology switching, such as the adoption of liquefied petroleum gas (LPG) stoves and light-emitting diodes (LED) lighting, triggered by subsidy removal, and from the adoption of high-efficiency equipment, stimulated by more stringent and comprehensive MEPS.

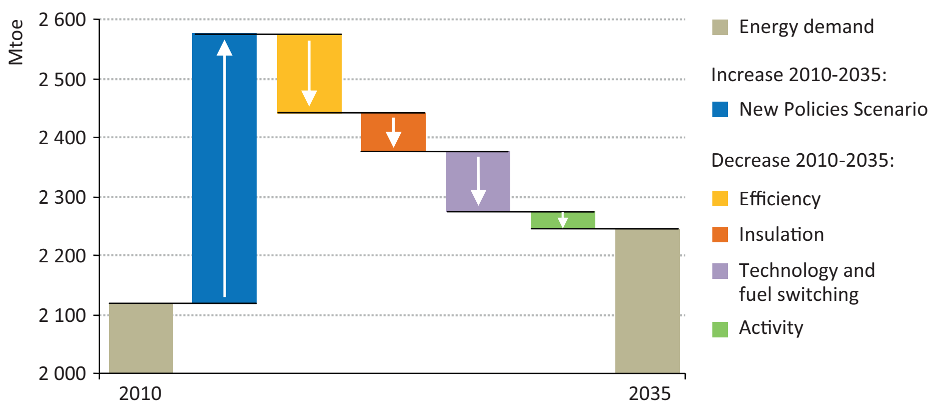
4. GBPN and CEU (2012); IEA analysis.

Trends by sub-sector

Residential sector buildings

Energy savings in the buildings sector stem from reductions in heating and cooling demand, resulting from greater insulation; efficiency savings from higher-efficiency equipment and technology switching (*e.g.* from gas-fired boiler space heating to the use of heat pumps); and reduction in overall demand due to the removal of energy subsidies (Figure 11.2). Retrofits play a greater role for OECD countries, where the stock turnover is not very high.

Figure 11.2 ▷ Savings in residential energy demand in the Efficient World Scenario relative to the New Policies Scenario by contributing factor

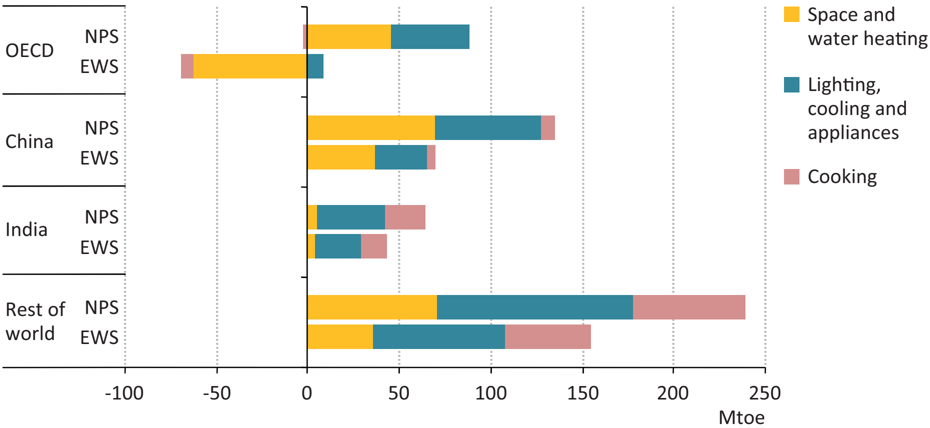


Note: Details on decomposition analysis can be found in Chapter 9, Box 9.4.

Standard end-uses in residential buildings include space and water heating, appliances, lighting, cooking and cooling. In the Efficient World Scenario, reductions in residential energy use in space and water heating account for 56% of the cumulative savings at the world level to 2035, compared with the New Policies Scenario. In the OECD, this accounts for two-thirds of cumulative savings (Figure 11.3). Appliances, lighting and cooling make up almost another 20% of the reduction. Unlike in OECD regions, space cooling is a key priority in non-OECD countries, due to climate conditions. Interestingly, out of the 50 largest metropolitan areas in the world today, the vast majority with high annual cooling degree-days are in non-OECD countries (Sivak, 2009).[5] In those countries, appliances, cooling and lighting achieve significant energy savings, attributable to the spread of mandatory labelling schemes and MEPS. Cooking is also a key end-use sector in terms of energy savings potential, due to present widespread use of inefficient cooking technologies, most using traditional biomass.

5. Cooling degree-days are the number of degrees per day that the daily average temperature is above a given "comfort" temperature.

Figure 11.3 ▷ **Change in energy demand in the residential sector in the Efficient World Scenario and the New Policies Scenario from 2010 to 2035 by end-use**



Note: NPS = New Policies Scenario; EWS = Efficient World Scenario.

Service sector buildings

In the Efficient World Scenario, energy consumption in the services sector is 19% lower in 2035, about two-thirds of the reduction coming from more efficient heating and cooling and better insulation (including automated building energy management systems). Deployment of higher-efficiency solutions increases in the service sector, as in the residential sector. The fabric of existing and new buildings incorporates integrated design, better insulation and shading to optimise thermal efficiency and use of daylight. Heating, cooling and ventilation systems are controlled better and are more efficient, taking advantage of natural ventilation and cooling, heat pump technology, heat recovery and/or cool storage and other energy saving techniques, when appropriate. New lighting systems are much more efficient and provide for greater user control, while exploiting the energy benefits of day-lighting when possible. The adoption of advanced LED and plasma lighting technology is accelerated to reduce lighting energy consumption in lighting of both high and low intensity. Fixed speed pumps give way to variable-speed systems, with more appropriate sizing for the required task. Commercial information technology and refrigeration systems are also improved to exploit a greater proportion of the technical savings potential available from efficient equipment.

Space heating

In the Efficient World Scenario, energy savings in space heating come about by the greater use of insulation and high-efficiency glazing in both new build and retrofits, coupled with increased rates of retrofitting. Savings also arise from the increased use of more efficient heating equipment, such as condensing boilers, micro combined heat and power (CHP) plants and heat pumps, and from improved control via intelligent thermostats. New building designs take greater advantage of passive and integrated design techniques to make better use of ambient energy flows, such as solar gains, while minimising overheating. The overall energy savings are attributable to a blend of efficiency gains, due to the use of more efficient technologies for the same fuel, *e.g.* efficient gas boilers, and change from gas- or oil-based boilers to more efficient heat pumps. Space heating savings are larger in the OECD than the non-OECD region throughout the projection period, because the former has greater demand for space heating and correspondingly greater scope for reductions. This greater demand for space heating in the OECD mainly arises from the climate in the region having more heating degree-days and a demand for higher average thermal comfort levels.

In many cases, the higher-efficiency technologies bring substantial improvements in the quality of service and important benefits beyond simple energy, economic and emissions savings. Use of integrated design and improved insulation gives better thermal comfort than reliance on thermo-mechanical heating systems as it helps to even out the differences in radiative temperature to which the human body is highly sensitive. Efficient glazing, using selective radiative coatings to reflect heat back into a room, inert gas-filled cavities, or even evacuated cavities, together with low conductivity frames not only saves energy but also makes a particularly strong contribution to overall thermal comfort. Additionally, it helps reduce noise, compared with standard single glazing. Insulation also eliminates thermal bridges and mould growth and thus improves indoor air quality and health. In many markets, these factors are valued highly.

Equipment

There are favourable prospects for improving the efficiency of energy-using equipment, although there still remain many barriers and also lock-in effects. Some building equipment, such as heating systems and plumbing, may be long-lasting and relatively difficult to change. Others, such as consumer electronic devices, may be very short-lived. For such equipment, the most efficient step is to ensure the equipment meets the highest attainable standards when it is bought and installed (Box 11.1).

Lighting and appliances are the end-use sectors that offer the fastest energy savings. In the case of residential sector lighting, incandescent lamps, which are typically replaced annually, due to their short lifetimes, are replaced initially by compact fluorescent lamps (CFLs) that last six times as long and use a quarter of the energy. Over the medium term, solid state lighting, such as LEDs, gain a substantial part of the market, while average LED efficiency levels continue to rise.

In the case of electrical appliances, energy efficiency levels continue to be driven upwards, in line with established technology learning curves. In OECD countries, the most efficient refrigerators today consume 20% of the energy of the average refrigerator on the market in the mid-1990s.[6] It is assumed that the current most efficient technology gradually becomes

6. For the European Union, A+++ appliances use 20% of the D to E class average, which is the mean threshold for the labelling scheme established in 1995.

the global norm, while technology improvement continues to occur. Similar potential for improvement exists in air conditioners, where global average efficiency levels are roughly a third of the levels attained by the most efficient technologies on today's market and yet further technical improvements are possible (Econoler, *et al.*, 2011). Other major electricity using end-use equipments in households, such as televisions, clothes washers, dryers, dishwashers, rice cookers, and information and communication technologies (ICT), all have strong savings potential (Waide, 2011) above and beyond the levels within the New Policies Scenario. Additional savings are achieved by smart solutions for demand management, including automation and active controls.

Box 11.1 ▷ Determining the cost-effective efficiency potential of appliances in the Efficient World Scenario

The Efficient World Scenario combines the same growth in electrical appliances as that projected in the New Policies Scenario, with greater efficiency wherever this is attainable cost effectively. The efficiency levels reached have been determined using the BUENAS (Bottom-Up Energy Analysis System) model, an international appliance policy model developed by Lawrence Berkeley National Laboratory (LBNL). BUENAS covers thirteen economies, which together account for 77% of global energy consumption, and twelve different end-uses, including air conditioning, lighting, refrigerators and industrial motors (LBNL, 2012).

This type of model is particularly important in assessing the impact of minimum energy performance standards (MEPS) and energy labelling, which are the key policies driving equipment energy efficiency gains and their associated electricity and fossil-fuel savings in the buildings sector. In the Efficient World Scenario, we assume that these policies are fully enacted where already in place and are introduced where not in place yet. In addition, in cases where the equipment coverage of such policies is only partial, the coverage is assumed to be extended so that almost all energy used by end-use equipment in buildings is covered by these policies. Consequently, the share of equipment energy use that is subject to MEPS increases from typical current levels of 30-60% in OECD economies, 55% in China and from 0-10% in other countries, to 95% in all countries in 2035 under the Efficient World Scenario.

Despite the very significant savings these policies produce, the modelling of the cost-effective savings potential is conservative, as it only includes currently-available technologies and applies current equipment prices. In reality, the price of high-efficiency equipment is likely to go down over time, as manufacturers find ways to lower costs through economies of scale, process improvement and other innovations. The US Department of Energy has recently allowed for this effect in its equipment rulemakings.

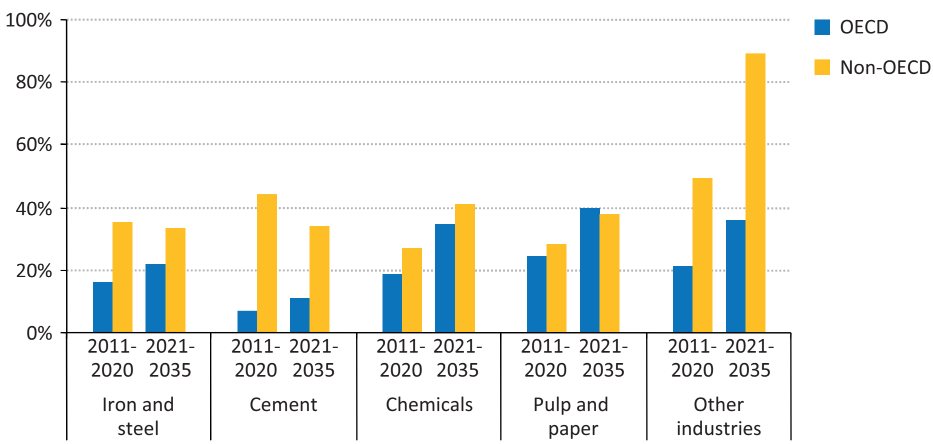
With such improvements in building shell and end-use equipment, there is a significant reduction in the energy intensity of buildings. For the residential sector, energy demand grows at an average annual rate of 0.23% from 2010-2035, much slower than the growth in building floor area, which increases by an average annual rate of 1.7%. This decoupling of energy demand from floor space is achieved by a near 30% reduction in the energy required per square metre of residential floor space over the *Outlook* period.

Industry

Techno-economic potential and policy framework

In 2010, industry was responsible for 28% of global final energy use and 32% of energy-related carbon dioxide (CO_2) emissions (including indirect emissions).[7] Energy-intensive industries, such as iron and steel, cement, chemicals, and pulp and paper, currently account for roughly half of total final industrial energy consumption. In our projections, most of the increase in industrial production through to 2035 occurs in non-OECD countries (Figure 11.4).

Figure 11.4 ▷ Cumulative new industry capacity as a share of currently installed global capacity in the Efficient World Scenario



Note: Includes replacements of currently existing capacity.

Source: IEA analysis.

The potential for energy efficiency improvements in industry varies across sub-sectors. While in many OECD countries large energy-intensive industries already use efficient technologies, further improvements can be realised by replacing older facilities, optimising processes or through enhanced energy management practices. Untapped potential

7. Industry sector energy demand is calculated in accordance with IEA energy balances, *i.e.* neither demand from coke ovens, blast furnaces, nor petrochemical feedstocks is included.

also remains in the non-energy-intensive industry sector. In non-OECD countries, new manufacturing facilities in energy-intensive industries are often equipped with the latest efficient technologies. These new plants are often large scale and therefore more energy efficient, since production size has a strong influence on specific energy consumption (energy consumption per unit of output). However, older infrastructure in non-OECD regions is in most cases less efficient and accelerating the closure of plants with outdated technology can produce significant energy savings. Pure technological changes can achieve only a part of the energy savings; the rest requires systems optimisation and wider process changes (Box 11.2).

Box 11.2 ▷ Types of energy efficiency improvements in industry

Energy efficiency improvements in industry can be classified into three main categories:

- *Better equipment and technology*. It is estimated that the accelerated adoption of best available technology (BAT) could cut global industrial energy use by almost a third (IEA, 2012a). Replacing technologies such as inefficient compressors, which often lose up to 80% of input energy as heat, could contribute to radical energy cuts.
- *Managing energy and optimising operations*. Efficiency improvements through systems optimisation can, in some cases, achieve additional savings, up to 20% (UNIDO, 2011). Systems optimisation means going beyond component replacement towards integrated system design and operation. Optimisation of electric motor systems, such as fans, pumps, compressors and drives, has potential for particularly large and cost-effective savings in all industry sectors (IEA, 2011b).
- *Holistically transforming production systems*. More radical reductions in industrial energy use require an integrated approach to the management of resources and waste over the whole industrial process and consumption chain. Strategies for transforming production systems include increased use of recycled or waste materials and energy, sharing resources among industries and dematerialisation.

There are significant barriers to the implementation of energy efficiency measures in industry and these are often hard to overcome. They include the requirement for short payback periods, in some cases lack of awareness and know-how, and concern that time spent on efficiency improvement is a distraction from core business and that change could interrupt production or affect reliability. Government intervention can address these barriers, creating incentives for companies and ensuring that enabling and supporting systems are in place.

Since the 1970s, industrial energy efficiency policies have been implemented in many countries around the world. Key measures include the funding of research and technology development, incentives in the form of subsidies or energy taxes, emissions trading schemes, equipment performance requirements and energy management programmes. In addition, a variety of supporting measures, such as capacity building, provision of training, facilitating access to energy efficiency service providers and sources of finance are used to promote the uptake of energy efficient technologies and practices (IIP, 2012).

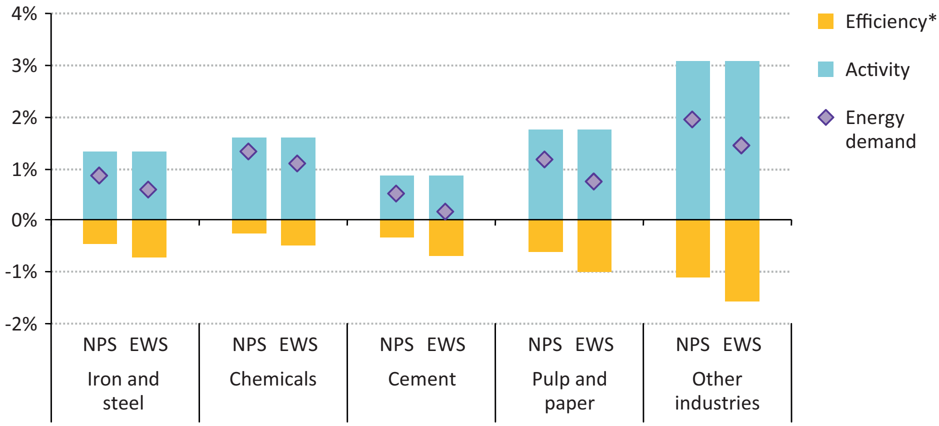
However, there are still gaps that existing policies and policies currently under discussion will not close. The Efficient World Scenario assumes a substantial extension and increase in the scale of the policy efforts that underlie the New Policies Scenario (see Chapter 10). In particular, it assumes accelerated deployment and further development of existing policy instruments, such as energy efficiency targets, benchmarking, energy audits and energy management requirements. These are complemented by supportive measures, like training, capacity building, the provision of information and guidance. The efficiency of industrial equipment and systems is promoted by the development of progressive energy performance requirements. Tools, guidance and information measures also help to promote the deployment of energy efficient systems and assist systems optimisation. In addition, new policy measures that go beyond the energy sector are developed, to promote the use of recycled materials, waste heat, and materials and processes that reduce manufacturing energy requirements. Due to the significant investments required and their relatively long payback periods, fiscal and financial incentives, as well as effective financing mechanisms, play an important role. Importantly, the verification processes for systems measurement and energy savings are improved so that energy efficiency benefits can be confidently assessed, contributing to easier access to finance.

In OECD countries, policy measures are taken to increase the rate of energy efficiency refurbishment and systems optimisation in existing facilities. In emerging and developing economies, greater emphasis is placed on establishing an efficient industrial base by ensuring that the most efficient technologies are used when designing and commissioning new facilities, and that there is an acceleration in the closure, or comprehensive retrofit of facilities with obsolete technology. Technology and knowledge transfer to developing countries is increased together with experience exchange on effective policy making.

Outlook

In the Efficient World Scenario, demand for final energy in the industry sector increases by 31% between 2010-2035, compared with a rise of 44% in the New Policies Scenario. Global energy consumption continues to grow in all sub-sectors, as the annual intensity improvements achieved (ranging from 0.5-1.6%) are unable to counteract the rapid growth in industrial production (Figure 11.5).

Figure 11.5 ▷ Average annual change in industrial activity, efficiency and energy demand by industrial sub-sector and scenario, 2010-2035



* Negative values for efficiency represent improvements.

Note: NPS= New Policies Scenario; EWS = Efficient World Scenario.

Most of the cumulative final energy savings in industry, with respect to the New Policies Scenario, come from reduced use of electricity (40%), followed by lower use of coal (23%) and natural gas (18%). Demand for oil remains broadly flat, while demand for gas, electricity and biomass increases significantly. China accounts for 39% of the cumulative energy savings and India for 14%. Only 16% of savings arise in OECD countries. The extensive deployment of energy-efficient technologies contributes to climate mitigation objectives by slowing growth in energy-related CO_2 emissions from the industry sector.

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Table 11.3 ▷ Global industry energy demand by fuel and energy-related CO_2 emissions in the Efficient World Scenario

	2010	2020	2035	CAAGR* 2010-35	Change versus New Policies	
					2020	2035
Total (Mtoe)	**2 421**	**2 901**	**3 171**	**1.1%**	**-4%**	**-9%**
Coal	676	769	748	0.4%	-4%	-9%
Oil	321	343	330	0.1%	-4%	-7%
Gas	463	577	688	1.6%	-4%	-8%
Electricity	638	838	999	1.8%	-6%	-12%
Heat	126	133	121	-0.2%	-4%	-8%
Bioenergy**	197	242	285	1.5%	-4%	-8%
CO_2 emissions (Gt)	**9.8**	**10.9**	**10.5**	**0.3%**	**-7%**	**-15%**

* Compound average annual growth rate. ** Includes other renewables.

Note: CO_2 emissions include indirect emissions from electricity and heat.

Trends by sub-sector

Iron and steel

Currently, some 70% of world steel is produced via the blast furnace/basic oxygen furnace route (World Steel Association, 2012). With blast furnaces accounting for by far the largest part of energy consumption, a particular focus in the past has been on reducing their energy consumption. In the Efficient World Scenario, widespread adoption of top pressure recovery turbines and blast furnace gas recovery takes place. Pulverised coal injection is increased, to reduce coke demand, and combined-cycle gas turbines are used in place of steam turbines, to increase the thermal efficiency of power generation from blast furnace gas.

When electric arc furnaces (EAF) are used for steel making, direct current arc furnaces can significantly reduce energy intensity; but this technology is applicable only to furnaces above a certain production size. In the Efficient World Scenario, we assume a higher proportion of scrap metal being recycled in some economies, resulting in major energy savings. We also assume a higher share of EAFs, which results in higher overall electricity consumption, but lower fuel consumption. Both process changes – a higher use of scrap metal and a higher share of EAFs – account for more than a third of all the energy savings in the iron and steel sector. Gas-based direct reduced iron (DRI) is another option for less energy-intensive iron and steel making, as emphasised by the DRI facilities planned in Iran and under construction in Louisiana in the United States. However, the future development of DRI is uncertain, partly due to the uncertainty about the future development of gas prices. In the Efficient World Scenario, the combination of the above changes decreases the fuel intensity of iron and steel production between 2010-2035 by 11% in OECD countries and 19% in non-OECD countries. Energy savings in iron and steel in 2035, compared with the New Policies Scenario, are 35 Mtoe, or 6%.

