ENERGY EFFICIENCY

Market Report 2016

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

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- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
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International Energy Agency
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International Energy Agency
9 rue de la Fédération
75739 Paris Cedex 15, France

www.iea.org

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FOREWORD

It is becoming increasingly clear that energy efficiency needs to be central in energy policies around the world. All of the core imperatives of energy policy – reducing energy bills, decarbonisation, air pollution, energy security, and energy access – are made more attainable if led by strong energy efficiency policy. As the world transitions to clean energy, efficiency can make the transition cheaper, faster and more beneficial across all sectors of our economies. Indeed, there is no realistic, or affordable, energy development strategy that is not led by energy efficiency. For the IEA, it is the first fuel.

And yet energy efficiency is far from fulfilling its potential. Globally, two-thirds of the economic potential remains untapped. An entire 70% of the world's energy use takes place outside of any efficiency performance requirements. For example, two-thirds of energy consumption from buildings being built today has no codes or standards applied to it. A mere one-third of NDCs include energy efficiency related targets, despite IEA analysis that shows it is the single largest action in the optimal pathway to a decarbonised energy system.

For all these reasons, I have decided that, as part of our modernisation efforts of the IEA, there will be a strong focus on energy efficiency. Through analysis, policy guidance and knowledge exchange among all stakeholders, the Agency will support governments around the world in implementing and understanding energy efficiency policies. We will build on the successes of our acclaimed *Energy Efficiency in Emerging Economies Programme* and enhance further our collaboration with our member, accession, association and partner countries. Energy efficiency experience is transferable among countries and the IEA will facilitate that.

In the context of our new strategic focus, this report is an important step in understanding global trends in energy efficiency. It tracks the key indicators of energy intensity, energy efficiency investment and their impact. Our report finds – despite lower energy prices – progress is being made, but not fast enough. It shows where policy has made a real difference, but also highlights that much more can be achieved. It highlights the threat of a continuation of lower energy prices to the energy efficiency agenda, but also demonstrates clearly that strong, well-designed policy, can mitigate that threat.

The greatest efficiency gains have been led by policy, and the greatest untapped potentials lie where policy is absent or inadequate. There are lessons of success from around the world, including US vehicle standards, Japan's progressive Top-Runner programme, and China's Top 10 000 programme. The report focuses on the progress made in China. To our knowledge, China's energy efficiency story is told in great detail for the first time by this report. It is a story of great progress, achieving huge efficiency gains over the last ten years, but also revealing the opportunity for China to achieve much more on a path to the efficiency levels of other countries.

I hope this report will be of great interest to energy policy makers and professionals in all sectors and in all regions. It quantifies the latest trends, tracks global progress, and examines key drivers and market issues. It provides answers to the central question: how can the world achieve more? In this sense, it is a call to action. Energy efficiency is the one energy resource that every country possesses in abundance. The IEA is well determined that all countries fully exploit it.

Dr Fatih Birol
Executive Director,
International Energy Agency

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF MAPS

LIST OF TABLES

LIST OF BOXES

EXECUTIVE SUMMARY

Global energy intensity improved in 2015, but the rate of progress needs to accelerate much more

Global energy intensity – the amount of energy used per unit of gross domestic product (GDP) – improved by 1.8% in 2015. This is good news, surpassing the 1.5% gain seen in 2014, and tripling the annual rate (0.6%) seen in the previous decade. This improvement is particularly noteworthy in the context of lower energy prices, with the headline price of crude oil falling by as much as 60% since 2014.

However, global progress on energy intensity is still too slow, falling short of putting the world onto a sustainable pathway toward a decarbonised energy system. International Energy Agency (IEA) analysis shows that annual energy intensity improvements need to rise immediately to at least 2.6% in a trajectory consistent with our climate goals.

2015 saw a shift to emerging economies as the drivers of global intensity gains

Energy intensity did not decline uniformly across the globe. Gains in 2015 were higher in emerging and developing countries, at 2.5%, than industrialised countries, at 2%. This trend will need to continue and strengthen: in a 2°C pathway, average annual intensity improvements between now and 2030 are 3.7% in countries outside the Organisation for Economic Co-operation and Development (OECD) as compared with 2.2% for OECD countries.

Energy efficiency is driving down intensity and energy demand

Energy efficiency levels in IEA member countries improved, on average, by 14% between 2000 and 2015. This generated energy savings of 450 million tonnes of oil equivalent (Mtoe) in 2015, enough to power Japan for a full year. These savings also reduced total energy expenditure by 540 billion United States Dollars (USD) in 2015, mostly in buildings and industry. While GDP grew by 2% in IEA countries, efficiency gains led to the flattening of growth in primary energy demand.

China is driving global energy efficiency progress

Energy intensity in the People's Republic of China (hereafter "China") improved by 5.6% in 2015, up from an average of 3.1% per year over the previous decade. Primary energy demand increased by just 0.9% in 2015, the lowest growth rate since 1997, while the economy grew by 6.9%. China's progress on energy efficiency is now at a scale where it is making a significant mark on global energy markets. Without Chinese energy efficiency gains, the global energy intensity improvement would have been only 1.4%, instead of 1.8% in 2015.

Between 2006 and 2014, investment in energy efficiency in China totalled USD 370 billion, generating multiple benefits including reduced air pollution and lower energy expenditure by consumers. The energy savings from efficiency were as large as China's entire renewable energy supply, making efficiency and renewable energy China's twin clean fuels. In the power sector alone, energy efficiency gains avoided the need for over USD 230 billion in investment for new (mostly coal-fired) electricity generation. The avoided emissions from efficiency improvements were 1.2 billion tonnes of carbon dioxide (CO_2) in 2014, equivalent to the total CO_2 emissions of Japan.

Even with this significant progress, China can achieve much more: energy intensity levels in 2015 are still 50% higher than the OECD average. The 13th Five-Year Plan (2016-20) sets strong targets for energy efficiency and is expected to drive investment of a further USD 270 billion in energy efficiency over the next five years. As China continues to improve energy efficiency, the impact on the global energy markets will increase given the sheer size of its domestic energy use.

Public policy has been the key driver of efficiency improvements, but much more is possible and much more is needed

Government policy has been fundamental to improving energy efficiency. The growth of mandatory policies such as standards, in terms of both their range of coverage and the performance levels they require, is having a material effect on energy demand. For example, the total oil consumption savings from all national vehicle fuel economy standards on light-duty vehicles was 2.3 million barrels per day (mb/d) in 2015. This was equivalent to almost 2.5% of global oil supply – approximately the oil production of Brazil.

The past 15 years have seen some good policy progress, with a steady expansion of mandatory policies focused on improving energy efficiency. In 2015, 30% of final energy demand globally was covered by mandatory efficiency policies, up from 11% in 2000. The average performance levels mandated by policies have increased by 23% over the last decade, delivering greater savings.

Introduced this year, the IEA Efficiency Policy Progress Index (EPPI) tracks mandatory policies by combining their coverage and the strengthening of their performance levels. The EPPI shows growth of 7% in the last decade and establishes a baseline against which to measure future progress. Progress has been fastest in residential buildings, where expansion of building energy codes and tightening of minimum energy performance standards (MEPS) on heating and cooling equipment are driving improvements.

Plenty of scope exists for further improvements. If best-in-class standards had been applied to energy consuming equipment in all countries, residential energy consumption would have been 14% lower in 2015. Similarly, if all LDVs conformed to best-in-class fuel economy standards, oil demand would have been reduced by an additional 2 mb/d, boosting total savings to 4.3 mb/d, equivalent to the current production of Canada.

Policies to improve energy efficiency not only save energy, they produce multiple other benefits such as enhanced energy security and improved air quality. IEA analysis shows that policies to increase energy efficiency and decarbonise energy supply will be the major drivers of global reduction in emissions of key local air pollutants between now and 2040.