Chemicals

The chemical sector is very diverse and so are the technological options to save energy. Significant energy savings are possible from the recovery and use of waste heat, co-generation, efficiency gains in steam crackers, increasingly selective catalysts, and through increasing the size of crackers and furnaces. Additional savings can be realised from process intensification and the co-ordination of energy use with neighbouring plants. Moreover, the integration of petrochemical and refinery plants can result in not only energy savings, but also lower transport costs, lower storage requirements and increased feedstock flexibility. In the Efficient World Scenario, the wider deployment of these technologies and organisational measures reduces the sub-sector's energy use in 2035 by 5%, or 28 Mtoe, compared with the New Policies Scenario.

Cement

The energy intensity of cement production is largely dependent on the type of kiln technology employed for clinker production. Dry kilns with pre-heaters and a precalciner are significantly more efficient at clinker production than shaft kilns, which are still common in China and India, or wet/semi-dry/dry kilns which are commonly used in the European Union, Russia and the United States. Important savings can be achieved by implementing heat recovery. In the Efficient World Scenario, it is assumed that there is a complete transition by 2035 to dry kilns with preheaters and precalciners in North America and the European Union, while shaft kilns are completely phased out in India and China.

Energy savings are realised in raw materials preparation and grinding by the introduction of high-efficiency classifiers and by the use of vertical roller mills (CSI and ECRA, 2009). Compared to today, additional efforts are made to replace clinker with alternatives, such as fly ash, blast furnace slag, limestone and pozzolana, which yield substantial energy savings. The reduction of the clinker-to-cement ratio accounts for roughly a fifth of overall energy savings in the cement sector. Globally, the measures adopted reduce energy demand in cement manufacturing in 2035 by 8%, or 24 Mtoe, compared with the New Policies Scenario.

Pulp and paper

In pulp and paper production, the chemical pulping process is the most energy-intensive step. Black liquor gasification has the potential to save a significant amount of energy in this step, although its use is currently limited. In the mechanical pulp production process, the use of high-efficiency grinding, efficient refiners and pre-treatment of wood chips can reduce energy consumption substantially, compared with conventional processes. However, by far the greatest potential for savings is from higher use of recycled fibre. Much of this potential has already been realised in some economies, such as in the European Union, but the use of recycled paper in pulp production can be further increased, especially in many non-OECD countries. At the global level, 50% of waste paper is currently recycled (IEA, 2010). The use of recycled paper as an input to paper production is driven not only by energy considerations, but also by factors such as availability and product quality specifications. Technologies to reduce energy consumption in paper production include shoe press, heat recovery and new efficient drying techniques. Systems optimisation, in the form of improved process control, monitoring, and management can help to reduce energy consumption beyond the improvement achievable by single equipment components. The deployment of all of these options is increased in the Efficient World Scenario, reducing energy demand in pulp and paper in 2035 by 10%, or 19 Mtoe, compared with the New Policies Scenario.

Other industries

The category "other industries" includes the remaining industry sub-sectors, which generally are not energy intensive. This category includes a wide range of very different sub-sectors. The largest energy consumers are food and tobacco, machinery, non-ferrous metals, mining and quarrying, and textiles. In total, this category accounted for 49% of total industrial energy use in 2010, but in the Efficient World Scenario it achieves 65% of the total cumulative energy savings in industry from 2011-2035. This is because energy-intensive sectors have, in the past, made significant energy savings, so that the largest potential for additional energy savings now lies in non-energy-intensive sub-sectors, where the share of energy costs in total production costs rarely exceeds 5% (UNIDO, 2011). Roughly half of all savings in other industries is in the form of electricity, and it is estimated that 70% of all electricity used in industry is related to electric motor systems that are used for ventilation, pumps, compressed air and mechanical movement (IEA, 2011b). The introduction of variable-speed drives and the proper sizing of motors achieve significant savings, since electric motors operate more efficiently at full power. Further areas for energy improvements include boilers, furnaces and specific process technologies. The overall effect is an energy reduction in 2035, when compared with the New Policies Scenario, of 220 Mtoe or 11%.

Transport

Techno-economic potential and policy framework

There are substantial opportunities to improve energy efficiency across all transport sectors (road, aviation, maritime, rail and other), mainly through increased deployment of energy-efficient technologies, but also by improving the efficiency of transportation systems overall. In road transport, vehicles powered primarily by internal combustion engines (conventional and hybridised) are set to continue to dominate the passenger light-duty vehicle (PLDV) market through to 2035 (IEA, 2011a). We estimate that the fuel economy improvement potential of PLDVs over that period ranges from 40% to 67% (including hybridisation), compared with an average vehicle today, depending on the technology type and the region, and that this can be achieved with current technologies (IEA, 2012b). Improvements in vehicle fuel economy typically entail engine downsizing, weight reduction and changes in the thermodynamic cycle, but there is additional potential for savings by using dual clutch transmissions and improving auxiliary systems, aerodynamics, the rolling resistance of tyres, etc. A reduction of average vehicle size is another plausible option for reducing average fuel consumption by vehicle, but represents a change of consumer preferences and is therefore not taken into account in the Efficient World Scenario.

There is less scope for freight trucks to improve fuel efficiency, as they mostly use diesel engines, which are already better optimised for fuel consumption. The potential to reduce fuel consumption in trucks by 2035 is in the range of 30-50%, compared with today's vehicles (IEA, 2012b). Additional reductions of 5-15% are possible by educating drivers, as in the case of PLDVs (IEA, 2012c). However, there is less certainty surrounding the efficiency gains that are possible and not all will always be available. The full potential of hybridisation, for example, can be realised only when driving in stop-and-go situations, such as in urban areas or in regions with lower level speed variations, such as Europe; long haul trucks drive in a continuous manner, with less potential for regenerative braking. Furthermore, other policy objectives, such as reducing air pollution, are not always consistent with improving vehicle fuel economy.

The International Air Transport Association (IATA) estimates that fuel efficiency in new aeroplanes could be improved by up to 50% by 2035, due to new engine systems and hybrid wing bodies (IATA, 2009). Existing aeroplanes could be made 7-13% more fuel efficient, by retrofitting engines and deploying more efficient gas turbines or composite secondary structures, while additional fuel economy potential lies in improvements in air traffic management (12%) and operational improvements (6%). For maritime transport, improvements can come from improving vessel design, engines, propulsion systems or operational strategies, such as reducing ship speed (Crist, 2012). For rail, the technology opportunities encompass the scrappage of old inefficient trains, hybridisation of diesel rail, switching lines to electric rail and optimising operation.

While most of the technologies needed to achieve significant fuel economy improvements are already available, policy intervention is necessary to increase their deployment. Governments are focusing on improving the fuel economy of road vehicles, in passenger light-duty vehicles in particular (see Chapter 9, Table 9.1). Fuel-economy standards for PLDVs are already widely deployed in many OECD countries, while only China has adopted such standards among non-OECD countries, although India is discussing their adoption. Additional policy measures targeting the efficient fuel use of PLDVs, including fuel economy labelling, are also widely adopted. For road freight trucks, only Japan and the United States have adopted fuel-economy standards so far; the European Union, Canada and China are in the process of setting standards.[8] Information on fuel economy is often limited for trucks. There is currently no policy framework that explicitly aims at improving fuel efficiency in non-road transport sectors, even though energy efficiency guidelines have been adopted by different governmental bodies, such as the Energy Efficiency Design Index by the International Maritime Organization in early 2012.

Under the Efficient World Scenario, the policy framework is significantly strengthened. Stringent standards become mandatory for road vehicles in all countries and are progressively raised, such that the efficiency level of new vehicles reaches its maximum potential by 2035, provided the required payback period stays within certain limits (see Chapter 10, Figure 10.1). Fuel-economy standards need to be set at levels that are ambitious enough to accelerate the rate of improvement in the fuel economy of vehicles and this requires the standards setting process to take long-term technology learning curves into account. This is especially important, given the long lead times in the regulatory process and the time required by manufacturers to adapt their production. Stringent fuel-economy standards are also set in the Efficient World Scenario for freight vehicles, aviation and the maritime sector in all economies. Stringent and consistent fuel economy labelling schemes, and vehicle and fuel price signals, including the phase-out of fossil-fuel subsidies, are adopted to encourage fuel-efficient vehicle purchase and operation. They play a key role in driving the market towards fuel-efficient vehicles and in overcoming initial deployment hurdles. The further harmonisation of vehicle testing systems across regions

8. Road freight comprises light commercial vehicles (gross vehicle weight less than 3.5 tonnes), trucks (gross vehicle weight more than 3.5 tonnes) and heavy freight trucks (gross vehicle weight more than 16 tonnes).

helps reduce test facility investment in individual countries and facilitates the transfer of fuel-economy standards and labelling among countries. Improved information exchange among countries also supports improved efforts to raise compliance with standards and labelling requirements across jurisdictions. Other measures adopted include tyre rolling resistance labelling and incentives to assist feedback to drivers on fuel efficient techniques.

Outlook

The Efficient World Scenario has important long-term implications for energy demand in the transport sector. Total final energy demand from transport grows at an average 1.3% per year in 2010-2020 and then plateaus, reaching 2 780 Mtoe in 2035, or 15% lower than in the New Policies Scenario (Table 11.4). Only 5% of the cumulative energy savings in the transport sector over the *Outlook* period occur prior to 2020, as it takes time for more efficient technologies to have an impact on the entire vehicle fleet and because the New Policies Scenario already adopts numerous policies that lead to improvements in fuel economy in the period to 2020. Over the entire time horizon, however, growth in energy demand averages 0.6% per year, less than half the rate in the New Policies Scenario. In 2035, the sector's CO_2 emissions are 15% lower than in the New Policies Scenario.

Table 11.4 ▷ Global transport energy demand by fuel and energy-related CO_2 emissions in the Efficient World Scenario

	2010	2020	2035	CAAGR* 2010-35	Change versus New Policies	
					2020	2035
Total (Mtoe)	**2 377**	**2 704**	**2 780**	**0.6%**	**-3%**	**-15%**
Oil	2 201	2 449	2 414	0.4%	-3%	-15%
Gas	90	111	134	1.6%	-3%	-16%
Biofuels	59	108	176	4.5%	-2%	-15%
Electricity	24	35	56	3.5%	-1%	-2%
Other	3.4	0.2	0.2	-10.5%	0%	0%
CO_2 emissions (Gt)	**6.8**	**7.6**	**7.5**	**0.4%**	**-3%**	**-15%**

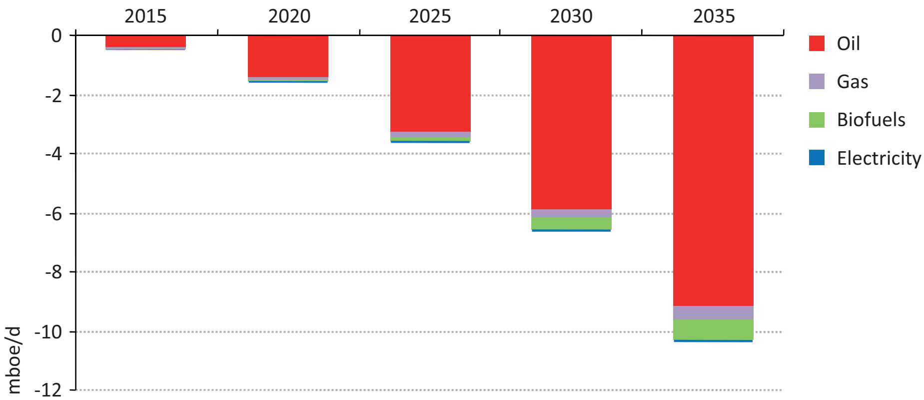
* Compound average annual growth rate.

By 2035, transport oil demand is 9.1 million barrels per day (mb/d) lower than in the New Policies Scenario, representing 72% of the total oil savings achieved across all sectors in the Efficient World Scenario (Figure 11.6). The use of other fuels is also reduced by 1.2 million barrels of oil equivalent per day (mboe/d), as the Efficient World Scenario retains the same policy assumptions for alternative fuels and electric vehicles as the New Policies Scenario. More than half of these savings are biofuels and most of the remainder are natural gas.

An important consideration in realising the full potential of fuel economy improvements is how a fall in fuel prices will affect driver behaviour. The potential "rebound effect" can be around 20% for passenger cars in the OECD, *i.e.* a fall in price of 10% increases the kilometres driven by 2%, and in non-OECD countries the change is potentially larger. In the

Efficient World Scenario, international oil prices in 2035 are $16 per barrel lower than in the New Policies Scenario, which increases passenger-kilometres driven in most countries and dampens the energy savings realised. Were end-user prices prevented from falling, *e.g.* through increased taxation, the savings would be higher (see Chapter 10, Box 10.2). There are, however, notable exceptions to this general rule in countries in the Middle East and Africa, where the assumption of partial removal of fossil-fuel subsidies offsets the effect of lower international oil prices and reduces the passenger-kilometres driven.

Figure 11.6 ▷ Fuel savings in the transport sector in the Efficient World Scenario



Today, almost 60% of energy demand in the transport sector is in OECD countries, but this share is set to shrink, as demand for mobility is growing rapidly in non-OECD countries, where the level of motorisation is still very low (IEA, 2011a). At the same time, many OECD countries and China are making persistent efforts further to reduce transport fuel demand, particularly oil use in PLDVs.

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In the Efficient World Scenario, non-OECD countries are responsible for more than two-thirds of cumulative energy savings in transport (Figure 11.7). Almost one-fifth of global savings are made in China, where the full implementation of the fuel-economy standards for PLDVs that are already planned and their extension to achieve a tested average of 3.4 litres per 100 kilometres (l/100 km) in 2035 (compared with 4.8 l/100 km in the New Policies Scenario) helps reduce total transport oil demand by 1.7 mb/d in 2035, compared with the New Policies Scenario. Almost 15% of cumulative global savings are achieved in the Middle East, where the adoption of fuel-economy standards and the reduction of fossil-fuel subsidies lowers oil demand by 1.2 mb/d in 2035, compared with the New Policies Scenario. India's oil demand is cut by 0.6 mb/d in 2035.

Despite the fact that both the United States and the European Union already have fuel-economy standards for 2025 and 2020, respectively (that are assumed to be implemented in the New Policies Scenario), they are responsible in the Efficient World Scenario for almost 20% of cumulative fuel demand savings, relative to the New Policies Scenario, because of the large size of their markets. By 2035, oil demand in the transport sector is 0.7 mb/d lower in both the United States and the European Union. In the United States, the savings are driven by further tightening of PLDV standards, to over 60 miles-per-gallon (mpg), around 3.8 l/100 km by 2035, increased sales of hybrid vehicles and more stringent standards for heavy trucks, reducing average on-road fuel consumption by about 45%, compared with today.

Box 11.3 ▷ Modal shift and behavioural change in transport energy efficiency

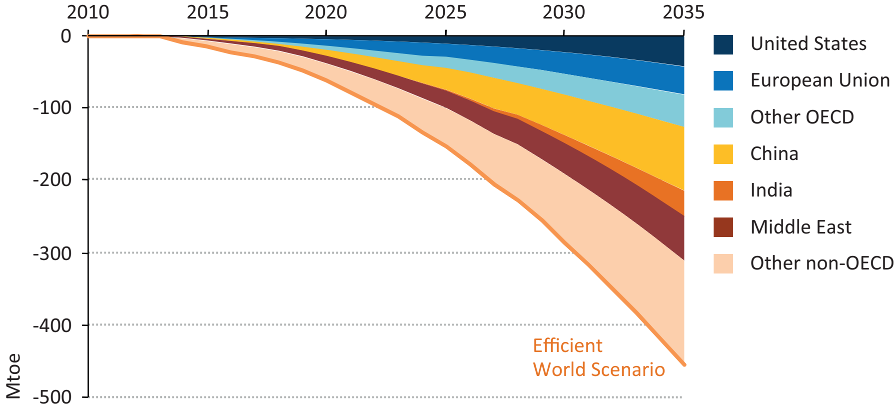
About 60% of the world's population is projected to live in urban areas by 2035, up from 50% today, creating an opportunity for holistic transport concepts targeting energy efficiency in urban planning. One option is to encourage passengers to shift to less energy-intensive transportation modes, such as rail, buses (*e.g.* bus rapid transit systems), trams, cycling and water-based transit. The use of bus rapid transit systems shows great potential as a cost-effective way to reduce the use of passenger cars (IEA, 2012a). Intelligent transport systems and improved logistics can greatly improve the energy efficiency of road and rail freight systems.

Other options that can help increase overall system efficiency are improved planning and operation of urban transport networks and systems, and sustainable mobility measures. These options include the optimisation of traffic signals and network flows, dedicated lanes for low energy-intensity, high carrier-capacity traffic, restrictions on parking, especially when this impedes traffic flows, congestion charging, car-pooling, and park-and-ride schemes.

However, these measures are assumed to be deployed to no greater extent in the Efficient World Scenario than in the New Policies Scenario. The savings realised in the Efficient World Scenario are, accordingly, entirely due to the adoption of more efficient vehicle technology. Nonetheless the energy savings potential from mode shifting and other transport system measures is considerable, particularly for individual mobility. Emerging economies with quickly-growing demand for mobility and cities that are undergoing rapid development have scope to integrate traffic optimisation and modal shift into urban planning policy. There is less scope for mode shifting in freight as local delivery, in particular, will continue to be dominated by road transport.

Quantifying the global potential to improve energy efficiency through modal shift and behavioural change is very difficult, as it depends heavily on local characteristics. But, for the purpose of illustration, we estimate that a global reduction in individual PLDV travel by 10% in 2035, in favour of electric rail, would cut projected oil demand in our New Policies Scenario by 2.3 mb/d.

Figure 11.7 ▷ **Energy savings in the transport sector by region* in the Efficient World Scenario relative to the New Policies Scenario**



* Excludes international bunkers.

Trends by sub-sector

Road transport accounts for more than 85% of the 10.2 mboe/d of energy that is saved in the transport sector by 2035 under the Efficient World Scenario (Figure 11.8). The remaining savings are concentrated in aviation and maritime, even though much of the potential in these areas is already realised in the New Policies Scenario, driven by increasing international oil prices. Nonetheless, by 2035 a new aeroplane in the Efficient World Scenario is about five percentage points more efficient than in the New Policies Scenario.

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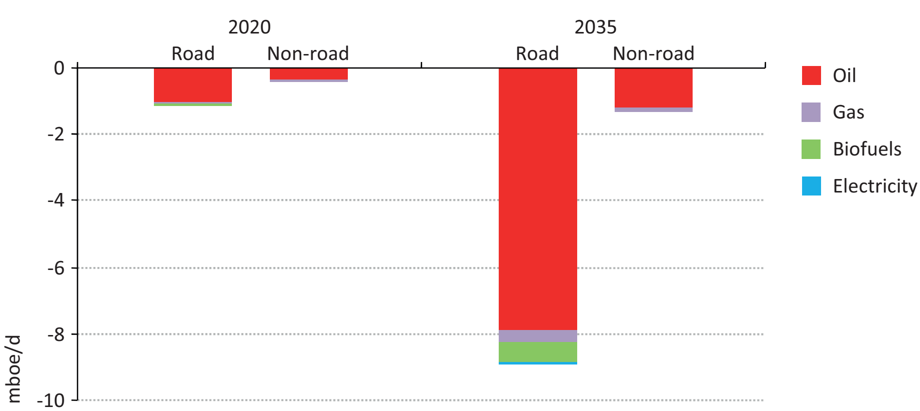
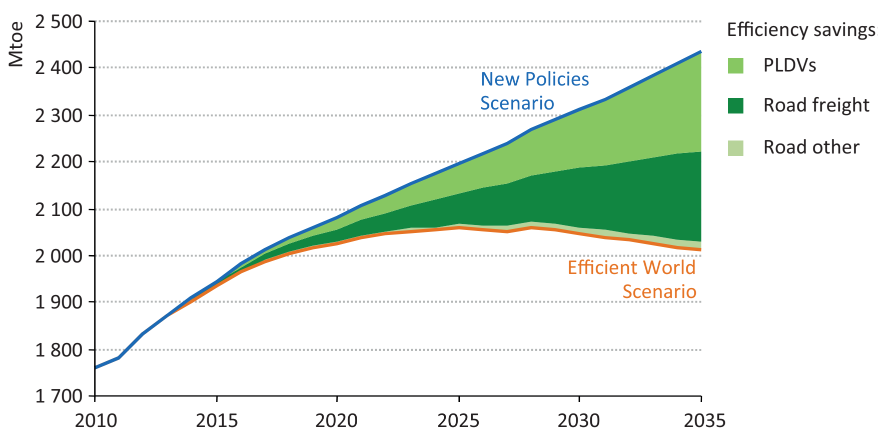
Figure 11.8 ▷ **Energy savings in the transport sector in the Efficient World Scenario relative to the New Policies Scenario by sub-sector**



The dominant contribution road transport makes to the sector's total energy savings is due to its sheer size (relative to the other sub-sectors) and the significant potential to improve its efficiency that goes unrealised in the New Policies Scenario. Around three-quarters of all fuels used in the transport sector today are consumed in road transport, and due to currently low motorisation rates in non-OECD countries, there is significant scope for additional growth. By 2035, the stock of PLDVs is projected to be more than twice as large as today, at 1.7 billion vehicles. In the New Policies Scenario, oil demand from PLDVs grows by 1.2% per year on average and in 2035 it constitutes almost half of global transport oil demand. The largest growth in transport oil demand, however, comes from road freight traffic. It accounts for about one-third of global road fuel demand today, and this share is set to rise in the New Policies Scenario with increasing movement of goods (see Chapter 3). Only Japan and the United States currently have fuel-economy standards for heavy freight vehicles (both of which are considered in the New Policies Scenario), and since most truck operators require payback periods below eighteen months before committing to fleet upgrades (which is shorter than many current technologies deliver), the realisation of the large technical potential is far from certain without government intervention.

In the Efficient World Scenario, around 95% of cumulative fuel savings in road transport arise in PLDVs and road freight, split fairly evenly between the two (Figure 11.9). The average global tested fuel economy of new PLDVs reaches 3.5 l/100 km in 2035, compared with 4.9 l/100 km in the New Policies Scenario and around 7.6 l/100 km in 2010. The disproportionately large savings achieved in road freight reflect the current dearth of plans to improve efficiency in this sub-sector.

Figure 11.9 ▷ Energy savings in road transport in the Efficient World Scenario relative to the New Policies Scenario



We assume that reducing fuel consumption is given at least as much attention as other policy objectives, such as improving safety and air quality, and that policies are put in place to overcome the initial deployment hurdles associated with the purchase of more efficient trucks. The average on-road fuel economy of heavy trucks (gross vehicle weight in excess of 18 tonnes) reaches 19 l/100 km in 2035, compared with 28 l/100 km in the New Policies Scenario and 36 l/100 km in 2010.

Power generation and electricity demand

Techno-economic potential and policy framework

Just as there are opportunities to save energy through the deployment of more energy efficient demand-side technologies, savings may also be made through improvements in supply-side efficiency in the power sector. These include the faster introduction of efficient electricity generation plants and the phasing out of less efficient ones; the adoption of higher-efficiency transformers to reduce transmission and distribution (T&D) losses; the adoption of smart-grid technologies; and the greater use of modern, high efficiency, combined heat and power generators. Fuel substitution can also contribute to efficiency improvements, because gas-fired generation from combined-cycle gas turbines (CCGTs) is considerably more efficient than coal-fired power generation. Globally, energy demand in the power sector was 4 839 Mtoe in 2010, two-thirds more than the buildings sector and double the transportation sector. The power sector is also the largest sector in terms of carbon emissions, representing 41% of global energy-related CO_2 emissions in 2010.

Currently there are many inefficient power plants in operation around the world and many more are planned or under construction. In many OECD countries, ageing plants, with low efficiencies, continue to run because the incremental cost of generation can be very low. In several non-OECD countries, another important factor behind the high share of inefficient plants is that fuel prices are often low due to fossil-fuel subsidies or abundant low-cost domestic fossil-fuel supplies. In many countries, transmission and distribution losses of electricity are extremely high, due to the poor quality of the network infrastructure or the manner in which the grid is operated.

A number of measures are currently being used or considered specifically to improve efficiency in the power sector. For generation, they can take the form of minimum efficiency standards for new plants or specific incentives and targets for CHP. For electricity networks, regulations aimed at reducing losses from power grids create direct incentives for the adoption of more energy-efficient technologies and practices.

In addition to explicitly efficiency-orientated measures, a number of policies being applied to the power sector for other purposes have the secondary effect of improving efficiency. Measures that raise the cost of fossil fuels, such as removing subsidies or establishing a CO_2 price, increase the value of energy efficiency in generation. Policies designed to reduce pollution from power plants can also have the secondary effect of closing older, less efficient power plants.

In the Efficient World Scenario, supply-side energy efficiency options are more widely deployed than in the New Policies Scenario. This is achieved through a co-ordinated set of government policies to encourage more efficient use of fossil fuels in the generation and dispatch of electricity and in its delivery to end-users.

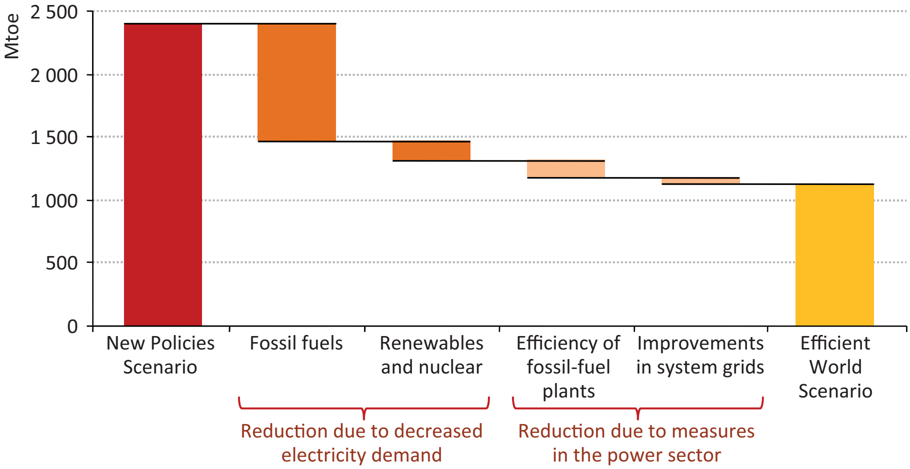
These policies include:

- Setting minimum energy efficiency standards for new thermal power plants that prohibit the construction of new subcritical coal plants and have the effect of replacing them with supercritical, ultra-supercritical or integrated gasification combined-cycle (IGCC) plants.
- Setting minimum energy efficiency standards for new gas and oil plants that lead to increased capacity additions of combined-cycle gas turbines (CCGTs).
- Supportive regulatory and incentive measures for the deployment of combined heat and power (CHP) plants, in place of heat-only plants, in conjunction with the imposition of efficiency standards to improve average CHP plant efficiency.
- The introduction of efficiency and emission standards on existing coal, natural gas and oil plants, which have the effect of reducing refurbishments of old plants and of shortening plant lifetimes, thereby increasing the proportion of new, higher-efficiency, capacity additions.
- Support mechanisms for the deployment of smart grid technologies, to enhance the ability to optimise power flows and reduce transmission and distribution losses.
- Setting and strengthening minimum efficiency requirements for transformers, to reduce transmission and distribution losses in the power network.

Outlook

In the Efficient World Scenario, electricity demand growth from 2010-2035 is reduced by one-third, compared with the New Policies Scenario. As a result, electricity demand is 14% lower than in the New Policies Scenario by 2035. This translates into total savings in gross electricity generation of some 5 460 terawatt-hours (TWh) in 2035, which is larger than the combined power output of China and India in 2010. By 2035, fossil fuel-fired generation in the Efficient World Scenario falls by 22%, compared with the New Policies Scenario, peaking around 2015 and declining thereafter. Nuclear and renewables-based electricity generation are affected less than fossil fuels, as their expansion is policy-driven in many countries. Their output is 4% and 6% lower than the New Policies Scenario respectively by 2035, principally due to lower electricity demand, particularly in the period after 2020. While the majority of savings in the power sector in the Efficient World Scenario, relative to the New Policies Scenario, stem from demand-side measures, improvements in supply-side efficiency reduce primary energy consumption in 2035 by almost an additional 195 Mtoe, or 15% of the overall power sector savings (Figure 11.10). These savings can be split into two categories: improved power plant efficiencies and reduced losses in transmission and distribution. The overall efficiency of fossil-fuel generation gradually rises to 49% in 2035 – an improvement of six percentage points compared with 2010. This is a 70% larger increase in efficiency than that seen in the New Policies Scenario, where overall efficiency increases by three and a half percentage points. Transmission and distribution losses decline, reaching 7.6% in 2035 compared with 8.3% in the New Policies Scenario (Box 11.4).

Figure 11.10 ▷ **Power generation energy savings by measure in the Efficient World Scenario**



Box 11.4 ▷ The value of smart grids

Electricity grids play a vital role in providing reliable electricity supplies to consumers. The fundamental building blocks of network infrastructure have changed little in over a century, but developments in electronics, information and communication technology over recent decades are changing the way in which this infrastructure is operated. These "smart grid" technologies have several advantages. For example, using information and communication technologies to remotely detect where and why a fault has occurred can reduce the amount of time required to restore supply to consumers (IEA, 2011c).

Smart grid technologies also have the potential to yield improvements in efficiency. Technologies that monitor networks and reduce power flows at peak times also have the effect of reducing losses. Smart meters allow consumers to monitor their energy use in real time and adjust their consumption accordingly, especially in response to time dependent tariffs. This could allow consumers to reduce their electricity bills and at the same time reduce the need for expenditure on fuel and generation capacity in the power sector, resulting in benefits for the economy as a whole. Smart grids may also indirectly enable greater integration of distributed generation, including renewables and combined heat and power. The degree to which this potential is realised will depend on how quickly and broadly smart grid technologies are adopted worldwide, and – in the case of smart meters – on the degree to which consumers will change their behaviour in response to the information provided by these new technologies.

In the Efficient World Scenario, we assume an improvement in grid efficiency, relative to the New Policies Scenario. This reflects investment in more efficient grid infrastructure and grid operation, including smart grid technologies.

At a regional level, the reduced growth in electricity demand in the Efficient World Scenario, relative to the New Policies Scenario, is especially marked in non-OECD countries. In China, the energy consumed by the power sector increases by almost 100% over the *Outlook* period in the New Policies Scenario, but in the Efficient World Scenario it grows by 60%. The equivalent increase in India is 43% lower in the Efficient World Scenario than in the New Policies Scenario. In the OECD, the primary energy used by the power sector increases by 10% in the New Policies Scenario, but falls by 7% in the Efficient World Scenario. The overall reductions in the use of fossil fuels in power generation in OECD and non-OECD countries are similar in relative terms. The share of the fossil-fuel reduction accounted for by coal is greater in the non-OECD, however, while gas takes more of the reduction in the OECD countries. Nuclear power experiences a larger relative reduction in the OECD countries.

Box 11.5 ▹ The potential of combined heat and power

The global average efficiency of power plants that generate only electricity is 41%. Almost three-fifths of the primary energy used in these plants becomes waste heat, of no economic value. Combined heat and power (CHP) generation allows some of this energy to be used, either for industrial processes or for space and water heating in residential and commercial buildings. This leads to a significant improvement in overall efficiency, CHP units having a global average efficiency of 62% when the useful electricity and heat produced are both taken into account. New CHP plants can achieve efficiencies of over 85%. A number of countries have adopted policies to support the use of CHP. The US federal government has adopted a goal of deploying 40 gigawatts (GW) of new industrial CHP by the end of 2020 (US White House, 2012), and many states offer incentives for CHP projects (US EPA, 2012). In Europe, the EU's Cogeneration Directive of 2004 obliged member states to take steps designed to promote and monitor the development of CHP in their countries and to remove barriers to its deployment: it is intended that these provisions will be superseded by new requirements in the forthcoming Energy Efficiency Directive (see Chapter 9). At a national level, European countries have used a number of policy tools, including green certificates and feed-in tariffs, to support CHP.

A key constraint on the deployment of CHP is the difficulty of distributing heat over long distances. Because of this, CHP units must be located close to demand, potentially increasing costs. Lack of data makes analysis of CHP on a global level difficult. In the IEA's statistics, the heat produced by CHP installations is measured only if the heat is sold by the producer to another entity. Heat produced in an industrial CHP facility and used by the same firm is not reported and only the corresponding fuel consumption is accounted for. This makes it difficult to analyse the current extent of CHP use globally, and to model its future development.

Table 11.5 ▷ Installed capacity, fuel consumption and electricity generation in the Efficient World Scenario

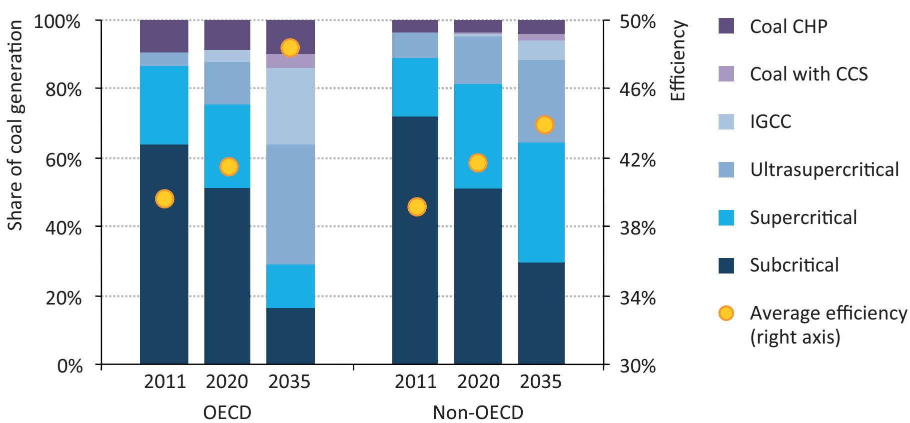
	Capacity (GW)				Consumption (Mtoe)				Generation (TWh)			
	2010	2020	2035	Δ NPS*	2010	2020	2035	Δ NPS*	2010	2020	2035	Δ NPS*
OECD	**2 718**	**3 059**	**3 269**	**-11%**	**2 267**	**2 202**	**2 102**	**-16%**	**10 848**	**11 246**	**11 567**	**-13%**
Coal	669	599	374	-25%	876	720	394	-35%	3 747	3 217	1 998	-28%
Gas	819	955	1 042	-13%	471	472	506	-17%	2 544	2 672	2 975	-15%
Oil	218	123	58	-14%	71	32	13	-35%	309	139	58	-36%
Nuclear	327	321	317	-3%	596	603	621	-3%	2 288	2 315	2 382	-3%
Renewables	685	1 062	1 478	-6%	253	375	568	-8%	1 960	2 904	4 155	-6%
Non-OECD	**2 465**	**3 756**	**5 029**	**-12%**	**2 572**	**3 183**	**3 862**	**-18%**	**10 560**	**14 793**	**19 612**	**-16%**
Coal	980	1 346	1 444	-21%	1 373	1 572	1 556	-28%	4 940	6 197	6 669	-27%
Gas	532	788	1 103	-10%	632	713	887	-15%	2 216	2 979	4 263	-14%
Oil	217	208	152	-15%	204	158	95	-24%	691	554	345	-26%
Nuclear	68	148	241	-5%	122	284	473	-5%	468	1 087	1 814	-5%
Renewables	668	1 267	2 090	-5%	241	457	852	-6%	2 245	3 975	6 522	-6%
World	**5 183**	**6 815**	**8 299**	**-11%**	**4 839**	**5 385**	**5 964**	**-17%**	**21 408**	**26 039**	**31 180**	**-15%**
Coal	1 649	1 945	1 817	-22%	2 249	2 292	1 950	-29%	8 687	9 413	8 667	-27%
Gas	1 351	1 742	2 145	-11%	1 102	1 184	1 393	-16%	4 760	5 651	7 237	-15%
Oil	435	331	209	-14%	275	190	108	-26%	1 000	693	403	-28%
Nuclear	394	468	558	-4%	719	887	1 094	-4%	2 756	3 402	4 196	-4%
Renewables	1 354	2 329	3 568	-5%	494	832	1 420	-7%	4 206	6 879	10 677	-6%

* Change in Efficient World Scenario relative to New Policies Scenario.

In the Efficient World Scenario, global installed power capacity in 2035 is around 8 300 GW, some 1 050 GW lower than in the New Policies Scenario (Table 11.5). More than three-quarters of the reduction in capacity is in fossil-fuel plants, with the biggest contribution coming from coal (49%), followed by gas (26%). A reduction in wind power capacity accounts for more than one-third of the remaining capacity difference. Retirements of power plants over the *Outlook* period amount to above 2 350 GW, an increase of 19% compared with the New Policies Scenario. Gross capacity additions are over 5 200 GW in the Efficient World Scenario, a decrease of 11% from the New Policies Scenario.

The increase in the efficiency of coal-fired generation is more pronounced in the Efficient World Scenario than in the New Policies Scenario, as older plants are mothballed or decommissioned earlier and there is a greater uptake of newer, more efficient plants. There is a marked shift away from subcritical coal plants in all regions, particularly in the OECD, where their share of coal generation drops from 63% in 2011, to 51% in 2020 and to 16% in 2035 (Figure 11.11). Subcritical plants are displaced by more efficient coal technologies, such as high pressure and temperature ultra-supercritical plants or IGCC plants. Furthermore, a combination of new build and retirements means that after a period of growth in the early years of the *Outlook*, coal generation peaks before 2020 and declines almost to the 2010 level by 2035 in the Efficient World Scenario.

Figure 11.11 ▷ Coal-fired capacity by technology in the Efficient World Scenario



Note: Data are for electricity-only plants.

Compared with the New Policies Scenario, the average improvement in the efficiency of fossil fuel-based generation by 2035 is 3.6 percentage points higher in the OECD in the Efficient World Scenario and around 2 percentage points higher in the non-OECD region. The bigger improvement in the OECD arises from a larger reduction in the share of coal-fired generation in total generation than in non-OECD countries and a greater increase in the share of gas-fired generation. In addition, the coal plants that are in operation later in the projection period are more efficient. This is especially true for the United States, where constructing highly-efficient coal plants instead of refurbishing old inefficient plants raises the average coal plant efficiency by six percentage points.

Pathways to energy efficiency

Country and regional profiles

What is included in the profiles?

This chapter presents the results of the Efficient World Scenario in profiles for the world and five major countries and regions: the United States, the European Union, Japan, China and India. The regions covered represented nearly 60% of global energy demand in 2010. The profiles are aimed at providing decision makers with a data-rich set of information on the potential, costs and benefits of achieving a high energy efficiency pathway. The policy, technology and economic assumptions that underlie the Efficient World Scenario, and the results presented in the profiles, are described in Chapter 10 (A blueprint for an energy-efficient world) and Chapter 11 (Unlocking energy efficiency at the sectoral level).

The presentation is primarily in the form of figures and tables. For each country and region, we show the potential for energy savings, including the change in total primary energy demand and the efficiency gains achievable in different sectors, given our assumptions about technology improvements and adopted policies; key energy efficiency indicators (energy intensity,[1] energy demand per capita and sectoral indicators) are also provided. Costs and benefits associated with the Efficient World Scenario are shown in the form of the additional investment required, the impact on fossil-fuel import bills and economic and emissions indicators. A set of country/region-specific policy opportunities are listed to show, based on bottom-up analysis, what actions might appropriately be adopted to achieve the energy efficiency gains. These are ordered by sector, according to where the energy savings potential is greatest.

How to read the profiles

The country and regional profiles that follow are presented in a consistent format. Each contains a set of figures and tables corresponding to the categories described below. Major findings are drawn from these and listed in Highlights at the opening of the profiles; at their conclusion, we identify policy opportunities[2] for realising energy efficiency gains.

Primary energy demand by scenario (Figures 12.1a to 12.6a)

These charts show the change in total primary energy demand by fuel in the Efficient World Scenario relative to the New Policies Scenario between 2010 and 2035. The tables that accompany these charts show total primary energy demand by source in 2010 and 2035 in the Efficient World Scenario (EWS). The category "other renewables" includes wind, solar photovoltaic (PV), geothermal, concentrating solar power and marine.

1. See Chapter 9 for an explanation of the choice of this indicator.

2. For the buildings sector, many such opportunities include the adoption of minimum energy performance standards (MEPS).

Key indicators (Tables 12.1a to 12.6a)

These tables show historical data for energy efficiency indicators and projections in 2020 and 2035 in the New Policies Scenario (NPS) and the Efficient World Scenario (EWS). Economy-wide energy intensity is the ratio of primary energy demand (in tonnes of oil equivalent [toe]) to gross domestic product (GDP), measured in market exchange rate (MER) terms and in year-2011 dollars. Energy demand per capita is the ratio of primary energy demand (in toe) to population. Energy intensity at the sector level is measured in units that relate to the service provided:

- Residential energy intensity is the energy consumed (in kilowatt-hours [kWh]) per unit of floor space (in square metres [m^2]). Energy consumed includes all household end-uses.[3]
- Services energy intensity is the energy consumed per unit of economic value-added (VA) of the services sector (in MER terms and in thousands of year-2011 dollars, [$1 000 VA]).
- Fuel consumption in transport is the average volume of gasoline-equivalent liquid fuel consumed (in litres [l]) (across all vehicle sales) per unit of distance travelled (in 100 kilometres [km]). Fuel consumption by passenger light-duty vehicles (PLDVs) is shown under test-cycle conditions, as this is the metric used in current policy making; on-road conditions are shown as the relevant metric for fuel consumption for heavy trucks.
- Other industries energy intensity is indexed to the year 2000.
- The average thermal efficiency of fossil-fuelled power plants is the indicator shown for the power sector.

Impact on world GDP (Figure 12.1b)

This chart shows the impact of the Efficient World Scenario on real world GDP and economic value-added by sector. Projections are provided by OECD (2012).

Fossil fuel net trade and import bills (Figures 12.2b to 12.6b)

These charts show fossil fuel net trade and import bills for oil, gas and coal in 2010 and in 2035 in the New Policies Scenario and Efficient World Scenario. Fossil fuel net trade is shown in million barrels per day (mb/d) for oil, billion cubic metres (bcm) for gas and million tonnes coal equivalent (Mtce) for coal. Negative values signify exports and export revenues.

Economic and environment benefits (Tables 12.1b to 12.6b)

These tables show historical data for GDP in purchasing power parity (PPP) terms, import bills, consumer expenditures on energy, and energy-related emissions and projections for

3. The indicator illustrates current intensity and future reduction potential, and should not be used for regional comparison due to the inherent variations, such as family size, average area of a dwelling and climatic conditions.

2020 and 2035 in the New Policies Scenario and Efficient World Scenario. Energy-related emissions are shown for carbon dioxide (CO_2) (in gigatonnes [Gt]) and the major air pollutants, sulphur dioxide (SO_2), nitrogen oxides (NO_X) and particulate matter ($PM_{2.5}$) (all in million tonnes [Mt]). Historical and projected emissions of major air pollutants are from IIASA (2012).

Additional investment (Figures 12.1c to 12.6c)

These charts show incremental investment needs in end-use sectors (industry, transport, residential and services) in the Efficient World Scenario, relative to the New Policies Scenario.

Change in energy consumption in energy-intensive industries (Figures 12.1d to 12.6d)

These charts show the change in energy consumption in the iron and steel, chemicals, cement, and pulp and paper industry from 2010 to 2035 in the Efficient World Scenario. The net change in energy consumption for each industry is the result of the difference in energy consumption due to changes in activity and energy savings due to energy efficiency improvements. An accompanying table shows consumption levels in the Efficient World Scenario.

Oil savings in the transport sector (Figures 12.1e to 12.6e)

These charts show oil savings (in mb/d) achieved in different transport sub-sectors in the Efficient World Scenario, relative to the New Policies Scenario. Other road includes light commercial vehicles, trucks less than 16 tonnes, buses and two/three wheelers.