Policy has also protected the efficiency market from declining energy prices

Lower energy prices are a cause for concern as they reduce the returns on energy efficiency investments. However, to date, consumer prices have remained relatively steady or fallen much less than headline prices for energy commodities. While the headline crude oil price declined by as much as 60% between mid-2014 to mid-2016, taxes embedded in retail fuel prices have limited the end-user price drop to a range of 38% (in the United States) to 16% (in Germany).

In parallel, fuel economy standards applied in many countries are driving efficiency gains in new vehicles. In the United States, in the context of lower fuel prices, 2015 saw light-duty truck sales grow to record highs. Because these trucks are less efficient than cars, this shift has had a negative impact on the average efficiency levels of all vehicle sales. Counteracting this effect, the efficiency of light-duty trucks has steadily improved, driven by efficiency standards. Between 2013 and 2015, the fuel economy of light-duty trucks sold in the United States improved by 4.4%. The net effect was a decline in the annual improvement rate of the efficiency of all new passenger vehicles, from 1.8% on average between 2005 and 2013 to 1% between 2013 and 2015.

China became the world's largest new passenger vehicle market in 2015, with sales surpassing those in the United States. Chinese fuel economy gains accelerated between 2013 and 2015, with an average annual gain of 2.3% despite a 26% fall in retail gasoline prices. This improvement was driven by the phasing in of China's first corporate average fuel consumption standards in 2012.

In the residential sector, energy efficiency investment in buildings in OECD countries increased by 9% in 2015, even as natural gas prices fell 10% between 2014 and 2016. Electricity prices were stable, albeit near all-time high levels, over the same period. Efficiency actions in buildings appear to be driven less by price and more by the implementation of policy instruments such as MEPS.

The energy efficiency market is growing

As policies have expanded, so has investment in energy efficiency. The IEA estimates that global investment in energy efficiency was USD 221 billion in 2015, an increase of 6% from 2014. Investment in efficiency was two-thirds greater than investment in conventional power generation in 2015. Investment growth was strongest in the buildings sector, at 9%, with the United States making up close to a quarter of all efficiency investment in the sector. China has emerged as the largest energy efficient vehicle market, comprising 41% of efficient vehicle investment worldwide.

Energy efficiency services are now a sizeable, distinct market sector. In 2015, energy service companies (ESCOs), whose primary business model is delivering energy efficiency solutions, had a total turnover of USD 24 billion. China is the largest market, with over 600 000 people now employed in ESCOs and revenue growth of 7% in 2015. ESCO revenues in the United States were USD 6.4 billion in 2015, more than doubling over the past ten years.

Evidence indicates that the energy efficiency market will grow in the coming years. Mergers and acquisitions of energy efficiency services firms have been increasing, with utilities, technology providers and energy equipment manufacturers all stepping into the market. The low energy demand outlook in IEA countries has prompted a number of traditional energy utilities to adopt the provision of energy services as a way to expand their revenues. In addition, growth in remote monitoring, control and data analytics are enabling new business models and service solutions.

Finance for dedicated energy efficiency products and services is also expanding. Since their launch in 2012, the value of "green" bonds has grown to over USD 40 billion in 2015, of which over USD 8 billion is dedicated to energy efficiency. Other financial products are also starting to develop. In the United States, for example, property assessed clean energy financing and asset-backed securities have shown impressive growth following an evolution of funding models and rule changes.

Conclusion

This report demonstrates the central role of policy in driving energy efficiency. The biggest global gains in energy efficiency are linked to mandatory policy instruments such as MEPS. While the expansion of policies has been effective in generating energy savings and reducing emissions, more is required and more is possible. Improvements in energy intensity and energy efficiency are still far from achieving our climate goals. Analysis in this report emphasises that policies must be strengthened and their coverage expanded to boost the potential of energy efficiency.

Government policies are vital to curbing the risk that lower energy prices could undermine energy efficiency efforts. High energy prices cannot be relied on as a main factor driving investments in energy efficiency. Equally, low prices should not diminish the case for efficiency to be at the forefront of national energy policy. Efficiency policies, properly integrated with renewable energy policies, will need to continue to expand and strengthen even at a time when the short-term pressure to act may be diminished.

Energy efficiency is the only energy resource possessed by all countries. Global collaboration and knowledge exchange will be essential elements of strengthening action on energy efficiency in all countries. The IEA, with its global perspective, will lead this exchange so that energy efficiency can deliver its full potential in support of globally shared energy and environmental policy goals. Harnessing the potential of energy efficiency is key to transitioning to a sustainable and secure energy system that generates prosperity for our world.

1. ENERGY EFFICIENCY TRENDS AND CORE INDICATORS

Highlights

Energy intensity improving but slower than needed

- **The global economy is becoming less energy intense, but progress must accelerate to put the world's energy system on a sustainable pathway.** Global energy intensity, measured as total primary energy supply (TPES) per unit of gross domestic product (GDP), improved by 1.8% in 2015 despite headline energy prices declining. This was more than double the average annual rate over the previous ten years. However, global annual intensity needs to improve (i.e. decline) by 2.6% per year between 2016 and 2030 to achieve our climate change goals.

- **Emerging economies improved their energy intensity more than industrialised economies in 2015, and will need to continue to lead the way.** The greatest gain was in the People's Republic of China (hereafter "China"), where intensity improved by 5.6%. In all scenarios developed by the International Energy Agency (IEA), emerging countries lead intensity gains over the foreseeable future.

- **Energy demand growth slowed to 0.8% in 2015, while global GDP grew by 2.7%**. Annual energy demand growth rates are at decade-long lows in most large countries. Several signs suggest that energy demand in countries belonging to the Organisation for Economic Co-operation and Development (OECD) is in long-term decline after peaking in 2007. Energy demand in OECD countries has been essentially flat since 2012.

Energy efficiency generating sizeable energy savings

- **Efficiency improvements in IEA countries since 2000 have saved enough energy to power Japan for one year.** Annual energy savings in 2015 reached 19 exajoules (EJ) or 450 million tonnes of oil-equivalent (Mtoe), equivalent to 13% of total final energy consumption (TFC) in IEA countries.

- **In China, energy efficiency has been a key means of satisfying energy demand.** China's energy efficiency gains since 2000 saved a total of 14 EJ (326 Mtoe) of primary energy consumption in 2014 – and 350 million tonnes of coal. These savings represent 11% of China's TPES.

Multiple benefits of energy efficiency

- **Energy efficiency is delivering significant multiple benefits.** IEA countries saved an average of 490 United States dollars (USD) per capita and a total of USD 540 billion in energy expenditure in 2015 as a result of energy efficiency improvements since 2000. Avoided greenhouse gas (GHG) emissions totalled 1.5 billion tonnes of carbon dioxide ($GtCO_2$) in 2015 and 13 $GtCO_2$ cumulatively since 2000. Energy efficiency avoided over 1 trillion in investment in electricity generation. As awareness of these benefits grows – and of their economic and social value – they will become more important as drivers of further efficiency improvements.