Energy demand and savings in the residential sector (Figures 12.1f to 12.6f)

These charts show residential consumption in the New Policies Scenario and the Efficient World Scenario. Energy savings over the period 2010-2035 are shown according to change in activity[4] (*i.e.* the difference in energy service demand), efficiency measures like insulation (including retrofits and energy management systems) and technology improvements in space heating (including heat pumps), appliances, cooling, lighting and others (water heating and cooking). The tables that accompany the charts show fuel savings by change in activity and technology in million tonnes of oil equivalent (Mtoe) in 2020 and 2035, as well as their share of the overall savings achieved in the residential sector in those years.

Final energy consumption (Tables 12.1c to 12.6c)

These tables show historical data for final energy consumption by sector and energy source and projections for 2020 and 2035 in the New Policies Scenario (NPS) and the Efficient World Scenario (EWS). They are not balances.

4. Appears only at world level (Figure 12.1f), reflecting the reduction in demand due to partial subsidy removal in fossil fuel-net-exporting countries.

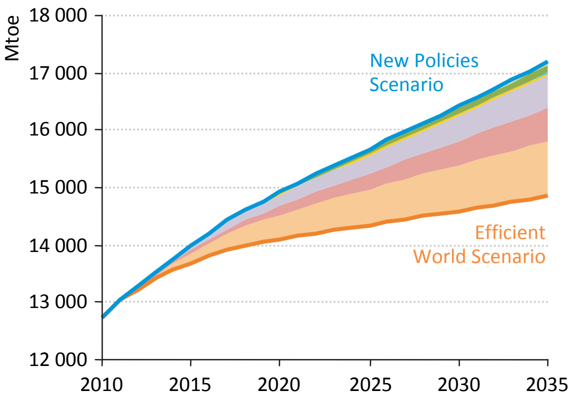
World

Highlights

- Primary energy savings achieved in the Efficient World Scenario in 2035 are equivalent to 18% of global energy demand in 2010.
- Efficiency gains boost GDP by 0.4% in 2035, relative to the New Policies Scenario.
- Additional investments required in end-use efficiency are $11.8 trillion over 2012-2035; this saves consumers $17.5 trillion in energy expenditures during that period.

Energy consumption

Figure 12.1a ▷ Global primary energy demand by scenario



EWS total primary energy demand	Mtoe 2010	Mtoe 2035
Other renewables	112	650
Bioenergy	1 277	1 749
Hydro	295	476
Nuclear	719	1 094
Gas	2 740	3 541
Oil	4 113	4 061
Coal	3 474	3 274

Table 12.1a ▷ World key indicators

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
Energy intensity (toe/million dollars, MER)	197	188	157	149	119	103
Energy demand per capita (toe/capita)	1.66	1.86	1.96	1.85	2.01	1.73
Residential energy intensity (kWh/m^2)	155	138	125	118	113	98
Services energy intensity (kWh/$1 000 VA)	219	216	191	174	148	120
Fuel consumption new PLDVs test-cycle (l/100 km)	8.5	7.6	5.8	5.1	4.9	3.5
Fuel consumption new heavy trucks on-road (l/100 km)	37	36	29	27	28	19
Energy intensity of other industries (2000=100)	100	84	72	68	56	50
Fossil-fuel power plant efficiency (%)	32%	34%	37%	37%	39%	41%

Costs and benefits

Figure 12.1b ▹ Changes in global real GDP and value-added by sector in the Efficient World Scenario relative to the New Policies Scenario

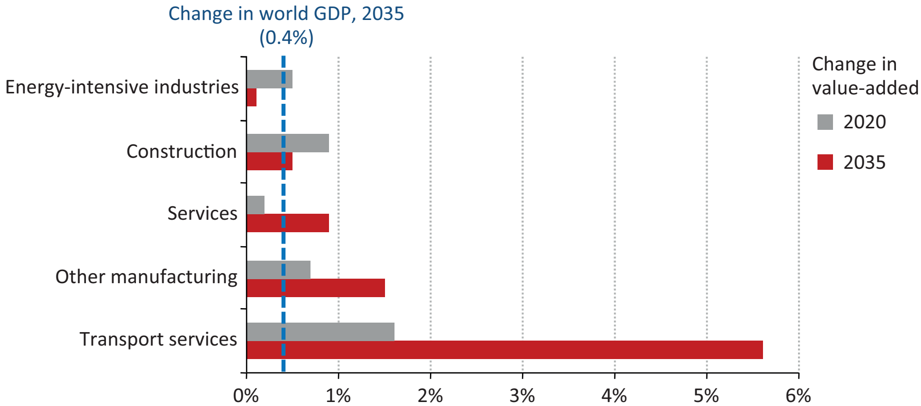


Table 12.1b ▹ Global economic and environmental benefits

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
GDP ($2011 trillion, PPP)	64.4	76.2	113.0	113.4	181.5	182.2
Consumer expenditures ($2011 billion)	4 502	5 851	8 524	8 066	10 594	9 016
CO_2 emissions (Gt)	27.4	30.2	34.6	32.0	37.0	30.5
SO_2 emissions (Mt)	97.3	86.3	75.1	69.7	72.4	62.0
NO_x emissions (Mt)	87.3	84.7	77.7	73.4	82.5	69.9
$PM_{2.5}$ emissions (Mt)	40.8	42.8	42.2	41.3	41.2	38.9

12

Figure 12.1c ▹ Global additional investment by end-use sector in the Efficient World Scenario relative to the New Policies Scenario

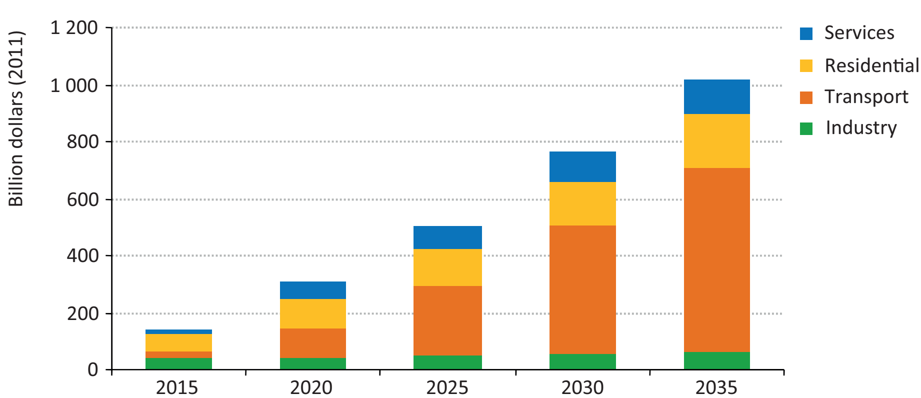
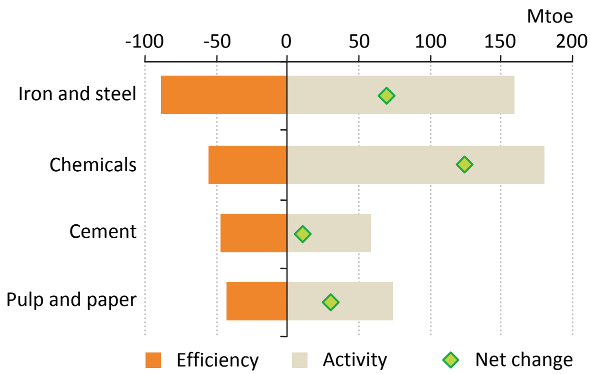


Figure 12.1d ▷ Global change in energy consumption in energy-intensive industries in the Efficient World Scenario, 2010-2035



Energy demand	Mtoe 2010	Mtoe 2035
Iron and steel	436	506
Chemicals	393	518
Cement	247	258
Pulp and paper	150	181

Figure 12.1e ▷ Global oil demand savings in the transport sector in the Efficient World Scenario relative to the New Policies Scenario

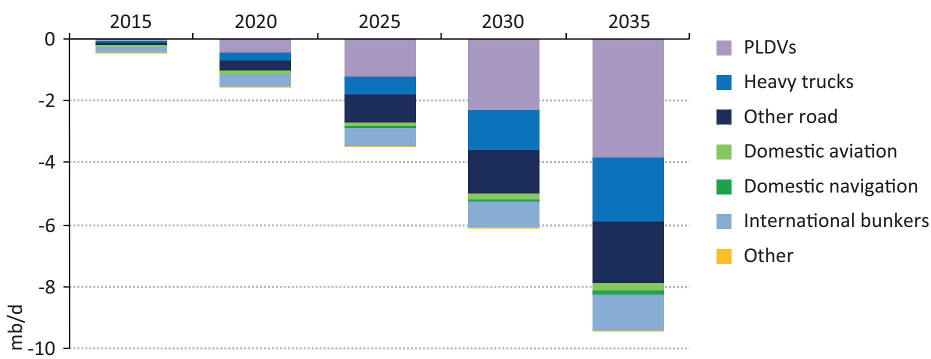
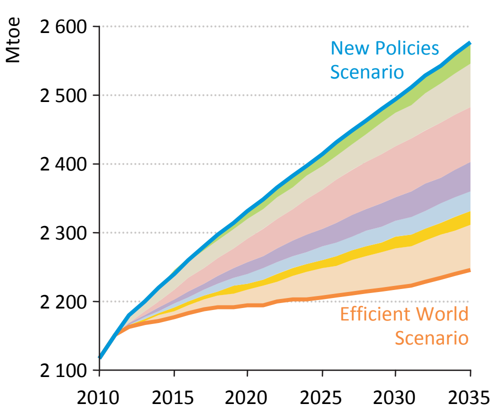


Figure 12.1f ▷ Global energy demand and savings in the residential sector in the Efficient World Scenario relative to the New Policies Scenario



Fuel savings	Mtoe 2020	Mtoe 2035	Share 2020	Share 2035
Activity	12	30	8%	9%
Insulation*	28	65	21%	20%
Space heating	34	78	25%	24%
Appliances	17	43	12%	13%
Cooling	14	29	10%	9%
Lighting	9	20	6%	6%
Others	24	67	17%	20%

* Includes energy management systems.

Table 12.1c ▷ World final energy consumption

	Energy demand (Mtoe)						% Change NPS to EWS	
			New Policies		Efficient World			
	2000	2010	2020	2035	2020	2035	2020	2035
Total final consumption	**7 078**	**8 678**	**10 223**	**11 750**	**9 789**	**10 363**	**-4**	**-12**
Coal	581	853	982	976	939	876	-4	-10
Oil	3 114	3 557	3 984	4 336	3 873	3 806	-3	-12
Gas	1 116	1 329	1 612	1 993	1 529	1 742	-5	-13
Electricity	1 091	1 537	2 047	2 676	1 893	2 297	-8	-14
Heat	247	278	303	305	287	270	-5	-12
Renewables	929	1 125	1 294	1 464	1 269	1 372	-2	-6
Industry	**1 907**	**2 421**	**3 035**	**3 497**	**2 901**	**3 171**	**-4**	**-9**
Coal	435	676	799	822	769	748	-4	-9
Oil	326	321	356	354	343	330	-4	-7
Gas	415	463	600	748	577	688	-4	-8
Electricity	459	638	890	1 133	838	999	-6	-12
Heat	100	126	138	131	133	121	-4	-8
Renewables	172	197	252	310	242	285	-4	-8
Transport	**1 952**	**2 377**	**2 778**	**3 272**	**2 704**	**2 780**	**-3**	**-15**
Oil	1 861	2 201	2 517	2 850	2 449	2 414	-3	-15
Electricity	19	24	36	57	35	56	-1	-2
Biofuels	10	59	111	206	108	176	-2	-15
Other fuels	62	93	115	159	112	134	-3	-16
Buildings	**2 451**	**2 910**	**3 302**	**3 748**	**3 080**	**3 193**	**-7**	**-15**
Coal	105	124	124	96	111	69	-10	-27
Oil	351	329	327	300	299	233	-9	-22
Gas	528	616	711	856	655	697	-8	-19
Electricity	583	831	1 062	1 402	960	1 161	-10	-17
Heat	143	148	160	170	150	145	-6	-15
Renewables	742	862	919	925	905	888	-1	-4
Other	**768**	**970**	**1 107**	**1 232**	**1 103**	**1 219**	**-0**	**-1**

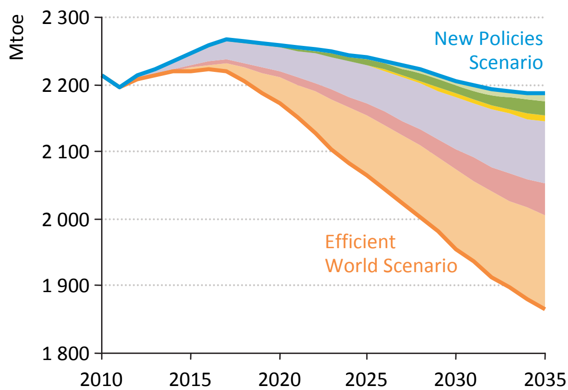
United States

Highlights

- Primary energy savings achieved in the Efficient World Scenario in 2035 are equivalent to 15% of the country's energy demand in 2010.
- Efficiency gains boost GDP by 1.7% in 2035 relative to the New Policies Scenario.
- Additional investments required in end-use efficiency are $1.9 trillion over 2012-2035; this saves consumers $2.5 trillion in energy expenditures during that period.

Energy consumption

Figure 12.2a ▷ United States primary energy demand by scenario



EWS total primary energy demand	Mtoe 2010	Mtoe 2035
Other renewables	18	89
Bioenergy	90	188
Hydro	23	28
Nuclear	219	239
Gas	556	534
Oil	805	513
Coal	503	276

Table 12.2a ▷ United States key indicators

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
Energy intensity (toe/million dollars, MER)	179	149	118	113	82	70
Energy demand per capita (toe/capita)	7.92	7.04	6.62	6.37	5.80	4.95
Residential energy intensity (kWh/m^2)	159	137	123	115	111	89
Services energy intensity (kWh/$1 000 VA)	235	218	185	174	144	113
Fuel consumption new PLDVs test-cycle (l/100 km)	10.0	8.8	5.9	5.9	4.5	3.8
Fuel consumption new heavy trucks on-road (l/100 km)	40	39	31	29	28	21
Energy intensity of other industries (2000=100)	100	85	71	69	55	50
Fossil-fuel power plant efficiency (%)	37%	40%	42%	42%	45%	49%

Costs and benefits

Figure 12.2b ▷ United States fossil fuel net trade (current) and import bills in the Efficient World Scenario and the New Policies Scenario

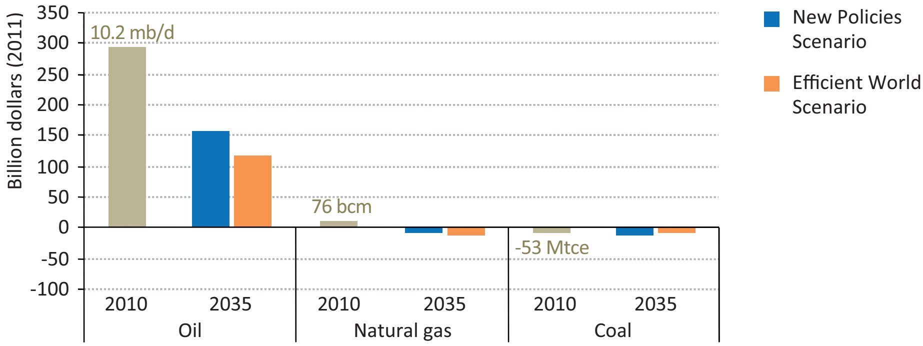


Table 12.2b ▷ United States economic and environmental benefits

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
GDP ($2011 trillion, PPP)	14.3	14.8	19.2	19.3	26.6	27.1
Energy-import bills ($2011 billion)	307	308	242	241	157	118
Consumer expenditures ($2011 billion)	1 067	1 106	1 378	1 318	1 379	1 136
CO_2 emissions (Gt)	5.7	5.3	5.2	4.9	4.3	3.5
SO_2 emissions (Mt)	13.8	7.5	4.2	4.0	3.3	2.7
NO_x emissions (Mt)	18.0	12.7	7.7	7.4	6.1	5.2
$PM_{2.5}$ emissions (Mt)	1.2	1.0	0.9	0.9	0.9	0.8

12

Figure 12.2c ▷ United States additional investment by end-use sector in the Efficient World Scenario relative to the New Policies Scenario

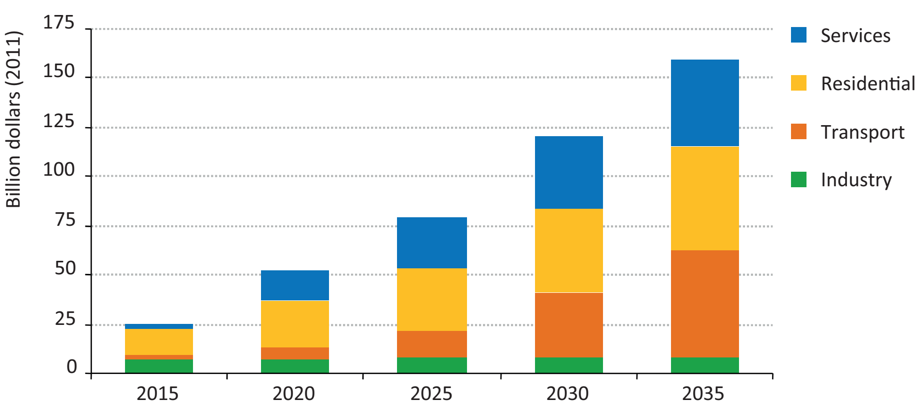
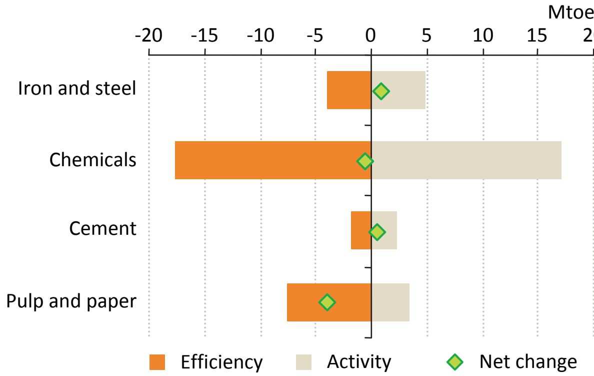


Figure 12.2d ▷ **United States change in energy consumption in energy-intensive industries in the Efficient World Scenario, 2010-2035**



Energy demand	Mtoe	
	2010	2035
Iron and steel	20	21
Chemicals	71	70
Cement	7	7
Pulp and paper	38	34

Figure 12.2e ▷ **United States oil demand savings in the transport sector in the Efficient World Scenario relative to the New Policies Scenario**

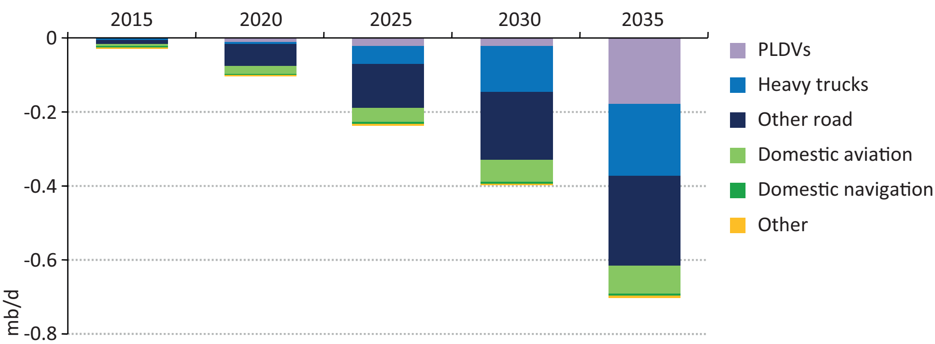
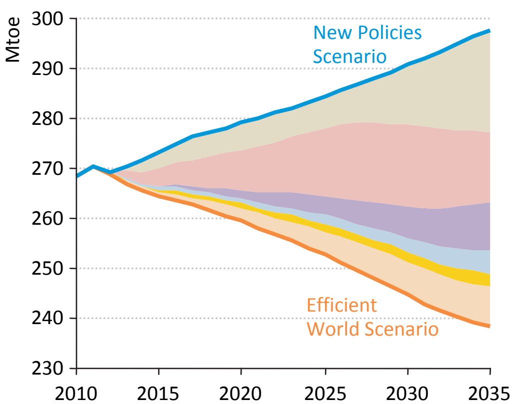


Figure 12.2f ▷ **United States energy demand and savings in the residential sector in the Efficient World Scenario relative to the New Policies Scenario**



Fuel savings	Mtoe		Share	
	2020	2035	2020	2035
Insulation*	5	21	27%	35%
Space heating	8	14	42%	23%
Appliances	2	10	9%	17%
Cooling	1	5	4%	8%
Lighting	1	3	5%	4%
Others	2	8	13%	13%

* Includes energy management systems.