Introduction

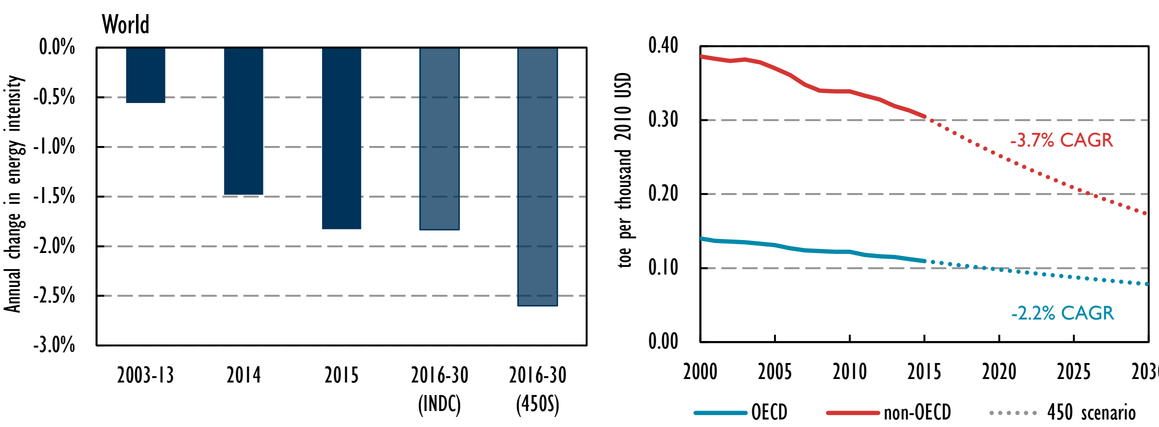
This chapter evaluates the core indicators of global and regional energy efficiency improvements and analyses what factors drive these changes. It first examines, at the high level, energy intensity indicators and changes in TFC[1] by key world regions and by country. Based on the results of a decomposition analysis, it then builds understanding of the dynamics that underpin changes in intensity and energy demand in IEA countries and key emerging economies. The decomposition reveals greater detail on the roles of energy efficiency, structural change and economic growth in driving changes in energy demand and intensity. Finally, the chapter estimates and quantifies energy savings and other benefits from energy efficiency improvements.

Global trends in energy intensity

Intensity improvements are slower than needed

Global energy intensity improved by 1.8% in 2015 and 1.5% in 2014 – triple the average improvement of 0.6% between 2003 and 2013 (Figure 1.1).[2] These energy intensity improvements were achieved even as headline crude oil prices declined significantly in 2015 – an early but positive indicator that intensity gains are driven by more than just energy prices.

Figure 1.1 Changes in energy intensity from 2003-30 by region and by scenario



Notes: CAGR = compound annual growth rate; toe = tonnes of oil equivalent; 450S = 450 Scenario. Energy intensity is calculated as TPES per thousand 2010 USD of GDP at market exchange rates.

Sources: IEA (2015), *World Energy Outlook*, OECD/IEA: Paris; IEA (2016a), "World energy balances", *IEA World Energy Statistics and Balances* (database), DOI: http://dx.doi.org/10.1787/data-00512-en.

Despite these gains, the pace of intensity improvements is too slow to reach the established goal of limiting global temperature increase to 2°C. In the IEA (2015) 450 scenario,[3] as described in the *World Energy Outlook* (WEO), energy intensity improves by an average of 2.6% per year until 2030.

[1] TFC is the sum of consumption by all end-use sectors. Typically, it is broken down into energy demand in the following sectors: industry, 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 both are included in the transport sector.

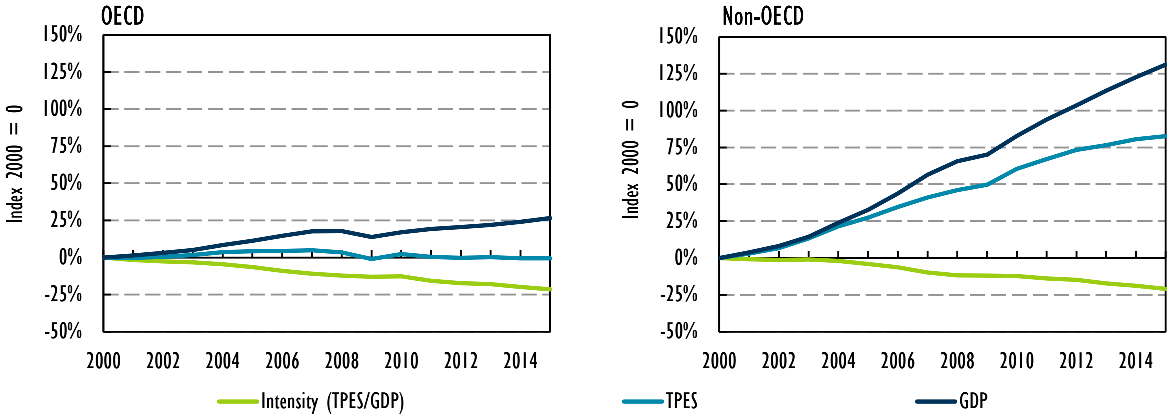
[2] Energy intensity is calculated using GDP measured with market exchange rates.

[3] The 450 Scenario is an IEA *World Energy Outlook* (*WEO*) scenario in which strong action is taken to limit global temperature increase to 2°C. The scenario assumes that compounded annual global economic growth is 3.7% between 2013 and 2020 and 3.8% between 2020 and 2030. Thus, actions to limit temperature increase must be sufficient to provide the appropriate counterbalance.

Clearly, even faster improvement must be achieved to limit the increase to "well below" 2°C. Pledges made through Nationally Determined Contributions (NDCs) within the Paris Agreement, highlighted in the IEA Intended Nationally Determined Contributions (INDC) Scenario,[4] are projected to result in an annual intensity improvement of just 2%. Across all scenarios, countries outside the OECD will take the lead in improving intensity; in the 450 Scenario they improve their energy intensity by 3.5% on average from now until 2030 (IEA, 2015).

Growth in global economic output outpacing growth in global energy demand is evident in both OECD and non-OECD countries (Figure 1.2). In OECD countries, demand for energy has remained relatively stable while GDP grew by 27% since 2000. In non-OECD countries, energy demand rose by 83% since 2000 while GDP grew by 131%. The observed trend is illustrative of an apparent decoupling of energy demand and economic growth.

Figure 1.2 Changes in factors of energy intensity by region



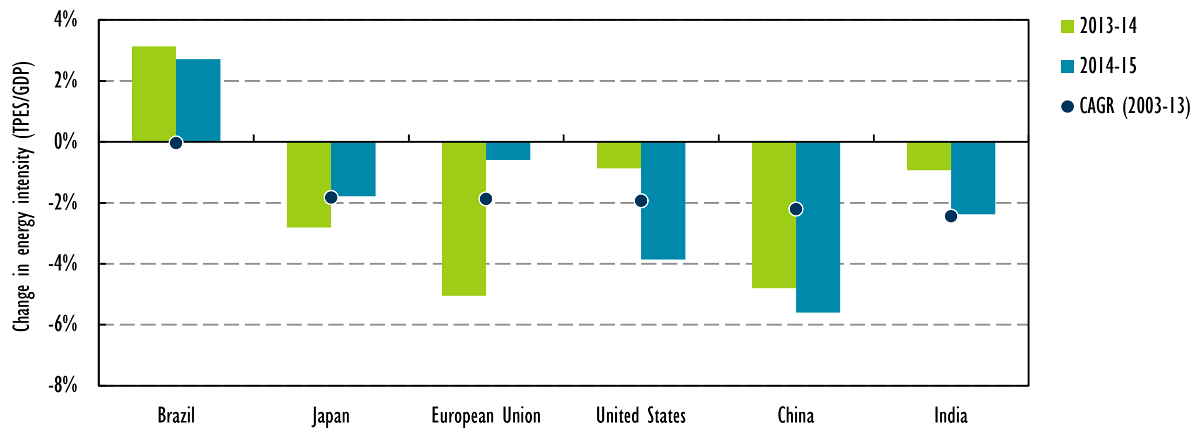
Note: GDP is in USD 2010 using market exchange rates.
Sources: IEA (2015), *World Energy Outlook*, OECD/IEA, Paris; IEA (2016a), "World energy balances", *IEA World Energy Statistics and Balances* (database), DOI: http://dx.doi.org/10.1787/data-00512-en.