Table 12.2c ▷ United States final energy consumption

	Energy demand (Mtoe)						% Change NPS to EWS	
			New Policies		Efficient World			
	2000	2010	2020	2035	2020	2035	2020	2035
Total final consumption	**1 546**	**1 500**	**1 546**	**1 482**	**1 497**	**1 299**	**-3**	**-12**
Coal	33	27	27	22	26	20	-3	-8
Oil	793	749	716	543	708	499	-1	-8
Gas	360	319	342	349	322	288	-6	-18
Electricity	301	327	359	403	342	344	-5	-15
Heat	5	7	6	4	5	3	-4	-10
Renewables	54	72	97	161	94	145	-3	-10
Industry	**332**	**280**	**290**	**275**	**280**	**253**	**-3**	**-8**
Coal	30	25	26	21	25	19	-3	-7
Oil	26	30	26	19	25	18	-3	-6
Gas	138	111	115	105	112	97	-3	-8
Electricity	98	76	79	77	76	70	-4	-8
Heat	4	5	4	3	4	3	-3	-8
Renewables	36	32	40	51	38	46	-4	-10
Transport	**588**	**583**	**576**	**480**	**572**	**437**	**-1**	**-9**
Oil	569	541	518	371	514	339	-1	-9
Electricity	0	1	1	4	1	4	0	0
Biofuels	3	25	39	77	38	70	-0	-8
Other fuels	15	16	18	28	18	24	-2	-12
Buildings	**459**	**486**	**523**	**571**	**488**	**453**	**-7**	**-21**
Coal	2	2	1	1	1	0	-8	-49
Oil	49	37	26	12	23	3	-13	-74
Gas	189	182	197	203	181	153	-8	-25
Electricity	202	251	279	322	265	269	-5	-16
Heat	1	1	1	0	1	0	-6	-29
Renewables	15	14	18	33	17	28	-5	-15
Other	**167**	**151**	**157**	**156**	**157**	**155**	**-0**	**-1**

Policy opportunities

- Make building energy codes and energy labelling schemes mandatory for all new and existing buildings; require renovations of existing buildings to incorporate stringent energy requirements and provide resources necessary for effective implementation.
- Strengthen appliance and equipment MEPS to best available technology with appropriate labelling scheme and make regular updates.
- Extend fuel-economy standards for heavy trucks to make a 45% improvement by 2035 relative to 2010.
- Require small and medium-size enterprises to carry out regular energy audits, and promote research and development into energy-efficient technologies.
- Introduce energy performance requirements for existing coal-fired power plants.

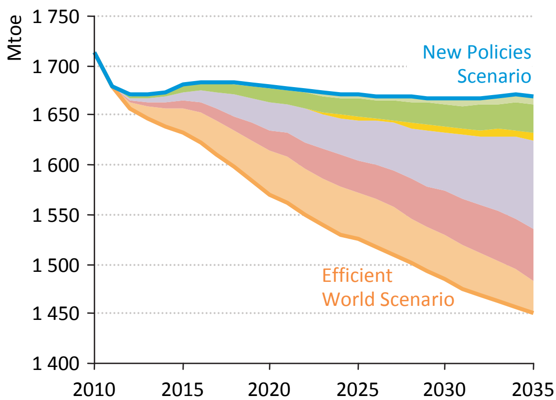
European Union

Highlights

- Primary energy savings achieved in the Efficient World Scenario in 2035 are equivalent to 13% of the region's energy demand in 2010.
- Efficiency gains boost GDP by 1.1% in 2035 relative to the New Policies Scenario.[5]
- Additional investments required in end-use efficiency are $2.2 trillion over 2012-2035; this saves consumers $4.9 trillion in energy expenditures during that period.

Energy consumption

Figure 12.3a ▷ European Union primary energy demand by scenario



EWS total primary energy demand	Mtoe 2010	Mtoe 2035
Other renewables	22	110
Bioenergy	130	203
Hydro	31	35
Nuclear	239	207
Gas	441	418
Oil	569	364
Coal	281	113

Table 12.3a ▷ European Union key indicators

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
Energy intensity (toe/million dollars, MER)	112	99	83	77	63	55
Energy demand per capita (toe/capita)	3.48	3.41	3.27	3.06	3.22	2.80
Residential energy intensity (kWh/m²)	201	193	185	167	177	142
Services energy intensity (kWh/$1 000 VA)	145	151	141	127	122	98
Fuel consumption new PLDVs test-cycle (l/100 km)	7.3	6.2	4.4	3.8	3.9	3.4
Fuel consumption new heavy trucks on-road (l/100 km)	33	31	28	24	26	16
Energy intensity of other industries (2000=100)	100	83	73	71	62	59
Fossil-fuel power plant efficiency (%)	37%	38%	39%	39%	40%	41%

5. GDP gains are for OECD Europe.

Costs and benefits

Figure 12.3b ▷ European Union fossil fuel net trade (current) and import bills in the Efficient World Scenario and the New Policies Scenario

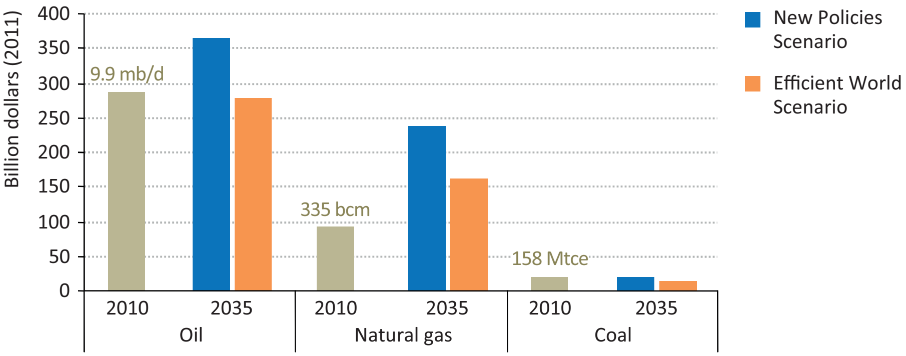


Table 12.3b ▷ European Union economic and environmental benefits

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
GDP ($2011 trillion, PPP)[5]	16.0	16.9	20.2	20.3	26.6	26.9
Energy-import bills ($2011 billion)	304	402	597	540	626	455
Consumer expenditures ($2011 billion)	1 299	1 567	1 887	1 739	2 001	1 606
CO_2 emissions (Gt)	3.9	3.6	3.3	3.0	2.7	2.3
SO_2 emissions (Mt)	2.0	4.5	2.7	2.5	2.0	1.9
NO_x emissions (Mt)	5.5	8.8	5.4	5.0	3.7	3.3
$PM_{2.5}$ emissions (Mt)	0.7	1.6	1.5	1.4	1.4	1.3

Figure 12.3c ▷ European Union additional investment by end-use sector in the Efficient World Scenario relative to the New Policies Scenario

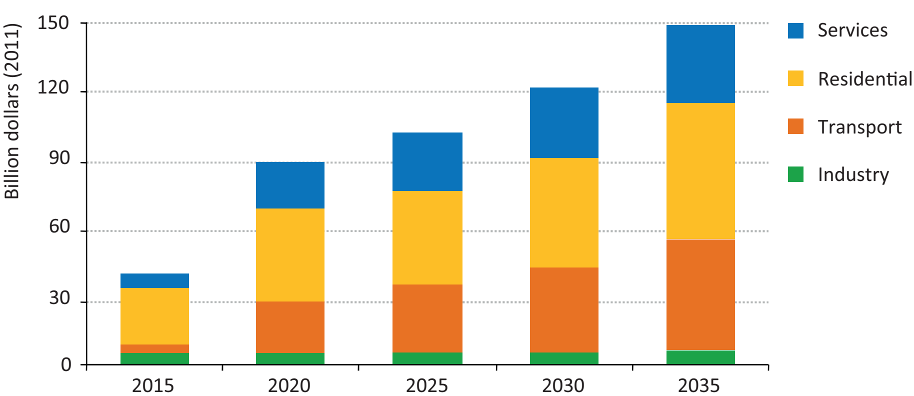
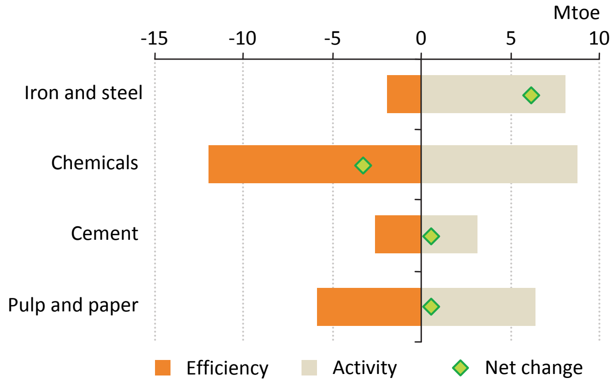


Figure 12.3d ▷ European Union change in energy consumption in energy-intensive industries in the Efficient World Scenario, 2010-2035



Energy demand	Mtoe 2010	Mtoe 2035
Iron and steel	33	39
Chemicals	55	52
Cement	16	17
Pulp and paper	32	33

Figure 12.3e ▷ European Union oil demand savings in the transport sector in the Efficient World Scenario relative to the New Policies Scenario

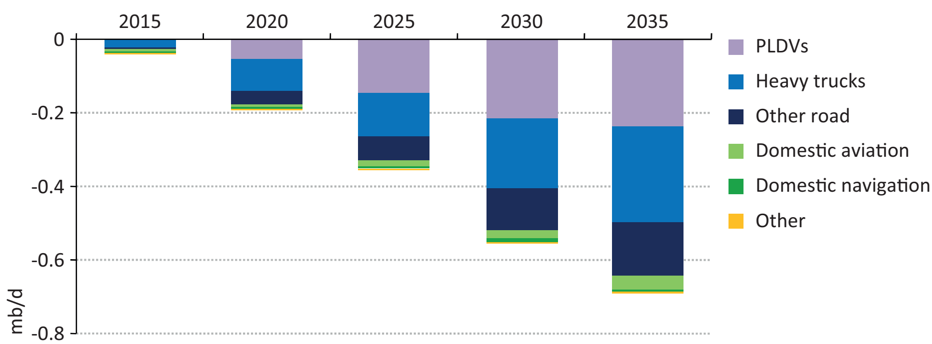
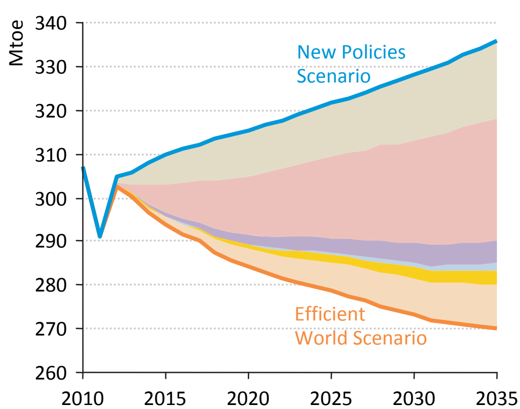


Figure 12.3f ▷ EU energy demand and savings in the residential sector in the Efficient World Scenario relative to the New Policies Scenario



Fuel savings	Mtoe 2020	Mtoe 2035	Share 2020	Share 2035
Insulation*	10	18	34%	27%
Space heating	13	28	43%	42%
Appliances	2	5	7%	8%
Cooling	0	2	1%	2%
Lighting	1	3	3%	5%
Others	4	10	13%	15%

* Includes energy management systems.

Table 12.3c ▷ European Union final energy consumption

	Energy demand (Mtoe)						% Change NPS to EWS	
			New Policies		Efficient World			
	2000	2010	2020	2035	2020	2035	2020	2035
Total final consumption	**1 169**	**1 194**	**1 201**	**1 227**	**1 134**	**1 068**	**-6**	**-13**
Coal	52	41	40	31	38	29	-5	-8
Oil	536	501	442	380	424	333	-4	-13
Gas	271	274	281	304	260	259	-7	-15
Electricity	217	244	262	288	245	252	-7	-13
Heat	44	53	58	62	55	52	-5	-17
Renewables	49	81	119	161	112	144	-6	-11
Industry	**306**	**273**	**287**	**290**	**279**	**277**	**-3**	**-4**
Coal	38	25	27	23	26	22	-1	-3
Oil	50	34	30	24	30	23	-2	-4
Gas	101	85	86	87	84	85	-2	-2
Electricity	91	89	97	99	93	93	-4	-5
Heat	10	16	16	16	15	15	-3	-7
Renewables	17	24	31	42	30	39	-3	-7
Transport	**303**	**319**	**296**	**270**	**286**	**231**	**-3**	**-14**
Oil	295	297	260	218	251	185	-4	-15
Electricity	6	6	7	10	7	10	0	1
Biofuels	1	13	26	38	25	32	-3	-15
Other fuels	1	2	3	4	3	4	-3	-10
Buildings	**421**	**470**	**495**	**544**	**446**	**437**	**-10**	**-20**
Coal	12	13	11	6	9	4	-15	-29
Oil	80	64	54	42	46	28	-14	-33
Gas	149	170	176	196	157	153	-11	-22
Electricity	115	145	154	176	141	145	-9	-18
Heat	34	37	42	47	40	37	-6	-20
Renewables	30	42	58	78	53	69	-9	-11
Other	**139**	**132**	**123**	**122**	**123**	**122**	**-0**	**0**

Policy opportunities

- Require deep renovations of existing buildings to incorporate stringent energy requirements and provide resources necessary for effective implementation.
- Strengthen appliance and equipment MEPS to best available technology with appropriate labelling; extend to more products and make regular updates.
- Implement fuel-economy standards for heavy trucks; extend and strengthen PLDV policy targets to 2035.
- Ensure the synergies of energy efficiency measures and the emissions trading system are exploited to mutually reinforce both policies and optimise their impact.

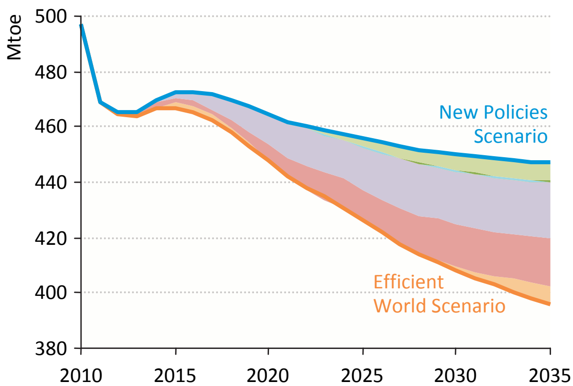
Japan

Highlights

- Primary energy savings achieved in the Efficient World Scenario in 2035 are equivalent to 10% of the country's energy demand in 2010.
- Efficiency gains boost GDP by 0.4% in 2035 relative to the New Policies Scenario.[6]
- Additional investments required in end-use efficiency are $0.5 trillion over 2012-2035; this saves consumers $1.2 trillion in energy expenditures during that period.

Energy consumption

Figure 12.4a ▷ Japan's primary energy demand by scenario



EWS total primary energy demand	Mtoe 2010	Mtoe 2035
Other renewables	4	32
Bioenergy	7	15
Hydro	7	9
Nuclear	75	45
Gas	86	82
Oil	203	27
Coal	115	85

Table 12.4a ▷ Japan's key indicators

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
Energy intensity (toe/million dollars, MER)	94	84	70	67	56	50
Energy demand per capita (toe/capita)	4.09	3.90	3.70	3.57	3.78	3.35
Residential energy intensity (kWh/m^2)	139	125	111	103	101	82
Services energy intensity (kWh/$1 000 VA)	188	178	168	155	155	123
Fuel consumption new PLDVs test-cycle (l/100 km)	7.2	6.2	4.3	4.3	3.9	3.0
Fuel consumption new heavy trucks on-road (l/100 km)	32	27	24	21	20	14
Energy intensity of other industries (2000=100)	100	83	80	79	73	71
Fossil-fuel power plant efficiency (%)	43%	45%	50%	49%	52%	53%

6. GDP gains are for Japan and Korea.

Costs and benefits

Figure 12.4b ▷ Japan's fossil fuel net trade (current) and import bills in the Efficient World Scenario and the New Policies Scenario

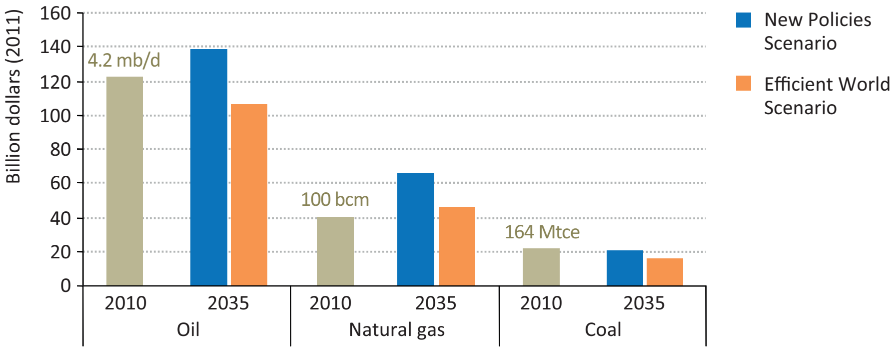


Table 12.4b ▷ Japan's economic and environmental benefits

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
GDP ($2011 trillion, PPP)[6]	5.7	6.0	7.2	7.2	9.0	9.0
Energy-import bills ($2011 billion)	141	186	243	223	226	170
Consumer expenditures ($2011 billion)	379	445	509	476	503	406
CO_2 emissions (Gt)	1.2	1.1	1.0	1.0	0.9	0.8
SO_2 emissions (Mt)	0.8	0.6	0.5	0.5	0.5	0.4
NO_x emissions (Mt)	2.3	1.7	1.0	1.0	0.8	0.7
$PM_{2.5}$ emissions (Mt)	0.2	0.2	0.1	0.1	0.1	0.1

Figure 12.4c ▷ Japan's additional investment by end-use sector in the Efficient World Scenario relative to the New Policies Scenario

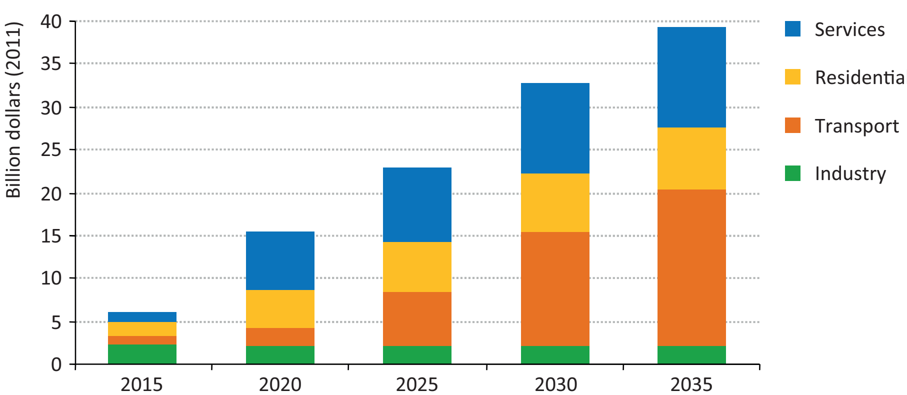
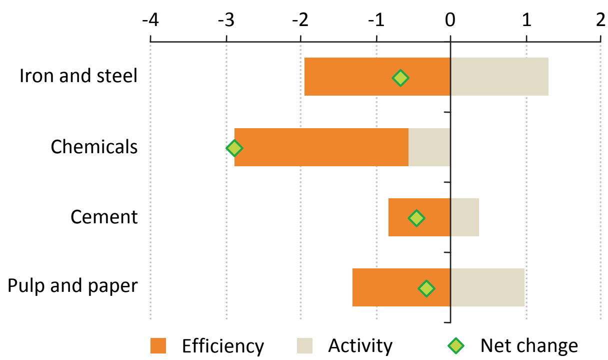


Figure 12.4d ▷ Japan's change in energy consumption in energy-intensive industries in the Efficient World Scenario, 2010-2035



Energy demand	Mtoe	
	2010	2035
Iron and steel	21	21
Chemicals	17	14
Cement	4	3
Pulp and paper	7	6

Figure 12.4e ▷ Japan's oil demand savings in the transport sector in the Efficient World Scenario relative to the New Policies Scenario

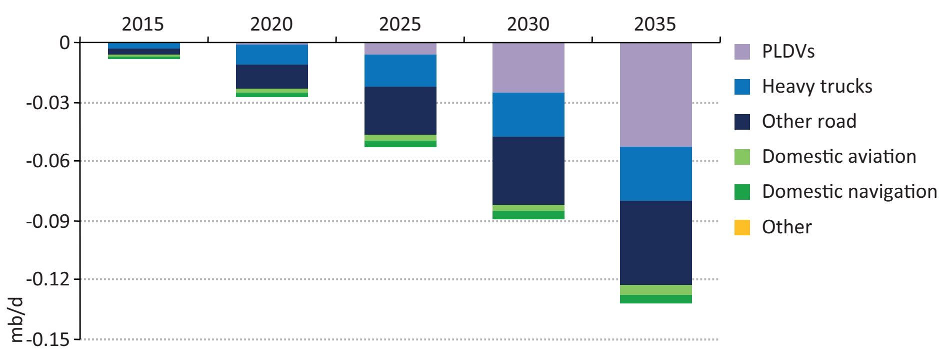
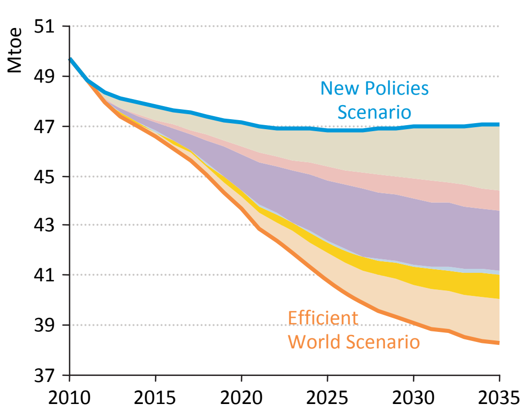


Figure 12.4f ▷ Japan's energy demand and savings in the residential sector in the Efficient World Scenario relative to the New Policies Scenario



Fuel savings	Mtoe		Share	
	2020	2035	2020	2035
Insulation*	1	3	28%	30%
Space heating	0	1	8%	9%
Appliances	1	2	42%	28%
Cooling	0	0	1%	2%
Lighting	0	1	5%	11%
Others	1	2	16%	21%

* Includes energy management systems.

Table 12.4c ▷ Japan's final energy consumption

	Energy demand (Mtoe)						% Change NPS to EWS	
			New Policies		Efficient World			
	2000	2010	2020	2035	2020	2035	2020	2035
Total final consumption	**345**	**325**	**318**	**306**	**307**	**273**	**-4**	**-11**
Coal	27	29	28	27	28	27	-1	-1
Oil	210	171	158	135	155	121	-2	-10
Gas	23	34	39	43	36	36	-6	-17
Electricity	81	86	88	93	83	81	-6	-12
Heat	1	1	1	1	1	1	-6	-19
Renewables	4	3	4	7	4	7	-1	3
Industry	**100**	**90**	**92**	**91**	**91**	**89**	**-1**	**-2**
Coal	26	28	27	27	27	26	-1	-1
Oil	35	23	22	18	22	18	-1	-1
Gas	5	8	11	13	10	13	-1	0
Electricity	31	29	29	30	29	28	-2	-4
Heat	-	-	-	-	-	-	-	-
Renewables	3	3	3	4	3	4	-3	-6
Transport	**88**	**77**	**67**	**51**	**66**	**45**	**-2**	**-13**
Oil	86	75	65	49	64	42	-2	-13
Electricity	2	2	2	3	2	2	-7	-16
Biofuels	-	-	-	-	-	-	-	-
Other fuels	-	-	0	0	0	0	-8	-22
Buildings	**111**	**114**	**116**	**124**	**108**	**100**	**-8**	**-20**
Coal	1	1	1	1	0	0	-5	-16
Oil	42	31	30	30	28	22	-7	-26
Gas	18	26	28	30	25	23	-8	-25
Electricity	48	56	57	60	52	51	-8	-16
Heat	1	1	1	1	1	1	-6	-19
Renewables	1	1	1	3	1	3	8	18
Other	**47**	**43**	**42**	**40**	**42**	**40**	**-0**	**0**

Policy opportunities

- Implement rigorous and mandatory building energy codes, with stringent energy requirements for existing buildings.
- Develop a strategy towards net zero-energy buildings in new construction and encourage the introduction of energy management systems in buildings.
- Extend and strengthen PLDV fuel-economy standards. Extend fuel-economy standards for heavy trucks to make a 45% improvement in 2035 relative to 2010.
- Introduce pricing mechanism to improve energy management and reporting for large industry and power generation.

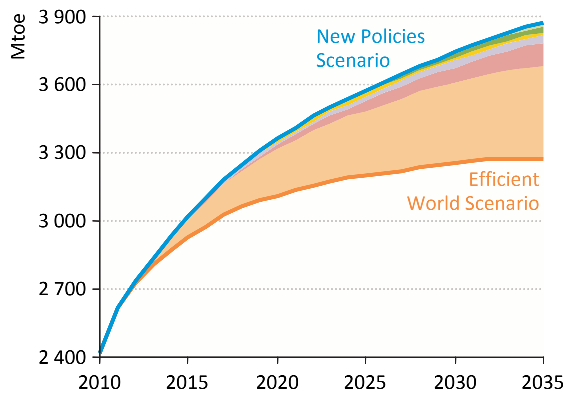
China

Highlights

- Primary energy savings achieved in the Efficient World Scenario in 2035 are equivalent to 25% of the country's energy demand in 2010.
- Efficiency gains boost GDP by 2.1% in 2035 relative to the New Policies Scenario.
- Additional investments required in end-use efficiency are $2.4 trillion over 2012-2035; this saves consumers $4.9 trillion in energy expenditures during that period.

Energy consumption

Figure 12.5a ▷ China's primary energy demand by scenario



EWS total primary energy demand	Mtoe 2010	Mtoe 2035
Other renewables	16	123
Bioenergy	206	201
Hydro	62	116
Nuclear	19	244
Gas	92	422
Oil	420	612
Coal	1 602	1 559

Table 12.5a ▷ China's key indicators

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
Energy intensity (toe/million dollars, MER)	456	350	228	211	141	119
Energy demand per capita (toe/capita)	0.94	1.80	2.41	2.23	2.79	2.36
Residential energy intensity (kWh/m^2)	132	109	98	90	85	71
Services energy intensity (kWh/$1 000 VA)	336	270	208	183	134	108
Fuel consumption new PLDVs test-cycle (l/100 km)	8	8	6.7	5.0	4.8	3.4
Fuel consumption new heavy trucks on-road (l/100 km)	43	40	30	30	29	21
Energy intensity of other industries (2000=100)	100	70	56	51	40	33
Fossil-fuel power plant efficiency (%)	28%	32%	35%	35%	38%	38%

Costs and benefits

Figure 12.5b ▷ China's fossil fuel net trade (current) and import bills in the Efficient World Scenario and the New Policies Scenario

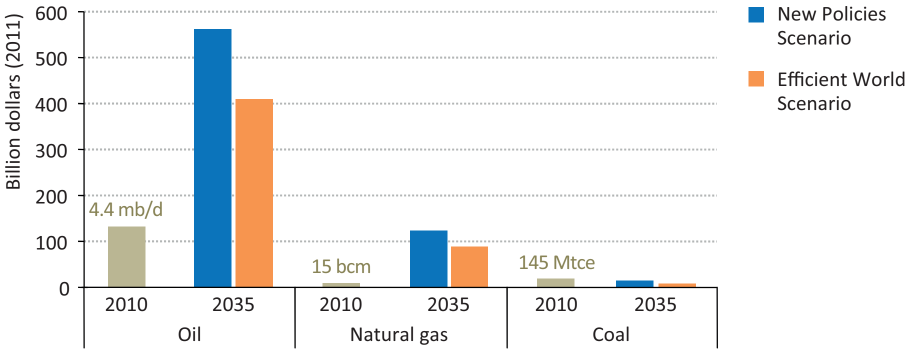


Table 12.5b ▷ China's economic and environmental benefits

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
GDP ($2011 trillion, PPP)	6.4	10.7	22.8	22.9	42.6	43.5
Energy-import bills ($2011 billion)	61	154	454	412	695	503
Consumer expenditures ($2011 billion)	267	586	1 264	1 135	1 884	1 441
CO_2 emissions (Gt)	5.4	7.2	9.5	8.6	10.2	8.3
SO_2 emissions (Mt)	32.4	29.5	26.1	24.3	21.0	18.5
NO_x emissions (Mt)	16.4	21.1	22.3	20.8	22.0	18.4
$PM_{2.5}$ emissions (Mt)	12.9	14.8	12.8	12.4	10.9	10.0

12

Figure 12.5c ▷ China's additional investment by end-use sector in the Efficient World Scenario relative to the New Policies Scenario

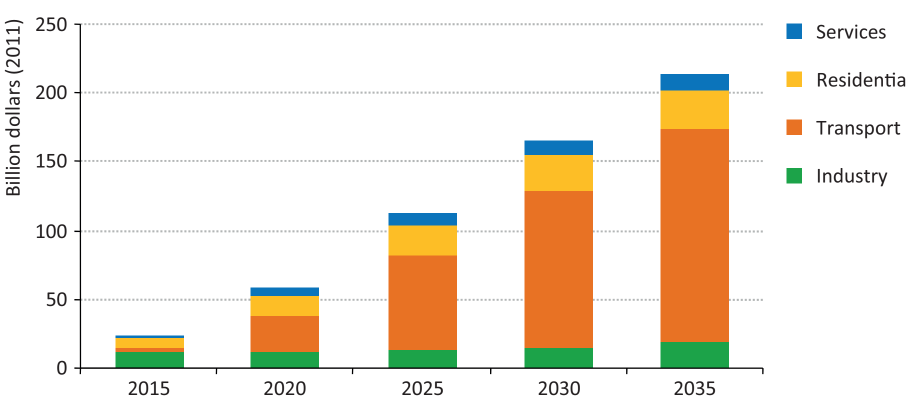
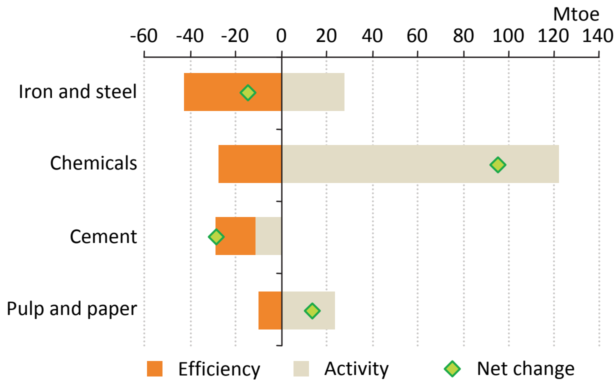


Figure 12.5d ▷ China's change in energy consumption in energy-intensive industries in the Efficient World Scenario, 2010-2035



Energy demand	Mtoe	
	2010	2035
Iron and steel	210	195
Chemicals	110	204
Cement	136	107
Pulp and paper	26	40

Figure 12.5e ▷ China's oil demand savings in the transport sector in the Efficient World Scenario relative to the New Policies Scenario

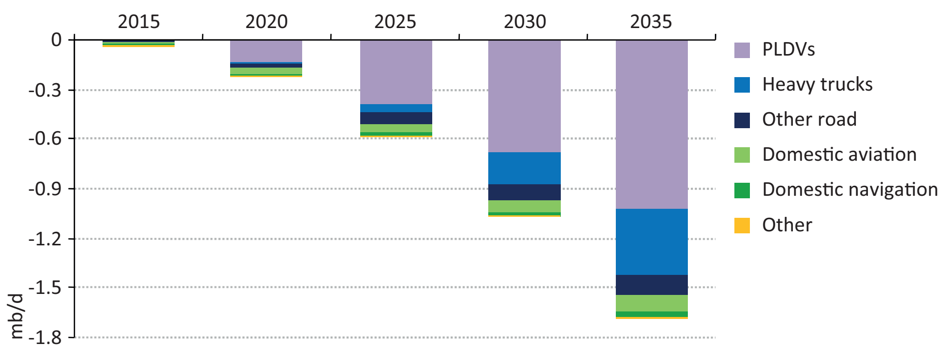
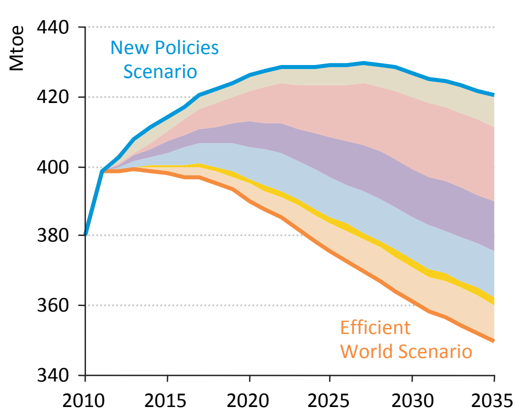


Figure 12.5f ▷ China's energy demand and savings in the residential sector in the Efficient World Scenario relative to the New Policies Scenario



Fuel savings	Mtoe		Share	
	2020	2035	2020	2035
Insulation*	4	9	12%	12%
Space heating	9	22	25%	31%
Appliances	7	14	20%	20%
Cooling	9	13	26%	18%
Lighting	1	2	4%	3%
Others	5	11	13%	15%

* Includes energy management systems.

Table 12.5c ▻ China's final energy consumption

			Energy demand (Mtoe)				% Change	
			New Policies		Efficient World		NPS to EWS	
	2000	2010	2020	2035	2020	2035	2020	2035
Total final consumption	**824**	**1 506**	**2 099**	**2 402**	**1 983**	**2 087**	**-6**	**-13**
Coal	305	514	564	478	541	432	-4	-10
Oil	184	357	554	677	538	583	-3	-14
Gas	12	57	161	269	151	241	-6	-10
Electricity	92	300	544	736	484	611	-11	-17
Heat	25	64	80	74	75	66	-6	-11
Renewables	205	213	198	168	194	154	-2	-8
Industry	**331**	**714**	**1 001**	**1 090**	**945**	**968**	**-6**	**-11**
Coal	216	401	447	385	431	356	-3	-7
Oil	32	48	63	63	60	58	-6	-7
Gas	5	16	79	120	74	111	-6	-8
Electricity	60	203	356	472	327	396	-8	-16
Heat	19	45	56	50	53	45	-6	-10
Renewables	0	0	0	0	0	0	-	-
Transport	**87**	**184**	**351**	**517**	**342**	**430**	**-3**	**-17**
Oil	82	169	323	460	315	381	-3	-17
Electricity	1	3	10	19	10	18	-0	-2
Biofuels	-	1	6	22	5	18	-3	-19
Other fuels	4	10	12	16	12	12	-4	-21
Buildings	**323**	**452**	**552**	**586**	**501**	**483**	**-9**	**-18**
Coal	59	68	67	44	59	27	-12	-39
Oil	25	49	53	39	49	29	-7	-25
Gas	3	24	56	110	51	94	-8	-14
Electricity	26	81	162	226	132	178	-19	-21
Heat	7	19	23	24	22	21	-6	-12
Renewables	205	211	191	144	187	135	-2	-7
Other	**82**	**156**	**196**	**208**	**195**	**207**	**-0**	**-1**

Policy opportunities

- Strengthen industry-wide programmes aimed at energy conservation, including sectoral targets for energy intensity improvement, and ease access to finance for energy efficiency projects.
- Continue closing inefficient industry facilities; incentivise recycling of waste materials.
- Broaden and strengthen MEPS and labelling schemes to include all major categories of appliances and equipment.
- Strengthen building energy codes and extend to new and existing buildings in small and medium cities.
- Extend and strengthen PLDV fuel-economy standards to 2035 and implement heavy truck fuel-economy standards.

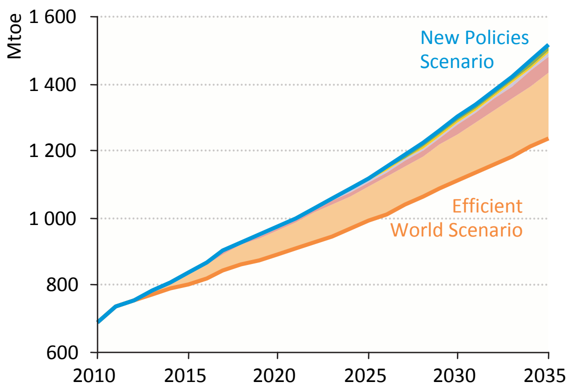
India

Highlights

- Primary energy savings achieved in the Efficient World Scenario in 2035 are equivalent to 40% of the country's energy demand in 2010.
- Efficiency gains boost GDP by 3.0% in 2035 relative to the New Policies Scenario.
- Additional investments required in end-use efficiency are $0.6 trillion over 2012-2035; this saves consumers $1.1 trillion in energy expenditures during that period.

Energy consumption

Figure 12.6a ▷ India's primary energy demand by scenario



EWS total primary energy demand	Mtoe 2010	Mtoe 2035
Other renewables	2	34
Bioenergy	170	206
Hydro	10	28
Nuclear	7	47
Gas	53	137
Oil	166	322
Coal	283	463

Table 12.6a ▷ India's key indicators

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
Energy intensity (toe/million dollars, MER)	601	442	313	286	210	171
Energy demand per capita (toe/capita)	0.45	0.59	0.73	0.67	1.00	0.82
Residential energy intensity (kWh/m^2)	220	188	154	147	124	108
Services energy intensity (kWh/$1 000 VA)	478	350	247	213	143	117
Fuel consumption new PLDVs test-cycle (l/100 km)	7	6	5.4	5.4	5.1	3.2
Fuel consumption new heavy trucks on-road (l/100 km)	44	42	33	33	31	22
Energy intensity of other industries (2000=100)	100	86	65	61	46	39
Fossil-fuel power plant efficiency (%)	29%	29%	33%	34%	38%	41%

Costs and benefits

Figure 12.6b ▷ India's fossil fuel net trade (current) and import bills in the Efficient World Scenario and the New Policies Scenario

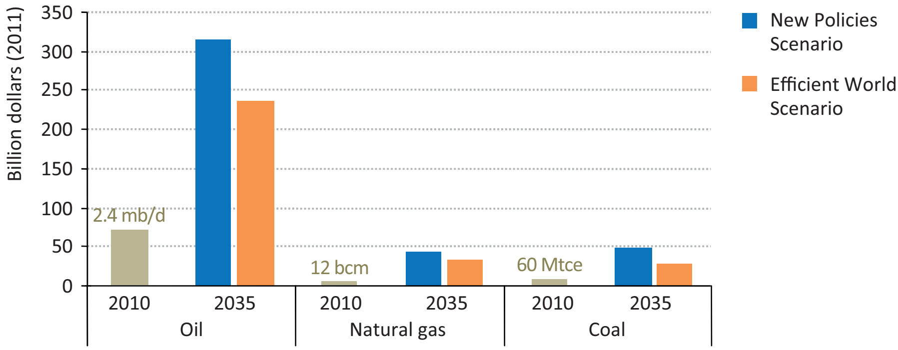


Table 12.6b ▷ India's economic and environmental benefits

	2000	2010	2020		2035	
			NPS	EWS	NPS	EWS
GDP ($2011 trillion, PPP)	2.8	4.2	8.3	8.4	19.2	19.8
Energy-import bills ($2011 billion)	42	83	200	180	406	296
Consumer expenditures ($2011 billion)	117	168	327	304	650	511
CO_2 emissions (Gt)	1.2	1.6	2.4	2.1	3.8	2.9
SO_2 emissions (Mt)	5.9	8.1	11.4	9.8	15.4	11.5
NO_x emissions (Mt)	4.2	5.5	6.8	6.3	11.8	9.5
$PM_{2.5}$ emissions (Mt)	6.0	6.1	6.6	6.3	6.8	6.1

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Figure 12.6c ▷ India's additional investment by end-use sector in the Efficient World Scenario relative to the New Policies Scenario

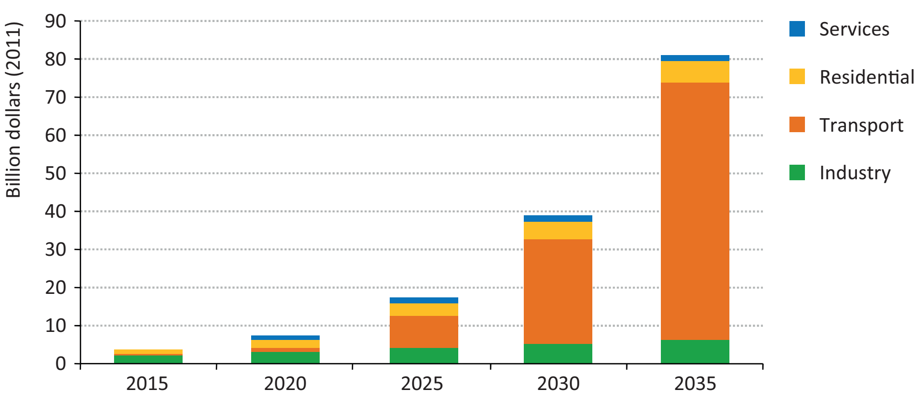
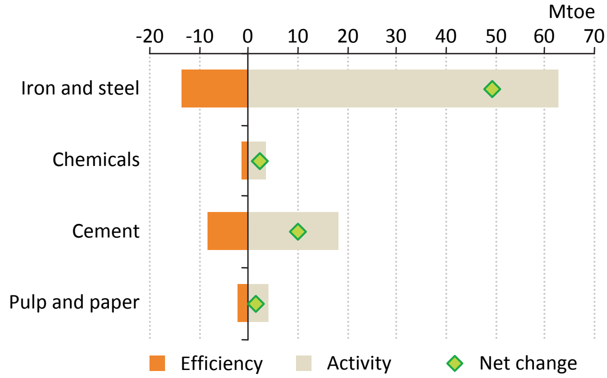


Figure 12.6d ▷ **India's change in energy consumption in energy-intensive industries in the Efficient World Scenario, 2010-2035**



Energy demand	Mtoe 2010	Mtoe 2035
Iron and steel	31	80
Chemicals	5	7
Cement	14	24
Pulp and paper	4	6

Figure 12.6e ▷ **India's oil demand savings in the transport sector in the Efficient World Scenario relative to the New Policies Scenario**

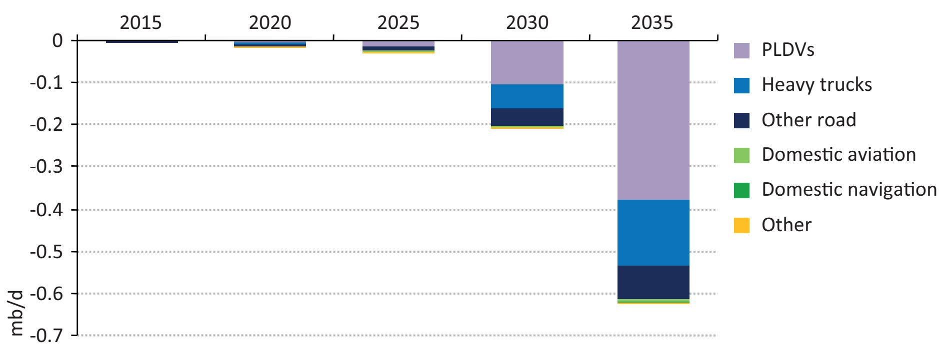
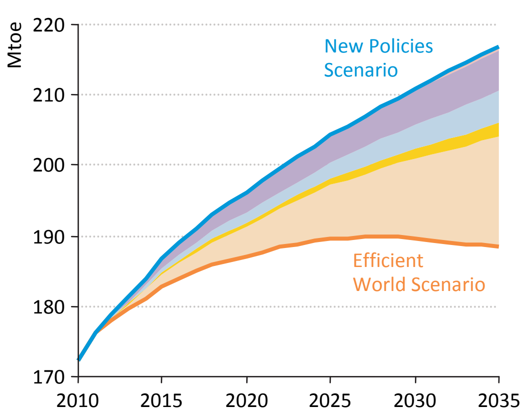


Figure 12.6f ▷ **India's energy demand and savings in the residential sector in the Efficient World Scenario relative to the New Policies Scenario**



Fuel savings	Mtoe 2020	Mtoe 2035	Share 2020	Share 2035
Insulation*	0	0	1%	1%
Space heating	0	0	1%	1%
Appliances	3	6	29%	21%
Cooling	1	5	16%	16%
Lighting	1	2	7%	7%
Others	4	16	46%	55%

* Includes energy management systems.