At the country level, the trends are more mixed. China achieved the greatest improvement in energy intensity (Figure 1.3). The Chinese economy consumed 5.6% less energy per unit GDP in 2015 than it did in 2014,[5] marking the second consecutive year in which the rate of energy intensity improvement surpassed the annual average over the previous decade. (Chapter 2 offers a more detailed analysis of China's intensity and efficiency improvements.) Intensity improvement was also above the recent average in the United States (US), where TPES declined by 1.5% despite economic growth of 2.4% (in contrast, TPES rose by 1.5% in 2014, when economic growth was also 2.4%). As a result of economic contraction in Brazil, TPES fell by 1.2% in 2015 but GDP fell by 3.8%, leading to a worsening of energy intensity. Similarly, Brazilian TPES grew by 3.2% in 2014, while GDP grew by 0.1%.

[4] The INDC Scenario assumes that CO_2 reduction targets in the INDCs put forward by countries under the Paris Agreement are achieved. For countries that have ratified the Paris Agreement, their INDCs are no longer considered "intended" and take on the status of NDCs. This report refers to the "INDC Scenario" based on the *WEO 2015* when the Paris Agreement had not yet been ratified.

[5] Energy intensity improvements in China for 2015 are reported by the National Bureau of Statistics of China (2016) using Chinese data.

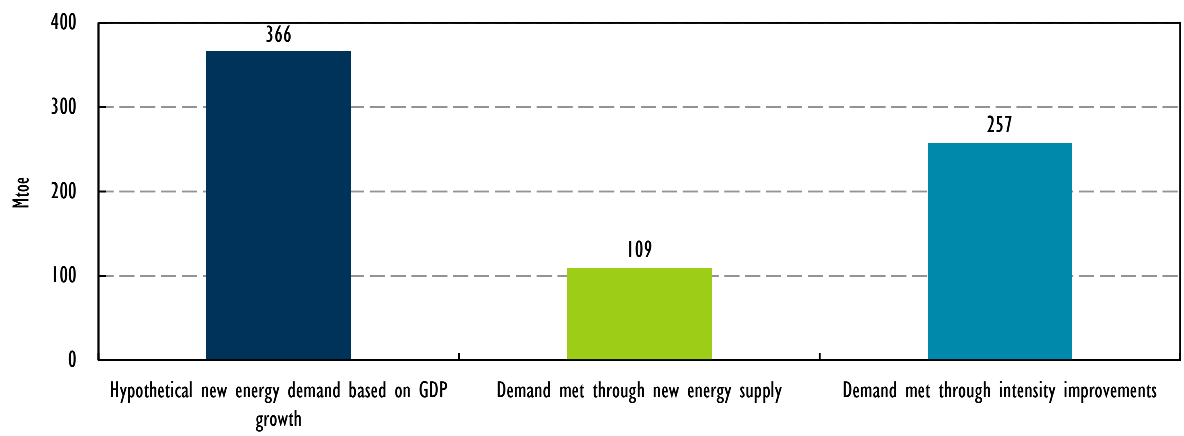
Figure 1.3 Changes in primary energy intensity for selected countries



Notes: GDP is measured in Mtoe per billion 2010 USD using market exchange rates. Primary energy demand is not adjusted for annual temperature changes.
Sources: IEA (2015), *World Energy Outlook*, OECD/IEA, Paris; IEA (2016a), "World energy balances", *IEA World Energy Statistics and Balances* (database), DOI: http://dx.doi.org/10.1787/data-00512-en. National Bureau of Statistics of China (2016), *Nation-Wide Dataset*, retrievable from http://data.stats.gov.cn/tablequery.htm?code=AD0H.

Energy intensity improvements are leading to material outcomes for the global energy system. Approximately 70% of hypothetical new demand for energy worldwide was met through energy intensity improvements in 2015 (Figure 1.4). In 2015, activity associated with global economic growth would have led to a pro-rata increase in demand for energy services of 366 Mtoe. Actual TPES increased by only 109 Mtoe, indicating that energy intensity gains 'fuelled' more than twice as much energy service demand as energy supply did. In other words, energy intensity gains avoided 257 Mtoe of energy consumption in 2015. The change in intensity includes both improvements in energy efficiency and structural changes in the economy.

Figure 1.4 Growth in world energy service demand met through intensity improvements and new supply, 2015



Note: New energy demand represents what demand would have been in 2015 if energy intensity had not improved in 2015 (i.e. if 2014 energy intensity were applied to 2015 GDP). This does not account for changes in the structure of the world economy.
Source: IEA (2016a), "World energy balances", *IEA World Energy Statistics and Balances* (database), DOI: http://dx.doi.org/10.1787/data-00512-en.

Box 1.1 Targeting energy productivity as an alternative to energy intensity

A segment of policy makers and advocacy groups within the OECD are reframing the energy efficiency debate to focus on policies and goals that seek to increase energy productivity, i.e. increasing the value of each unit of energy consumed in an economy, rather than reducing energy intensity.

Some argue that prioritising energy productivity improvements can expand the suite of actions available to policy makers to meet energy and climate goals. Energy productivity objectives could help shift the focus toward systemic energy efficiency improvements using urban planning, restructuring toward circular economy principles and other strategies.

Energy productivity is potentially more influential in emerging economies, where targets such as reducing energy intensity or energy demand can be seen as counter-productive to economic development goals. Under a productivity framework, policy makers in emerging economies could prioritise objectives to increase energy services and energy consumption, which would drive economic growth and achieve wider social objectives.

A focus on improving energy productivity can recast the political dynamics to build broader support for efficiency policies. In Australia, the focus on energy productivity has helped achieve bipartisan agreement to establish the National Energy Productivity Plan, and the government has set a target for improving energy productivity by 40% between 2015 and 2030. It is important that energy productivity objectives be designed and monitored alongside GHG emissions reduction goals. Such consideration is needed to ensure that targets around emissions mitigation are being achieved alongside targets for improvements in productivity and GDP growth.

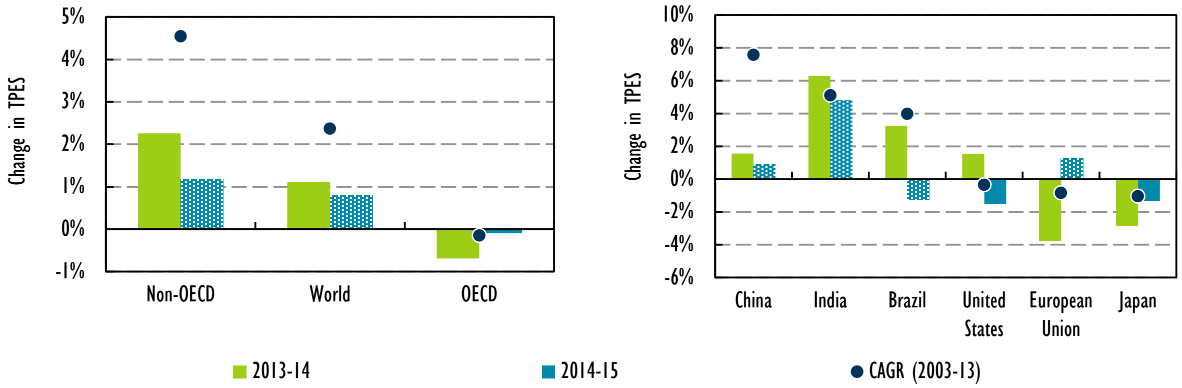
Global growth in energy demand slowed

In 2015, global total primary energy demand rose by 0.8% (Figure 1.5),[6] a rate slower than in 2014 and one-third of the compound average annual growth of 2.4% seen between 2003 and 2013. Non-OECD countries continue to contribute the bulk of new energy demand (more than 85% in 2015), with an annual rate of 4.5% between 2003 and 2013 while growth stagnated in OECD economies. A noticeable slow down in energy demand growth in non-OECD countries in 2014 and 2015 was driven by two main factors: slower growth in energy consumption in China and negative economic growth in Brazil.

In the coming years, the main driver of non-OECD energy demand may shift from China to India. India's TPES in 2014 grew at a faster rate than over the previous ten years. In 2013, India's TPES per capita of 0.62 toe was below the average on the African continent (0.67 toe per capita) and the lowest among large emerging countries. Approximately 240 million people in India have no access to modern energy services (IEA, 2015) and the country has significant potential for development and growth in average incomes. These factors place India as the central figure of future change in the global energy system.

[6] 2015 energy demand data in non-OECD countries are preliminary estimates.

Figure 1.5 Change in TPES by region

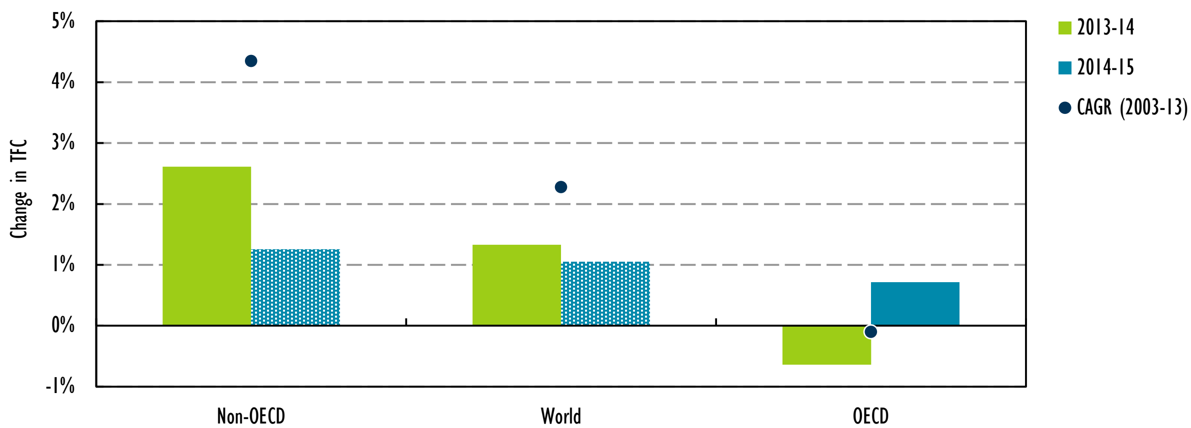


Note: Patterned columns indicate that data are provisional estimates by the IEA. Data for 2015 for China are from the National Bureau of Statistics of China (2016).
Sources: IEA (2015), *World Energy Outlook*, OECD/IEA, Paris; IEA (2016a), "World energy balances", *IEA World Energy Statistics and Balances* (database), DOI: http://dx.doi.org/10.1787/data-00512-en. National Bureau of Statistics of China (2016), *Nation-Wide Dataset*, retrievable from http://data.stats.gov.cn/tablequery.htm?code=AD0H.

Trends in final energy intensity and demand

While TPES is most commonly used to measure intensity improvements, TFC is also useful, as TFC intensity can more closely reflect changes in energy demand. Changes in the intensity of TPES, by contrast, can also be caused by changes in the structure of energy supply (i.e. if a country obtains more energy from renewable sources, which have no conversion losses). At the global level in 2015, TPES increased by only 0.8% while TFC increased by 1%.

Figure 1.6 Change in TFC by region, 2003-15

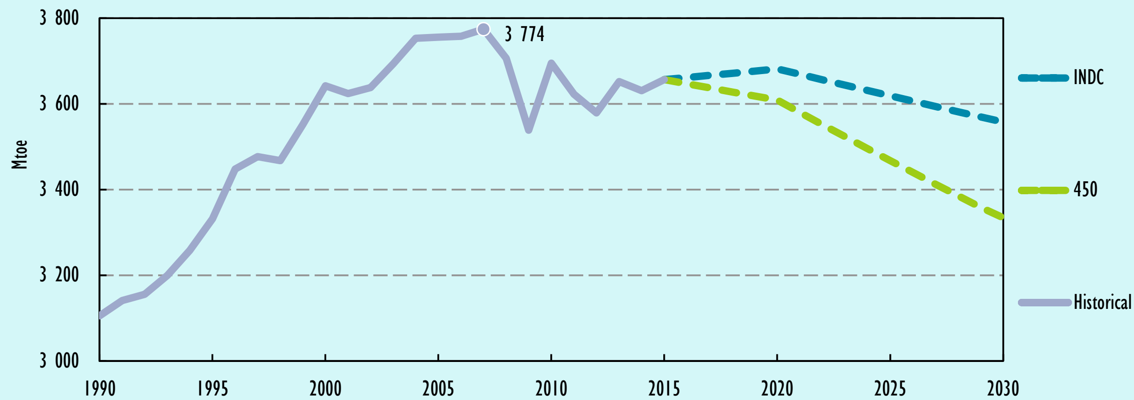


Note: Patterned columns indicate that data are provisional estimates by the IEA.
Sources: IEA (2015), *World Energy Outlook*, OECD/IEA, Paris; IEA (2016a), "World energy balances", *IEA World Energy Statistics and Balances* (database), DOI: http://dx.doi.org/10.1787/data-00512-en.

Box 1.2 Has energy demand in the OECD peaked?

Several signs suggest that TFC peaked in OECD countries in 2007 and is unlikely to return to those levels. In 2015, OECD consumption was approximately equal to that of 2002, despite economic growth of 23% over this period. In the IEA (2015a) WEO, annual OECD energy consumption does not rise above 2007 levels in any relevant future scenario (Figure 1.7). In a scenario in which countries deliver their NDC commitments, *WEO* projects that OECD energy consumption will rise slightly to 2020 before falling again. In the 450 Scenario, in which countries adopt additional policies to limit global temperature rise to 2°C, *WEO* projects that OECD consumption will fall to 3 334 Mtoe in 2030 – 12% lower than the 2007 peak. Stable or declining energy demand implies future uncertainty for energy markets that have long assumed steady growth.

Figure 1.7 TFC in OECD countries by WEO scenario



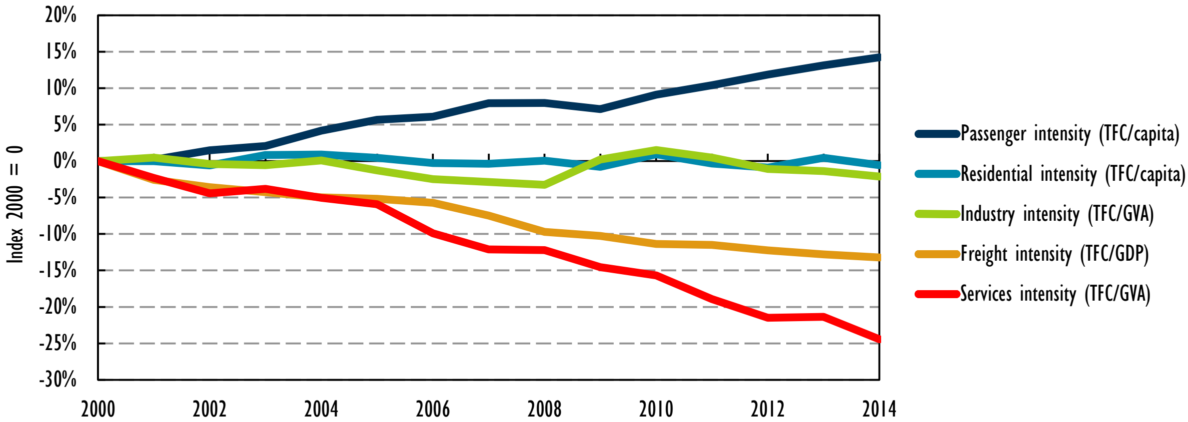
Source: IEA (2015), *World Energy Outlook*, OECD/IEA, Paris.