Table 12.6c ▻ India's final energy consumption

	Energy demand (Mtoe)						% Change NPS to EWS	
			New Policies		Efficient World			
	2000	2010	2020	2035	2020	2035	2020	2035
Total final consumption	**319**	**462**	**634**	**978**	**605**	**850**	**-5**	**-13**
Coal	33	76	122	188	113	158	-8	-16
Oil	96	132	185	340	179	296	-3	-13
Gas	10	23	29	51	29	47	1	-8
Electricity	32	61	111	212	98	175	-11	-17
Heat	-	-	-	-	-	-	-	-
Renewables	148	169	187	186	185	175	-1	-6
Industry	**87**	**152**	**236**	**375**	**220**	**322**	**-6**	**-14**
Coal	25	62	106	175	99	148	-7	-15
Oil	22	26	32	40	30	35	-6	-12
Gas	0	7	9	16	8	14	-6	-12
Electricity	14	28	51	98	47	80	-9	-19
Heat	-	-	-	-	-	-	-	-
Renewables	26	29	37	47	37	45	-2	-4
Transport	**32**	**55**	**85**	**225**	**85**	**190**	**1**	**-16**
Oil	31	52	76	200	77	170	1	-15
Electricity	1	1	2	2	2	2	-0	-0
Biofuels	0	0	2	10	2	8	0	-18
Other fuels	0	2	4	13	4	10	1	-23
Buildings	**159**	**198**	**234**	**272**	**220**	**233**	**-6**	**-14**
Coal	8	14	16	14	14	10	-12	-28
Oil	18	23	30	40	26	30	-13	-24
Gas	0	0	1	5	1	6	101	17
Electricity	10	21	40	83	33	66	-19	-21
Heat	-	-	-	-	-	-	-	-
Renewables	122	140	147	130	146	122	-1	-6
Other	**40**	**56**	**80**	**106**	**79**	**105**	**-0**	**-0**

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Policy opportunities

- Expand innovative programmes for industry, such as Perform, Achieve and Trade, offering market-based incentives for meeting improvement targets, and facilitate energy efficiency project financing by clustering small- and medium-size businesses.
- Implement rigorous and mandatory building energy codes; extend MEPS and labelling, with stringent energy requirements, to more energy-using appliances and equipment.
- Ensure that the efficiency savings continue to facilitate improved energy access, while electricity generation capacity is constrained in the near term.
- Implement PLDV fuel-economy standards.
- Continue support to the National Biomass Cookstove Initiative and extend it to cover all households by 2020.
- Direct investments in coal-fired power plants to modern and efficient technology.

ANNEXES

Policies and measures by scenario

World Energy Outlook 2012 (*WEO-2012*) presents projections for four scenarios, which are primarily differentiated by the underlying assumptions about government policies.

The ***Current Policies Scenario*** is based on the perpetuation, without change, of the government policies and measures that had been enacted by mid-2012.

The ***New Policies Scenario*** – our central scenario – takes into account broad policy commitments and plans that have already been implemented to address energy-related challenges as well as those that have been announced, even where the specific measures to implement these commitments have yet to be introduced. It assumes only cautious implementation of current commitments and plans.

The ***450 Scenario*** sets out an energy pathway that is consistent with a 50% chance of meeting the goal of limiting the increase in average global temperature to 2 °C compared with pre-industrial levels. For the period to 2020, the 450 Scenario assumes more vigorous policy action to implement fully the Cancun Agreements than is assumed in the New Policies Scenario. After 2020, OECD countries and other major economies are assumed to set economy-wide emissions targets for 2035 and beyond to collectively ensure an emissions trajectory consistent with stabilisation of the greenhouse-gas concentration at 450 parts per million.

The ***Efficient World Scenario,*** which has been developed especially for *WEO-2012,* is based on the core assumption that policies are put in place to allow the market to realise the potential of all known energy efficiency measures which are economically viable. The detailed methodology and assumptions for this scenario are presented and discussed in Chapters 9-11.

A number of the policy commitments and plans that were included in the New Policies Scenario in *WEO-2011* have since been enacted, so are now included in the Current Policies Scenario in this *Outlook.* These include, for example:

- Heavy-duty vehicle fuel-efficiency standards in the United States.
- Feed-in tariffs for renewable energy technologies in Japan.
- Programmes that put a price on CO_2 emissions (either through cap-and-trade programmes or carbon taxes) in New Zealand from 2010, in Australia as of mid-2012 and in Korea as of 2015.
- The gradual phase-out of fossil-fuel subsidies in a number of non-OECD countries.

The key policies that are assumed to be adopted in each of the main scenarios of *WEO-2012* are presented below, by sector and region. The policies are cumulative. That is, measures listed under the New Policies Scenario supplement those under the Current Policies Scenario, and measures listed under the 450 Scenario supplement those under the New Policies Scenario. The following tables start with broad cross-cutting policy frameworks and are followed by more detailed policy assumptions by sector as they have been adopted in this year's *Outlook*.

Table B.1 ▷ Cross-cutting policy assumptions by scenario for selected regions

	Current Policies Scenario	New Policies Scenario	450 Scenario
OECD			• Staggered introduction of CO_2 prices in all countries. • $100 billion annual financing provided to non-OECD countries by 2020.
United States	• State-level renewable portfolio standards (RPS) that include the option of using energy efficiency as a means of compliance. • Regional Greenhouse Gas Initiative (RGGI): mandatory cap-and-trade scheme covering fossil-fuel power plants in nine north-eastern states including recycling of revenues for energy efficiency and renewable energy investments.	• State-wide cap-and-trade scheme in California with binding commitments from 2013.	• 17% reduction in greenhouse-gas (GHG) emissions compared with 2005 by 2020. • CO_2 pricing implemented from 2020.
Japan[1]			• 25% reduction in GHG emissions compared with 1990 by 2020. • CO_2 pricing implemented from 2020.

European Union	• EU-level target to reduce GHG emissions by 20% in 2020, relative to 1990.
	• EU Emissions Trading System.
	• Renewables to reach a share of 20% in energy demand in 2020.
		• Partial implementation of the EU-level target to reduce primary energy consumption by 20% in 2020.
		  o Partial implementation of the EU Energy Efficiency Directive.
		  o National Energy Efficiency Action Plans.
			• 30% reduction in GHG emissions compared with 1990 by 2020.
			• EU ETS strengthened in line with the 2050 roadmap.
			• Full implementation of the EU Energy Efficiency Directive.

Australia and New Zealand	• Australia: Clean Energy Future Package - carbon prices through taxes/ETS as of mid-2015. • New Zealand: ETS from 2010.	• Australia: 5% reduction in GHG emissions compared with 2000 by 2020. • New Zealand: 10% cut in GHG emissions compared with 1990 by 2020.	• Australia: 25% reduction in GHG emissions compared with 2000 by 2020. • New Zealand: 20% reduction in GHG emissions compared with 1990 by 2020.
Korea	• Cap-and-trade scheme from 2015 (CO_2 emissions reductions of 4% compared with 2005 by 2020).	• 30% reduction in GHG emissions compared with business-as-usual by 2020.	• 30% reduction in GHG emissions compared with business-as-usual by 2020. • Higher CO_2 prices.

1. Japan released the Innovative Strategy for Energy and the Environment in September 2012, which aims to increase energy efficiency and the use of renewables, thereby reducing reliance on nuclear power and fossil fuels. Although not all of the details of the new strategy were available as this analysis was completed, it includes a target of electricity savings of 10% by 2030 compared with 2010.

Table B.1 ▷ Cross-cutting policy assumptions by scenario for selected regions (continued)

	Current Policies Scenario	New Policies Scenario	450 Scenario
Non-OECD	• Fossil-fuel subsidies are phased out in countries that already have policies in place to do so.	• Fossil-fuel subsidies are phased out in all net-importing regions by 2020 (at the latest) and in net-exporting regions where specific policies have already been announced.	• Finance for domestic mitigation. • Fossil-fuel subsidies are phased out by net-importers by 2020 and by exporters by 2035.*
Russia	• Gradual real increases in residential gas and electricity prices (1% per year) and in gas prices in industry (1.5% per year). • Implementation of 2009 energy efficiency legislation.	• 15% reduction in GHG emissions by 2020, compared with 1990. • 2% per year real rise in residential gas and electricity prices. • Industrial gas prices reach export prices (minus taxes and transport) in 2020. • Partial implementation of the 2010 energy efficiency state programme.	• 25% reduction in GHG emissions by 2020, compared with 1990. • Quicker rise in residential gas and electricity prices. • CO_2 pricing from 2020. • More support for nuclear and renewables. • Full implementation of the 2010 energy efficiency state programme.
China	• Implementation of measures in the 12th Five-Year Plan, including a 17% cut in CO_2 intensity by 2015 and a 16% reduction in energy intensity by 2015 compared with 2010.	• 40% reduction in CO_2 intensity compared with 2005 by 2020. • CO_2 pricing from 2020. • Share of 15% of non-fossil fuel in total supply by 2020.	• 45% reduction in CO_2 intensity compared with 2005 by 2020; higher CO_2 pricing. • Reduction of local air pollutants from 2010 to 2015 (8% for sulphur dioxide, 10% for nitrogen oxides).
India	• Trading of renewable energy certificates. • National solar mission and national mission on enhanced energy efficiency. • 11th Five-Year Plan (2007-2012).	• 20% reduction in CO_2 intensity compared with 2005 by 2020.	• 25% reduction in CO_2 intensity compared with 2005 by 2020.
Brazil	• 2011 National Energy Plan.	• 36% reduction in GHG emissions compared with business-as-usual by 2020.	• 39% reduction in GHG emissions compared with business-as-usual by 2020. • CO_2 pricing from 2020.

*Except in the Middle East where subsidisation rates are assumed to decline to a maximum of 20% by 2035.

Note: Pricing of CO_2 emissions is either by an emissions trading scheme (ETS) or taxes.

Table B.2 ▷ Power sector policies and measures as modelled by scenario in selected regions

	Current Policies Scenario	New Policies Scenario	450 Scenario
OECD			
United States	• State-level renewable portfolio standards (RPS) and support for renewables prolonged over the projection period. • Lifetimes of most US nuclear plants extended beyond 60 years. • Funding for CCS (demonstration-scale).	• Shadow price of carbon adopted from 2015, affecting investment decisions in power generation. • Mercury and Air Toxics Standard (MATS). • Cross-State Air Pollution Rule (CSAPR) regulating sulphur oxides and nitrogen oxides emissions. • Extension and strengthening of support for renewables and nuclear, including loan guarantees.	• CO_2 pricing implemented from 2020. • Extended support to renewables, nuclear and CCS. • Efficiency and emission standards preventing refurbishment of old inefficient plants.
Japan	• Support for renewables generation. • Decommissioning of units 1-4 of Fukushima Daiichi nuclear power plant.	• Shadow price of carbon adopted from 2015, affecting investment decisions in power generation. • Lifetime of nuclear power plants limited to 40 years for plants built until 1990 and 50 years for all others. • Increased support for renewables generation.	• CO_2 pricing implemented from 2020. • Share of low-carbon electricity generation to increase by 2020 and expand further by 2030. • Expansion of renewables support. • Introduction of CCS to coal-fired power generation.
European Union	• Climate and Energy Package: ○ Emissions Trading System. ○ Support for renewables sufficient to reach 20% share of energy demand in 2020. ○ Financial support for CCS, including use of credits from the Emissions Trading System New Entrants' Reserve. • Early retirement of all nuclear plants in Germany by the end of 2022. • Removal of some barriers to combined heat and power (CHP) plants resulting from the Cogeneration Directive 2004.	• Extended and strengthened support to renewables-based electricity generation technologies. • Further removal of barriers to CHP due to partial implementation of the Energy Efficiency Directive.	• Emissions Trading System strengthened in line with the 2050 roadmap. • Reinforcement of government support in favour of renewables. • Expanded support measures for CCS.

Note: CCS = carbon capture and storage.

Table B.2 ▷ Power sector policies and measures as modelled by scenario in selected regions (continued)

	Current Policies Scenario	New Policies Scenario	450 Scenario
Non-OECD			
Russia	• Competitive wholesale electricity market.	• State support to the nuclear and hydropower sectors; a support mechanism for non-hydro renewables introduced from 2014.	• CO_2 pricing implemented from 2020. • Stronger support for nuclear power and renewables.
China	• Implementation of measures in 12th Five-Year Plan. • Start construction of 40 GW of new nuclear plants by 2015. • Start construction of 120 GW of hydropower by 2015. • Wind capacity additions of 70 GW by 2015. • Solar additions of 5 GW by 2015. • Priority given to gas use to 2015.	• 12th Five-Year Plan renewables targets for 2015 are exceeded. • 70 to 80 GW of nuclear capacity by 2020. • 200 GW of wind capacity by 2020. • Solar capacity of 50 GW by 2020; subsidies for building-integrated PV projects. • 30 GW of biomass capacity by 2020. • CO_2 pricing implemented from 2020.	• Higher CO_2 pricing. • Enhanced support for renewables. • Continued support to nuclear capacity additions post 2020. • Deployment of CCS from around 2020.
India	• Renewable Energy Certificate trade for all eligible grid-connected renewable-based electricity generation technologies. • National solar mission target of 20 GW of solar PV capacity by 2022. • Increased use of supercritical coal technology.	• Renewable energy support policies and targets, including small hydro. • Coal-fired power stations energy efficiency mandates.	• Renewables (excluding large hydro) to reach 15% of installed capacity by 2020. • Expanded support to renewables, nuclear and efficient coal. • Deployment of CCS from around 2020.
Brazil	• Increase of wind, biomass and hydro (small and large) capacity. • Auctions for renewables-based power generation.	• Enhanced deployment of renewables technologies. • Implementation of measures in the Ten-Year Plan for Energy Expansion (PDE2020).	• CO_2 pricing implemented from 2020. • Further increases of generation from renewable sources.

Note: CCS = carbon capture and storage.

Table B.3 ▷ Transport sector policies and measures as modelled by scenario in selected regions

OECD	Current Policies Scenario	New Policies Scenario
United States	• CAFE standards: 34.5 miles-per-gallon for PLDVs by 2016, and further strengthening thereafter. • Renewables Fuel Standard. • Truck standards for each model year from 2014 to 2018 reduce average on-road fuel consumption by up to 18% in 2018.	• CAFE standards: 54.5 miles-per-gallon for PLDVs by 2025. • Renewables Fuel Standard. • Truck standards for each model year from 2014 to 2018 reduce average on-road fuel consumption by up to 21% in 2018. • Support to natural gas in road freight. • Increase of ethanol blending mandates.
Japan	• Fuel economy target for PLDVs: 16.8 kilometres per litre (km/l) by 2015. • Average fuel economy target for road freight vehicles: 7.09 km/l by 2015. • Fiscal incentives for hybrid and electric vehicles; subsidies for electric vehicles.	• Fuel economy target for PLDVs: 20.3 km/l by 2020. • Target share of next generation vehicles 50% by 2020.
European Union	• Climate and Energy Package: renewables to reach 10% of transport energy demand in 2020; CO_2 emission standards for PLDVs by 2015 (130 g CO_2/km through efficiency measures, additional 10 g CO_2/km by alternative fuels). • Support to biofuels. • Emissions Trading System to include aviation from 2012.	• More stringent emission target for PLDVs (95 g CO_2/km by 2020), and further strengthening post 2020. • Emission target for LCVs (147 g CO_2/km by 2020), and further strengthening post 2020. • Enhanced support to alternative fuels.

450 Scenario	
All OECD	
On-road emission targets for PLDVs in 2035	65 g CO_2/km
Light-commercial vehicles	Full technology spill-over from PLDVs.
Medium- and heavy-freight traffic	45% more efficient by 2035 than in New Policies Scenario.
Aviation	50% efficiency improvements by 2035 (compared with 2010) and support for the use of biofuels.
Other sectors such as maritime and rail	National policies and measures.
Fuels	Retail fuel prices kept at a level similar to New Policies Scenario.
Alternative clean fuels	Enhanced support to alternative fuels.

Notes: CAFE = Corporate Average Fuel Economy; PLDVs = passenger light-duty vehicles; LCV = light-commercial vehicles.

Table B.3 ▷ Transport sector policies and measures as modelled by scenario in selected regions (continued)

	Current Policies Scenario	New Policies Scenario
Non-OECD		
China	• Subsidies for hybrid and electric vehicles. • Promotion of fuel-efficient cars. • Ethanol blending mandates 10% in selected provinces.	• Fuel economy target PLDVs: 6.9 l/100 km by 2015, 5.0 l/100 km by 2020. • Extended subsidies for the purchase of alternative vehicles. • Increased biofuels blending.
India	• Support for alternative fuel vehicles.	• Extended support for alternative fuel vehicles. • Proposed auto fuel efficiency standards to reduce average test-cycle fuel consumption by 1.3% per year between 2010 and 2020. • Increased utilisation of natural gas in road transport.
Brazil	• Ethanol targets in road transport 20% to 25%. • Biodiesel blending mandate of 5%. • Voluntary fuel efficiency labelling scheme for PLDVs.	• Increase of ethanol targets and biodiesel mandates. • Local renewable fuel targets for urban transport.

450 Scenario	
All non-OECD	
On-road emission targets for PLDVs in 2035	85 g CO_2/km
Light-commercial vehicles	Full technology spill-over from PLDVs.
Medium- and heavy-freight traffic	45% more efficient by 2035 than in New Policies Scenario.
Aviation	50% efficiency improvements by 2035 (compared with 2010) and support for the use of biofuels.
Other sectors such as maritime and rail	National policies and measures.
Fuels	Retail fuel prices kept at a level similar to New Policies Scenario.
Alternative clean fuels	Enhanced support to alternative fuels.

Note: PLDVs = passenger light-duty vehicles.

Table B.4 ▷ Industry sector policies and measures as modelled by scenario in selected regions

	Current Policies Scenario	New Policies Scenario	450 Scenario
OECD			**All OECD**
United States	• Support for high-energy efficiency technologies. • Energy Star Program for Industry.	• Tax reduction and funding for efficient technologies. • R&D in low-carbon technologies. • Energy certification programme.	• CO_2 pricing introduced from 2025 at the latest in all countries. • International sectoral agreements with energy intensity targets for iron and steel and cement industries. • Enhanced energy efficiency standards. • Policies to support the introduction of CCS in industry.
Japan	• Energy efficiency benchmarking. • Tax credits for investments in energy efficiency. • Mandatory energy management for large business operators. • Top-runner programme setting minimum energy standards, including for lighting, space heating, and transformers.	• Maintenance and strengthening of top-end/low carbon efficiency standards by: ○ Higher efficiency CHP systems. ○ Promotion of state-of-the-art technology and faster replacement of aging equipment.	
European Union	• Emissions Trading System. • Effort sharing decision: ○ Energy Performance Directive for Buildings. ○ Eco-Design Directive (including minimum standards for electric motors). • Voluntary energy efficiency agreements in several countries.	• Partial implementation of Energy Efficiency Directive. • Directive on energy end-use efficiency and energy efficiency, including the development of: ○ Inverters for electric motors. ○ High-efficiency co-generation. ○ Mechanical vapour compression. ○ Innovations in industrial processes.	

Notes: ETS = emissions trading system; R&D = research and development; CHP = combined heat and power; CCS = carbon capture and storage.

Table B.4 ▷ Industry sector policies and measures as modelled by scenario in selected regions (continued)

	Current Policies Scenario	New Policies Scenario	450 Scenario
Non-OECD			**All non-OECD**
Russia	• Competitive wholesale electricity market price. • Mandatory energy audits for energy-intensive industries. • Complete phase-out of open hearth furnaces in the iron and steel industry.	• Industrial gas prices reach the equivalent of export prices (minus taxes and transportation) in 2020. • Elaboration of comprehensive federal and regional legislation on energy savings, including implementation of energy management systems.	• CO_2 pricing introduced as of 2020 in Russia, China, Brazil and South Africa. • Wider hosting of international offset projects. • International sectoral agreements with targets for iron and steel and cement industries. • Enhanced energy-efficiency standards. • Policies to support the introduction of CCS in industry.
China	• Priority given to gas use to 2015 (12th Five-Year Plan). • Partial implementation of the Top-10 000 energy-consuming enterprises programme. • Small plant closures and phasing out of outdated production capacity.	• Full implementation of the Top-10 000 energy-consuming enterprises programme. • CO_2 pricing implemented from 2020. • Contain the expansion of energy-intensive industries. • Partial implementation of reduction in energy intensity of large-scale companies by 21% during the 12th Five-Year Plan period (2011-2015). • Enhanced use of energy service companies and energy performance contracting. • Industrial Energy Performance Standard. • Mandatory adoption of coke dry quenching and top-pressure turbines in new iron and steel plants. • Support non-blast furnace iron making.	

India	• Perform Achieve and Trade (PAT) mechanism, targeting a 5% reduction in energy use by 2015 compared with 2010.	• Further implementation of National Mission for Enhanced Energy Efficiency recommendations including:
		  ○ Enhancement of cost-effective improvements in energy efficiency in energy-intensive large industries and facilities through tradable certificates.
		  ○ Financing mechanism for demand-side management programmes.
		  ○ Development of fiscal instruments to promote energy efficiency.
		• Mandatory adoption of coke dry quenching and top-pressure turbines in new iron and steel plants.	

Brazil	• Encourage investment and R&D in energy efficiency. • National Climate Change Plan including improvements in energy efficiency.	• Higher use of charcoal in blast furnaces as a substitute for coal. • Implementation of measures included in the 2010 energy efficiency state programme.	