Final energy intensity is improving in both the services and industrial sectors

The greatest improvement in final energy intensity (TFC/GDP) since 2000 has been in the services sector (Figure 1.8), where economic growth outpaced energy demand growth in both OECD and non-OECD countries. Intensity in the services sector fell by 24% between 2000 and 2014, a compound annual average change of 2% per year. Conversely, the energy intensity of passenger transport, as measured by TFC per capita, increased by 15% globally between 2000 and 2015. This reflects the growing demand for personal vehicle transport in non-OECD countries, driven by rising per capita income. Energy use in personal transport has been growing annually five times faster than population. Personal transport levels in non-OECD countries are still lower than in OECD countries, suggesting that current growth trends will continue.

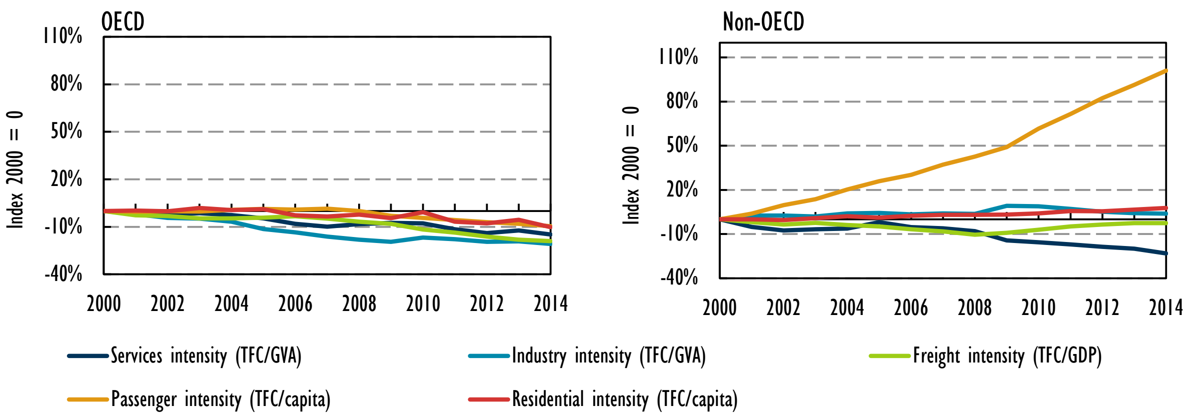
Industrial intensity is improving more rapidly in OECD countries than in non-OECD countries. In OECD countries between 2000 and 2014, industrial final energy use fell 0.9% per year on average while industrial GVA rose 0.8%. Non-OECD industrial intensity was stable over this period. In services, GVA has grown 7.2% per year on average in non-OECD countries against 5.5% growth in energy use; in OECD countries, GVA growth has been 2% while energy demand growth has been only 1%.

Figure 1.8 Change in world TFC intensity by sector, 2000-14



Notes: GVA = gross value added in given sector. Intensities are calculated as thousand tonnes of oil equivalent per billion 2010 USD using purchasing power parity. Passenger intensity is measured by passenger transport energy consumption per capita; residential is residential buildings energy consumption per capita; industry is industrial sector energy consumption per industrial sector GVA; services is services sector energy consumption per services sector GVA; freight sector is freight energy consumption per unit of world GDP.
Sources: IEA (2016a), "World energy balances", *IEA World Energy Statistics and Balances* (database), DOI: http://dx.doi.org/10.1787/data-00512-en; World Bank (2016a), "Services, etc., value added (% of GDP)," *World Bank Open Data*, http://data.worldbank.org/indicator/NV.SRV.TETC.ZS; World Bank (2016b), "Industry, value added (% of GDP)," *World Bank Open Data*, http://data.worldbank.org/indicator/NV.SRV.TETC.ZS.

Figure 1.9 Changes in OECD and non-OECD TFC intensity by sector, 2000-14



Sources: IEA (2016a), "World energy balances", *IEA World Energy Statistics and Balances* (database), DOI: http://dx.doi.org/10.1787/data-00512-en; World Bank (2016a), "Services, etc., value added (% of GDP)," *World Bank Open Data*, http://data.worldbank.org/indicator/NV.SRV.TETC.ZS. World Bank (2016b). "Industry, value added (% of GDP)," *World Bank Open Data*, 2016 http://data.worldbank.org/indicator/NV.SRV.TETC.ZS.

Energy efficiency improvements in IEA countries

Intensity data are useful in that they are consistent and comparable across countries and regions. However, they are too high-level to provide detailed insight into specific changes in energy efficiency by country and sector. Decomposition analysis can better isolate changes in energy intensity according to whether they reflect structural changes or efficiency improvements (Box 1.3). In this analysis, the "efficiency effect" refers to energy intensity improvements that result from energy efficiency measures in residential buildings, passenger and freight transport, and industry and services.

Box 1.3 Using decomposition to analyse energy efficiency

Decomposition analysis aims to identify the cause of changes to energy demand, separating out the role of structural changes to isolate changes in energy intensity. As described below, this isolated change in energy intensity can then be used as a proxy for energy efficiency improvements and is called the "efficiency effect." Three main factors are distinguished in the decomposition analysis:

Activity is the level of action that drives energy use. It is broken into sectors and measured by appropriate indicators: value-added output in the industry and services sectors; population in the residential sector; passenger-kilometres for passenger transport and tonne-kilometres for freight.

Structure reflects the mix of activity levels within a sector: the share of production represented by each sub-sector of industry or services; the floor area per person, number of dwellings per person and appliance ownership rates in the residential sector; and the modal share of vehicles in passenger and freight transport. Because different activity types have different energy intensities, shifts in the structure of activity affect energy demand.

Efficiency is the amount of energy used per unit of activity. This report uses the term "efficiency effect" to avoid confusion with the term "energy intensity."

The decomposition analysis is undertaken at the most disaggregated level possible (Table 1.1), so that changes in energy intensity can be used as a proxy for energy efficiency.

Table 1.1 Sectors and indicators included in the IEA decomposition analysis

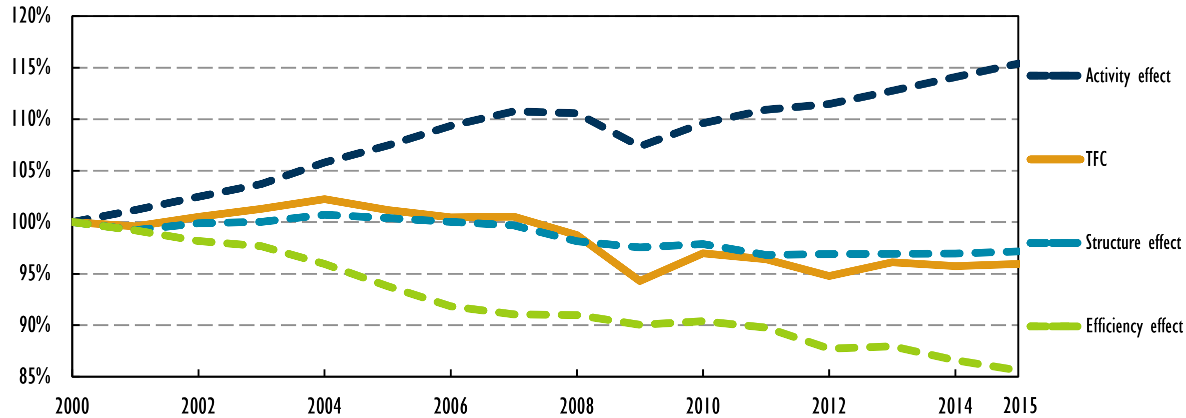
Sector	Service/sub-sector	Activity	Structure	Efficiency effect
Residential	Space heating	Population	Floor area/ population	Space heating energy*/ floor area
	Water heating	Population	Occupied dwellings/ population	Water heating energy/occupied dwellings
	Cooking	Population	Occupied dwellings/ population	Cooking energy/ occupied dwellings
	Space cooling	Population	Floor area/ population	Space cooling energy*/floor area
	Lighting	Population	Floor area/ population	Lighting energy/floor area
	Appliances	Population	Appliance stock/ population	Appliances energy/ appliance stock
Passenger transport	Car; bus; rail; domestic aviation	Passenger kilometre	Share of passenger kilometres by mode and persons per vehicle	Energy/vehicle kilometre
Freight transport	Truck; rail; domestic shipping	Tonne kilometre	Share of tonne kilometres by mode and tonnes per vehicle	Energy/vehicle kilometre
Manufacturing	Food, beverages and tobacco; paper, pulp and printing; chemicals; non-metallic minerals; primary metals; metal products and equipment; other manufacturing	Value-added	Share of value added	Energy/value-added
Services	Services	Value-added	Share of value added	Energy/value-added
Other industries**	Agriculture and fishing; construction	Value-added	Share of value added	Energy/value-added

* Adjusted for climate variation using heating degree-days.

** Because they are energy producing sectors and outside the scope of this analysis, the following sectors are not included: mining and quarrying; fuel processing; and electricity, gas and water supply. 'Other industries' are analysed only to a very limited extent.

Since 2013, the efficiency effect has increased in IEA countries; it is the most important factor pulling down TFC by 5% compared with 2000 levels (Figure 1.10). The efficiency effect increase in 2014 (1.6%) was the biggest since 2005 and higher than the average annual increase of 1% since 2000. The improvement in efficiency levels in 2014 was higher than the average annual increase of 1% since 2000.

Figure 1.10 Decomposition of total energy demand in IEA countries



Note: Analysis based on the *IEA Energy Efficiency Indicators* database (2016 edition). TFC in this analysis covers the following sectors: residential, industry and services, passenger and freight transport. It does not include agriculture, non-energy, and energy supply sectors. The energy consumption decomposed in this analysis represents 90% of TFC in IEA countries in 2015.

In IEA countries, efficiency improvements have offset growth in activity. By 2015, despite activity levels having increased by 15% since 2000, total final consumption in IEA countries slid to levels not seen since 1999. In practical terms, the efficiency effect has avoided the need for an additional 3.3 EJ of TFC since 2013, equivalent to the TFC of Australia.

Structural change has also contributed to lower energy demand in IEA countries over the past 15 years, largely because of a general shift in the industry and services sectors towards less energy-intensive sub-sectors. In contrast, structural change is increasing energy demand through larger homes in the residential sector. Energy savings associated with the structure effect in 2015 are, however, 80% lower than savings from the efficiency effect. This implies that energy efficiency has been the main driver for improved energy intensity in IEA countries.

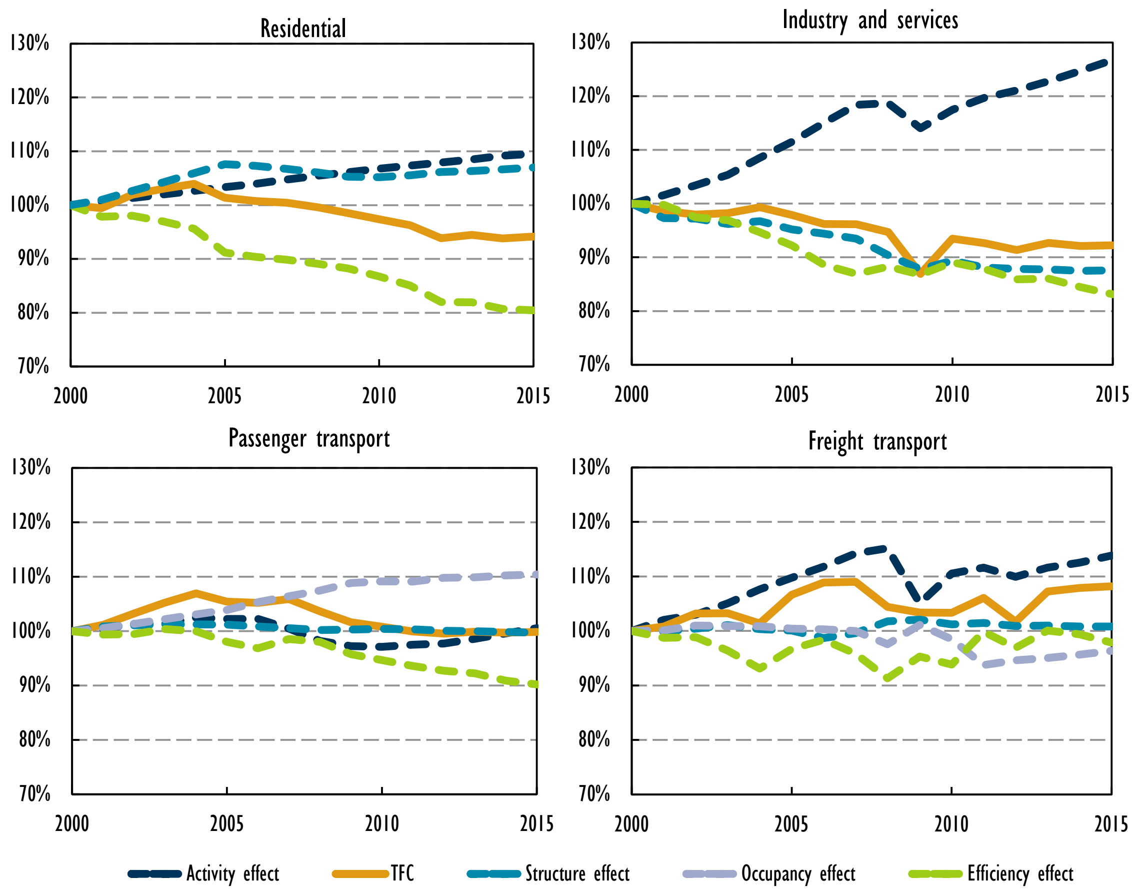
Energy efficiency improving at different rates in different sectors in IEA countries

Analysis of specific sectors reveals that energy efficiency is improving at different rates, with the residential and industry and services sectors showing the greatest change (Figure 1.11). In both transport sectors (passenger and freight), progress on energy efficiency has been slower. In industry and services, structure is an important component of *reduced* energy demand while in the residential sector structure works to *increase* energy demand.

Residential

Efficiency levels in residential buildings are 20% greater than in 2000 (Figure 1.11), pushing TFC down by 6% (1.5 EJ). Improved efficiency of buildings outweighs both the activity and structural effects, which increase energy consumption. Increasing population (activity) and the move to larger dwellings (structure) have had the combined effect of increasing energy consumption in the sector by 17%. Without energy efficiency improvements, residential buildings would have required an additional 22% (5.4 EJ) of energy consumption. Policies for energy efficiency have been strengthened the most in the residential sector (see Chapter 3), suggesting this is the key factor driving those improvements.

Figure 1.11 Sector decomposition of IEA energy demand



Note: Analysis based on the *IEA Energy Efficiency Indicators* database (2016 edition). In transport, the occupancy effect corrects for changes in the number of people per car and goods per freight vehicle. If the occupancy or load factor decreases, energy demand increases.

Industry and services

In the industry and services sector, the efficiency effect improved by 17% between 2000 and 2015 (Figure 1.11). Energy savings associated with improved efficiency in industry, services and agriculture have been 10.4 EJ, greater than Germany's TFC. Structural change is another important force behind the decline in industrial energy consumption. By 2015, the shift to less energy-intensive production avoided 7.5 EJ of energy, 24% of industrial energy consumption in IEA countries.