Table B.5 ▷ Buildings sector policies and measures as modelled by scenario in selected regions

	Current Policies Scenario	New Policies Scenario	450 Scenario
OECD			
United States	• AHAM-ACEEE Multi-Product Standards Agreement. • American Recovery and Reinvestment Act (2009): funding for energy efficiency and renewables. • Energy Star: federal tax credits for consumer energy efficiency; new appliance efficiency standards. • Energy Improvement and Extension Act of 2008.	• Extensions to 2025 of tax credits for energy-efficient equipment (including furnaces, boilers, air conditioners, air and ground source heat pumps, water heaters and windows), and for solar PV and solar thermal water heaters. • Budget proposals 2011 - institute programmes to make commercial buildings 20% more efficient by 2020; tax credit for renewable energy deployment. • Mandatory energy requirements in building codes in some states.	• Mandatory energy requirements in building codes in all states by 2020. • Extension of energy efficiency grants to end of projection period. • Zero-energy buildings initiative.
Japan	• Top Runner Programme. • Long-Term Outlook on Energy Supply and Demand (2009): energy savings using demand-side management.	• Extension of the Top Runner Programme to cover more products. • High-efficiency lighting: 100% in public facilities by 2020; 100% of lighting stock by 2030. • Voluntary buildings labelling; national voluntary equipment labelling programmes. • Net zero-energy buildings by 2030 for all new construction. • Increased introduction of gas and renewable energy.	• Rigorous and mandatory building energy codes for all new and existing buildings. • Net zero-energy buildings by 2025 for all new construction.
European Union	• Energy Performance of Buildings Directive. • Eco-Design and Energy Labelling Directive. • EU-US Energy Star Agreement: energy labelling of appliances.	• Energy Efficiency Directive. • Building energy performance requirements for new buildings (zero-energy buildings by 2021) and for existing buildings when extensively renovated. 3% renovation rate of central government buildings. • Mandatory energy labelling for sale or rental of all buildings and some appliances, lighting and equipment. • Further product groups in EcoDesign Directive. • Phase-out of incandescent light bulbs.	• Zero-carbon footprint for all new buildings as of 2015; enhanced energy efficiency in all existing buildings.

Notes: ACEEE = American Council for an Energy-Efficient Economy; AHAM = Association of Home Appliance Manufacturers.

Table B.5 ▷ Buildings sector policies and measures as modelled by scenario in selected regions (continued)

	Current Policies Scenario	New Policies Scenario	450 Scenario
Non-OECD			
Russia	• Implementation of 2009 energy efficiency legislation.	• Gradual above-inflation increase in residential electricity and gas prices. • New building codes, meter installations and refurbishment programmes, leading to efficiency gains in space heating (relative to Current Policies Scenario). • Information and awareness on energy efficiency classes for appliances. • Phase-out of incandescent >100 Watt light bulbs.	• Faster liberalisation of gas and electricity prices. • Extension and reinforcement of all measures included in the 2010 energy efficiency state programme; mandatory building codes by 2030 and phase-out of inefficient equipment and appliances by 2030.
China	• Civil Construction Energy Conservation Design Standard. • Appliance standards and labelling programme.	• Energy-efficient buildings to account for 30% of all new construction projects by 2020. • Civil Construction Energy Conservation Design Standard: heating energy consumption per unit area of existing buildings to be reduced by 65% in cold cold regions; 50% in hot-in-summer and cold-in-winter regions compared to 1980-1981 levels. New buildings: 65% improvement in all regions. • Energy Price Policy (reform heating price to be based on actual consumption, rather than on living area supplied). • Mandatory energy efficiency labels for appliances and equipment. • Labelling mandatory for new, large commercial and governmental buildings in big cities. • Mandatory codes for all new large residential buildings in big cities.	• More stringent implementation of Civil Construction Energy Conservation Design Standard. • Mandatory energy efficiency labels for all appliances and also for building shell.
India	• Measures under national solar mission. • Energy Conservation Building Code 2007, with voluntary requirements for commercial and residential buildings.	• Mandatory standards and labels for room air conditioners and refrigerators, voluntary for 5 other products. • Phase out of incandescent light bulbs by 2020. • Voluntary Star Ratings for the services sector.	• Mandatory energy conservation standards and labelling requirements for all equipment and appliances by 2025. • Increased penetration of energy efficient lighting.

Definitions

This annex provides general information on terminology used throughout *WEO-2012* including: units and general conversion factors; definitions of fuels, processes and sectors; regional and country groupings; abbreviations and acronyms.

Units

Area	Ha	hectare
	GHa	giga-hectare (1 hectare x 10^9)
	km^2	square kilometre
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)
	kg CO_2-eq	kilogrammes of carbon-dioxide equivalent
	g CO_2/km	grammes of carbon dioxide per kilometre
	g CO_2/kWh	grammes of carbon dioxide per kilowatt-hour
Energy	Mtce	million tonnes of coal equivalent (equals 0.7 Mtoe)
	boe	barrels of oil equivalent
	toe	tonne of oil equivalent
	ktoe	kilotonne of oil equivalent
	Mtoe	million tonnes of oil equivalent
	MBtu	million British thermal units
	kcal	kilocalorie (1 calorie x 10^3)
	Gcal	gigacalorie (1 calorie x 10^9)
	MJ	megajoule (1 joule x 10^6)
	GJ	gigajoule (1 joule x 10^9)
	TJ	terajoule (1 joule x 10^{12})
	PJ	petajoule (1 joule x 10^{15})
	EJ	exajoule (1 joule x 10^{18})
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
Gas	mcm	million cubic metres

	bcm	billion cubic metres
	tcm	trillion cubic metres
	scf	standard cubic foot
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	barrels per day
	kb/d	thousand barrels per day
	mb/d	million barrels per day
	mpg	miles per gallon
Power	W	watt (1 joule per second)
	kW	kilowatt (1 Watt x 10^3)
	MW	megawatt (1 Watt x 10^6)
	GW	gigawatt (1 Watt x 10^9)
	GW_{th}	gigawatt thermal (1 Watt x 10^9)
	TW	terawatt (1 Watt x 10^{12})

General conversion factors for energy

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

Currency conversions

Exchange rates (2011)	1 US Dollar equals:
Australian Dollar	0.97
British Pound	0.62
Canadian Dollar	0.99
Chinese Yuan	6.47
Euro	0.72
Indian Rupee	46.26
Japanese Yen	79.84
Korean Won	1 107.81
Russian Ruble	29.42

Definitions

Advanced biofuels

Advanced biofuels comprise different emerging and novel conversion technologies that are currently in the research and development, pilot or demonstration phase. This definition differs from the one used for "Advanced Biofuels" in the US legislation, which is based on a minimum 50% lifecycle greenhouse-gas reduction and which, therefore, includes sugarcane ethanol.

Advanced biomass cookstoves

Advanced biomass cookstoves are biomass gasifier-operated cooking stoves that run on solid biomass, such as wood chips and briquettes. These cooking devices have significantly lower emissions and higher efficiencies than the traditional biomass cookstoves (three-stone fires) currently used largely in developing countries

Agriculture

Includes all energy used on farms, in forestry and for fishing.

Biodiesel

Biodiesel is a diesel-equivalent, processed fuel made from the transesterification (a chemical process which removes the glycerine from the oil) of both vegetable oils and animal fats.

Bioenergy

Refers to the energy content in solid, liquid and gaseous products derived from biomass feedstocks and biogas. This includes biofuels for transport and products (e.g. wood chips, pellets, black liquor) to produce electricity and heat. Municipal solid waste and industrial waste are also included.

Biofuels

Biofuels are fuels derived from biomass or waste feedstocks and include ethanol and biodiesel. They can be classified as conventional and advanced biofuels according to the technologies used to produce them and their respective maturity.

Biogas

A mixture of methane and carbon dioxide produced by bacterial degradation of organic matter and used as a fuel.

Brown coal

Includes lignite and sub-bituminous coal where lignite is defined as non-agglomerating coal with a gross calorific value less than 4 165 kilocalories per kilogramme (kcal/kg) and sub-bituminous coal is defined as non-agglomerating coal with a gross calorific value between 4 165 kcal/kg and 5 700 kcal/kg.

Buildings

The buildings sector includes energy used in residential, commercial and institutional buildings, and non-specified other. Building energy use includes space heating and cooling, water heating, lighting, appliances and cooking equipment.

Bunkers

Includes both international marine bunkers and international aviation bunkers.

Capacity credit

Capacity credit refers to the proportion of capacity that can be reliably expected to generate electricity during times of peak demand in the grid to which it is connected.

Clean coal technologies

Clean coal technologies (CCTs) are designed to enhance the efficiency and the environmental acceptability of coal extraction, preparation and use.

Coal

Coal includes both primary coal (including hard coal and brown coal) and derived fuels (including patent fuel, brown-coal briquettes, coke-oven coke, gas coke, gas-works gas, coke-oven gas, blast-furnace gas and oxygen steel furnace gas). Peat is also included.

Coalbed methane

Methane found in coal seams. Coalbed methane (CBM) is a source of unconventional natural gas.

Coal-to-liquids

Coal-to-liquids (CTL) refers to the transformation of coal into liquid hydrocarbons. It can be achieved through either coal gasification into syngas (a mixture of hydrogen and carbon monoxide), combined using the Fischer-Tropsch or methanol-to-gasoline synthesis process to produce liquid fuels, or through the less developed direct-coal liquefaction technologies in which coal is directly reacted with hydrogen.

Coking coal

Coking coal is a type of hard coal that can be used in the production of coke, which is capable of supporting a blast furnace charge.

Condensates

Condensates are liquid hydrocarbon mixtures recovered from associated or nonassociated gas reservoirs. They are composed of C5 and higher carbon number hydrocarbons and normally have an API gravity between 50° and 85°.

Conventional biofuels

Conventional biofuels include well-established technologies that are producing biofuels on a commercial scale today. These biofuels are commonly referred to as firstgeneration and include sugarcane ethanol, starchbased ethanol, biodiesel, Fatty Acid Methyl Esther (FAME) and Straight Vegetable Oil (SVO). Typical feedstocks used in these mature processes include sugarcane and sugar beet, starch bearing grains, like corn and wheat, and oil crops, like canola and palm, and in some cases, animal fats.

Electricity generation

Defined as the total amount of electricity generated by power only or combined heat and power plants including generation required for own use. This is also referred to as gross generation.

Ethanol

Although ethanol can be produced from a variety of fuels, in this publication, ethanol refers to bio-ethanol only. Ethanol is produced from fermenting any biomass high in carbohydrates. Today, ethanol is made from starches and sugars, but second generation technologies will allow it to be made from cellulose and hemicellulose, the fibrous material that makes up the bulk of most plant matter.

Gas

Gas includes natural gas, both associated and non-associated with petroleum deposits, but excludes natural gas liquids.

Gas-to-liquids

Gas-to-liquids refers to a process featuring reaction of methane with oxygen or steam to produce syngas (a mixture of hydrogen and carbon monoxide) followed by synthesis of liquid products (such as diesel and naphtha) from the syngas using Fischer-Tropsch catalytic synthesis. The process is similar to those used in coal-to-liquids.

Hard coal

Coal of gross calorific value greater than 5 700 kilocalories per kilogramme on an ash-free but moist basis. Hard coal can be further disaggregated into anthracite, coking coal and other bituminous coal.

Heat energy

Heat is obtained from the combustion of fuels, nuclear reactors, geothermal reservoirs, capture of sunlight, exothermic chemical processes and heat pumps which can extract it from ambient air and liquids. It may be used for heating or cooling, or converted into mechanical energy for transport vehicles or electricity generation. Commercial heat sold is reported under total final consumption with the fuel inputs allocated under power generation.

Heavy petroleum products

Heavy petroleum products include heavy fuel oil.

Hydropower

Hydropower refers to the energy content of the electricity produced in hydropower plants, assuming 100% efficiency. It excludes output from pumped storage and marine (tide and wave) plants.

Industry

The industry sector includes fuel used within the manufacturing and construction industries. Key industry sectors include iron and steel, chemical and petrochemical, non-metallic minerals, and pulp and paper. Use by industries for the transformation of energy into another form or for the production of fuels is excluded and reported separately under other energy sector. Consumption of fuels for the transport of goods is reported as part of the transport sector.

International aviation bunkers

Includes the deliveries of aviation fuels to aircraft for international aviation. Fuels used by airlines for their road vehicles are excluded. The domestic/international split is determined on the basis of departure and landing locations and not by the nationality of the airline. For many countries this incorrectly excludes fuels used by domestically owned carriers for their international departures.

International marine bunkers

Covers those quantities delivered to ships of all flags that are engaged in international navigation. The international navigation may take place at sea, on inland lakes and waterways, and in coastal waters. Consumption by ships engaged in domestic navigation is excluded. The domestic/international split is determined on the basis of port of departure and port of arrival, and not by the flag or nationality of the ship. Consumption by fishing vessels and by military forces is also excluded and included in residential, services and agriculture.

Light petroleum products

Light petroleum products include liquefied petroleum gas (LPG), naphtha and gasoline.

Lignocellusosic feedstock

Lignocellulosic crops refers to those crops cultivated to produce biofuels from their cellulosic or hemicellulosic components, which include switchgrass, poplar and miscanthus.

Lower heating value

Lower heating value is the heat liberated by the complete combustion of a unit of fuel when the water produced is assumed to remain as a vapour and the heat is not recovered.

Middle distillates

Middle distillates include jet fuel, diesel and heating oil.

Modern biomass

Includes all biomass with the exception of traditional biomass.

Modern renewables

Includes all types of renewables with the exception of traditional biomass.

Natural decline rate

The base production decline rate of an oil or gas field without intervention to enhance production.

Natural gas liquids

Natural gas liquids (NGLs) are the liquid or liquefied hydrocarbons produced in the manufacture, purification and stabilisation of natural gas. These are those portions of natural gas which are recovered as liquids in separators, field facilities, or gas processing plants. NGLs include but are not limited to ethane, propane, butane, pentane, natural gasoline and condensates.

Non-energy use

Fuels used for chemical feedstocks and non-energy products. Examples of non-energy products include lubricants, paraffin waxes, coal tars and oils as timber preservatives.

Nuclear

Nuclear refers to the primary heat equivalent of the electricity produced by a nuclear plant with an average thermal efficiency of 33%.

Observed decline rate

The production decline rate of an oil or gas field after all measures have been taken to maximise production. It is the aggregation of all the production increases and declines of new and mature oil or gas fields in a particular region.

Oil

Oil includes crude oil, condensates, natural gas liquids, refinery feedstocks and additives, other hydrocarbons (including emulsified oils, synthetic crude oil, mineral oils extracted from bituminous minerals such as oil shale, bituminous sand and oils from coal liquefaction) and petroleum products (refinery gas, ethane, LPG, aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha, white spirit, lubricants, bitumen, paraffin waxes and petroleum coke).

Other energy sector

Covers the use of energy by transformation industries and the energy losses in converting primary energy into a form that can be used in the final consuming sectors. It includes losses by gas works, petroleum refineries, coal and gas transformation and liquefaction. It also includes energy used in coal mines, in oil and gas extraction and in electricity and heat production. Transfers and statistical differences are also included in this category.

Power generation

Power generation refers to fuel use in electricity plants, heat plants and combined heat and power (CHP) plants. Both main activity producer plants and small plants that produce fuel for their own use (autoproducers) are included.

Renewables

Includes bioenergy, geothermal, hydropower, solar photovoltaic (PV), concentrating solar power (CSP), wind and marine (tide and wave) energy for electricity and heat generation.

R/P ratio

Reserves-to-production (R/P) ratio is based on the sum of probable and proven reserves and the last year of available data for production.

Self-sufficiency

Self-sufficiency is indigenous production divided by total primary energy demand (TPED).

Total final consumption

Total final consumption (TFC) is the sum of consumption by the different end-use sectors. TFC is broken down into energy demand in the following sectors: industry (including manufacturing and mining), transport, buildings (including residential and services) and other (including agriculture and non-energy use). It excludes international marine and aviation bunkers, except at world level where it is included in the transport sector.

Total primary energy demand

Total primary energy demand (TPED) represents domestic demand only and is broken down into power generation, other energy sector and total final consumption.

Traditional biomass

Traditional biomass refers to the use of fuelwood, charcoal, animal dung and agricultural residues in stoves with very low efficiencies.

Transport

Fuels and electricity used in the transport of goods or persons within the national territory irrespective of the economic sector within which the activity occurs. This includes fuel and electricity delivered to vehicles using public roads or for use in rail vehicles; fuel delivered to vessels for domestic navigation; fuel delivered to aircraft for domestic aviation; and energy consumed in the delivery of fuels through pipelines. Fuel delivered to international marine and aviation bunkers is presented only at the world level and is excluded from the transport sector at the domestic level.

Regional and country groupings

Africa

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

Annex I Parties to the United Nations Framework Convention on Climate Change

Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom and United States.

APEC (Asia-Pacific Economic Cooperation)

Australia, Brunei Darussalam, Canada, Chile, China, Chinese Taipei, Indonesia, Hong Kong (China), Japan, Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, Philippines, Russia, Singapore, Thailand, United States and Vietnam.

ASEAN

Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam.

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, Kyrgyz Republic, Latvia, Lithuania, the former Yugoslav Republic of Macedonia, the Republic of Moldova, Romania, Russian Federation, Serbia , Tajikistan, Turkmenistan, Ukraine and Uzbekistan. For statistical reasons, this region also includes Cyprus, Gibraltar and Malta.

European Union

Austria, Belgium, Bulgaria, Cyprus, 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.

G-8

Canada, France, Germany, Italy, Japan, Russian Federation, United Kingdom and United States.

G-20

G-8 countries and Argentina, Australia, Brazil, China, India, Indonesia, Mexico, Saudi Arabia, South Africa, Korea, Turkey and the European Union.

Latin America

Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, the Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela and other Latin American countries (Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands,. Dominica, Falkland Islands, French Guyana, Grenada, Guadeloupe, Guyana, Martinique, Montserrat, St. Kitts and Nevis, Saint Lucia, Saint Pierre et Miquelon, St. Vincent and the Grenadines, Suriname and Turks and Caicos Islands).

Middle East

Bahrain, Islamic Republic of Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates and Yemen. It includes the neutral zone between Saudi Arabia and Iraq.

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 non-OECD Asian countries (Afghanistan, Bhutan, Cook Islands, East Timor, Fiji, French Polynesia, Kiribati, Laos, Macau, Maldives, New Caledonia, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu).

North Africa

Algeria, Egypt, Libya, Morocco and Tunisia.

OECD

Includes OECD Europe, OECD Americas and OECD Asia Oceania 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.

OPEC

Algeria, Angola, Ecuador, Islamic Republic of Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela.

Other Asia

Non-OECD Asia regional grouping excluding China and India.

Sub-Saharan Africa

Africa regional grouping excluding the North African regional grouping.

Abbreviations and Acronyms

APEC	Asia-Pacific Economic Cooperation
API	American Petroleum Institute
ASEAN	Association of Southeast Asian Nations
BTL	biomass-to-liquids
BGC	Basrah Gas Company
BGR	German Federal Institute for Geosciences and Natural Resources
CAAGR	compound average annual growth rate
CAFE	corporate average fuel economy (standards in the United States)
CBM	coalbed methane
CER	Certified emission reduction
CCGT	combined-cycle gas turbine
CCS	carbon capture and storage
CDM	Clean Development Mechanism (under the Kyoto Protocol)
CFL	compact fluorescent lamp
CH_4	methane
CHP	combined heat and power; the term co-generation is sometimes used
CMM	coal mine methane
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2**-eq**	carbon-dioxide equivalent

COP	Conference of Parties (UNFCCC)
CPC	Caspian Pipeline Consortium
CPS	Current Policies Scenario
CSP	concentrating solar power
CSS	cyclic steam stimulation
CSSF	common seawater supply facility
CTL	coal-to-liquids
CV	calorific value
E&P	exploration and production
EDI	Energy Development Index
EOR	enhanced oil recovery
EPA	Environmental Protection Agency (United States)
EPC	engineering, procurement and construction
ESCO	energy service company
EU	European Union
EUA	European Union allowances
EU ETS	European Union Emissions Trading System
EV	electric vehicle
EWS	Efficient World Scenario
FAO	Food and Agriculture Organization of the United Nations
FDI	foreign direct investment
FFV	flex-fuel vehicle
FOB	free on board
GCV	gross calorific value
GDP	gross domestic product
GHG	greenhouse gases
GT	gas turbine
GTL	gas-to-liquids
HDI	Human Development Index
HDV	heavy-duty vehicles
HFO	heavy fuel oil
IAEA	International Atomic Energy Agency
ICE	internal combustion engine
ICT	information and communication technologies
IGCC	integrated gasification combined-cycle
IIASA	International Institute for Applied Systems Analysis
IMF	International Monetary Fund
INOC	Iraq National Oil Company
IOC	international oil company

IPC	Iraq Petroleum Company
IPCC	Intergovernmental Panel on Climate Change
IPP	independent power producer
KRG	Kurdistan Regional Government
LCV	light commercial vehicle
LDV	light-duty vehicle
LED	light-emitting diode
LHV	lower heating value
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LRMC	long-run marginal cost
LTO	light tight oil
LULUCF	land use, land-use change and forestry
MER	market exchange rate
MDGs	Millennium Development Goals
MEPS	minimum energy performance standards
N_2O	nitrous oxide
NCV	net calorific value
NEA	Nuclear Energy Agency (an agency within the OECD)
NGL	natural gas liquids
NGV	natural gas vehicle
NOC	national oil company
NOx	nitrogen oxides
NPS	New Policies Scenario
OCGT	open-cycle gas turbine
ODI	outward foreign direct investment
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PHEV	plug-in hybrid vehicle
PLDV	passenger light-duty vehicle
PM	particulate matter
$PM_{2.5}$	particulate matter with a diameter of 2.5 micrometres or less
PPP	purchasing power parity
PSA	production-sharing agreement
PV	photovoltaic
RD&D	research, development and demonstration
RDD&D	research, development, demonstration and deployment
RRR	remaining recoverable resource
SAGD	steam-assisted gravity drainage

SCO	synthetic crude oil
SO_2	sulphur dioxide
SOMO	State Oil Marketing Organization of Iraq
SPM	single-point mooring
SRMC	short-run marginal cost
T&D	transmission and distribution
TFC	total final consumption
TPED	total primary energy demand
UAE	United Arab Emirates
UCG	underground coal gasification
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
UNPD	United Nations Population Division
URR	ultimate recoverable resource
US	United States
USC	ultra-supercritical
USGS	United States Geological Survey
WEO	World Energy Outlook
WEM	World Energy Model
WHO	World Health Organization
WTI	West Texas Intermediate
WTO	World Trade Organization
WTW	well-to-wheel

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PEFC/10-31-1510

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IEA PUBLICATIONS, 9 rue de la Fédération, 75739 PARIS CEDEX 15
Layout in France by Easy Catalogue - Printed in France by Corlet, November 2012
(61 2012 25 1P1) ISBN: 978 92 64 18084 0
Photo credits: GraphicObsession