On aggregate, the efficiency effect is affecting energy consumption in industry and services more than structural change. At the country level, however, the roles of structure and efficiency vary. This can be explained by the initial structure of the sector in 2000 and the relative growth of subsectors subsequently (to 2015). It should be noted that this analysis acknowledges but does not fully analyse the role of trade (Box 1.4). Countries that show important changes in trade patterns since 2000 may be reflecting greater structural change, which could influence results.

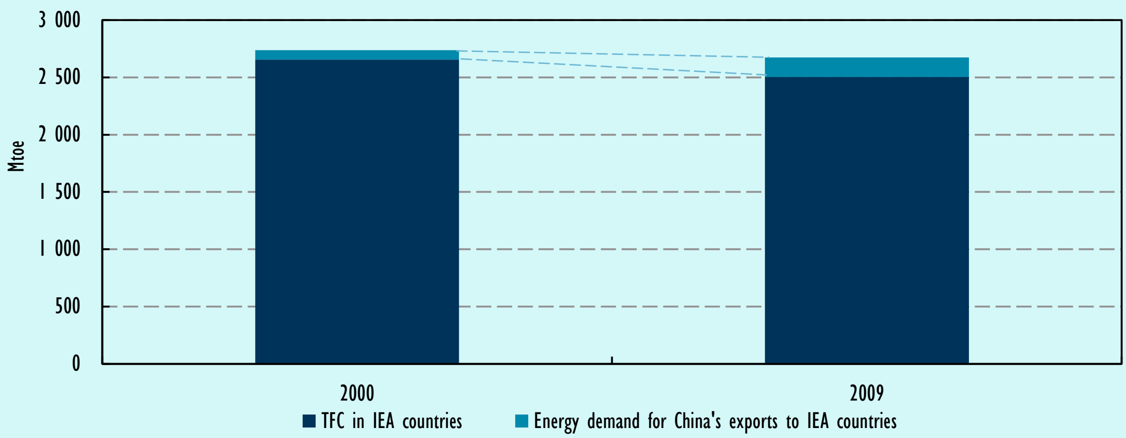
Box 1.4 Expansion of global trade drives changes in TFC and national efficiency improvements are spread internationally through trade

With increasing trade and the globalisation of manufacturing outputs, a country can reduce its TFC by outsourcing energy-intensive industrial production. Reduced TFC in IEA countries, for example, might be partly explained by moving production to China (as evidenced by the expansion of China's export-oriented industry sectors).

Using the World Input-Output Database (Timmer et al., 2015) for the period 2000 to 2009, coupled with structural decomposition analysis (Su and Ang, 2012), it is possible to quantify the role of international trade in changes of TFC in China and IEA countries.

Between 2000 and 2009, 26 IEA countries[1] reduced their TFC by 150 Mtoe (6.3 EJ). Over the same period, energy embodied in their imports from China increased by 87 Mtoe (3.6 EJ) (Figure 1.12). The increasing role of trade in the global energy landscape kept pace with the structure effect observed in Figure 1.11. During this time, the structure effect (described in the previous section) helped reduce IEA industry and services TFC by about 12%, corresponding to 165 Mtoe (6.9 EJ). But the energy embodied in IEA imports of energy-intensive products from China doubled, an increase of 51 Mtoe (2.1 EJ). In effect, a portion of the TFC was moved, rather than actually reduced.

Figure 1.12 Energy embedded in imports from China and IEA TFC, 2000 and 2009



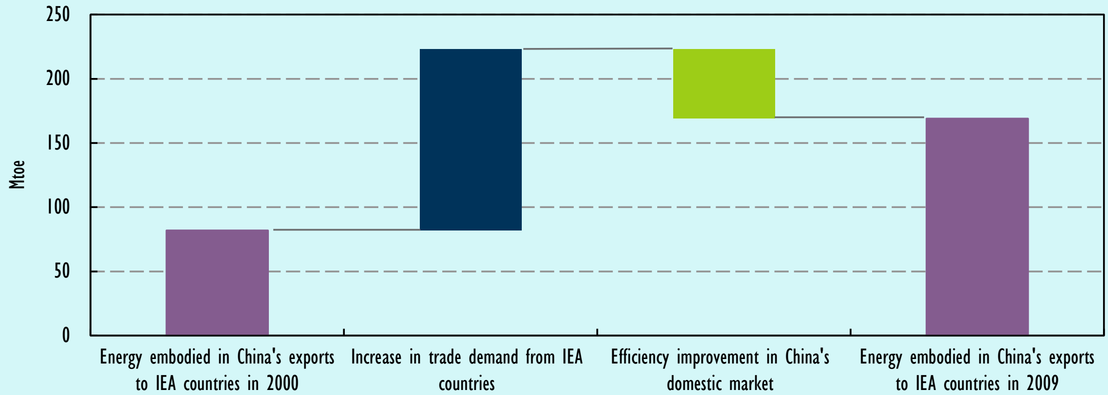
The impact of global trade on TFC varies significantly depending on the economic structure of each country. While TFC in China increased by 540 Mtoe (22.6 EJ) between 2000 and 2009, China's energy embodied in its overall exports accounted for 28% (150 Mtoe) of that growth, of which 4.6% (25 Mtoe) was exported to the United States, 5.9% (32 Mtoe) to the EU-27 and 17% (93 Mtoe) to the rest of the world.

The United States, by contrast, reduced its overall exports to the world in 2009 compared with 2000, which helped to reduce its own TFC by 9% despite increased exports to China. Overall, US TFC fell by 135 Mtoe (5.6 EJ) in 2009 relative to 2000, with the efficiency effect in the US market achieving energy savings of 158 Mtoe (6.6 EJ). The embodied energy from Chinese imports to the United States increased by 25 Mtoe (1 EJ), equal to 16% of the savings from energy efficiency. The United States also sent exports to China, which increased US energy consumption by 9.6 Mtoe (0.4 EJ), representing about 9% of the final demand effect on US TFC. The net trade effectively avoided about 15 Mtoe (0.6 EJ) of US TFC or 2% of TFC in 2009.

Box 1.4 Expansion of global trade drives changes in TFC and national efficiency improvements are spread internationally through trade (continued)

The story does not end there, as energy efficiency improvements since 2000 reduced the total impact of trade in both countries. Energy efficiency improvements in China helped realise energy savings of 284 Mtoe (11.8 EJ), of which 18.9% were allocated to 26 IEA countries in the form of energy embodied in China's exports. This means energy efficiency improvements in China avoided 53.6 Mtoe (2.2 EJ) in embodied energy of exports to consumers in these markets (Figure 1.13).

Figure 1.13 Role of energy efficiency improvement in China's domestic market on IEA TFC, 2000 and 2009



[1] Excluding New Zealand, Switzerland and Norway due to data constraints.

Passenger and freight transport

In passenger transport in IEA countries, the efficiency effect has improved by 10% between 2000 and 2015, keeping energy consumption from rising above 2000 levels. Another important outcome has been that activity levels (measured by passenger kilometres travelled) stabilised after fluctuations leading up to and stemming from the economic recession of 2008. In 2015, activity levels were the same as in 2000. This raises the question of whether passenger transport has reached a saturation level across IEA countries. If so, the sector is poised for declining energy consumption as scheduled vehicle efficiency standards are projected to improve efficiency in key IEA countries by 20% to 60% by 2025.

Energy consumption in freight transport also fluctuated over the period, along with the efficiency effect, but the end result was an increase of 8% in consumption in 2015 compared with 2000. To date, only Canada, China, Korea and the United States have implemented efficiency standards for freight.[7] Structural change has not been a significant factor in the variability of energy consumption in the sector: the shares of tonne kilometres hauled by different modes have not changed significantly since 2000. Occupancy, in this case load factor, has improved 4% since 2000 and has had the largest impact on reducing consumption. Improving load factors are, in fact, a form of energy efficiency: as companies optimise their fleet utilisation, they can deliver more goods while reducing total energy consumption.

[7] However, a number of other countries, and the European Union, are evaluating or are in the process of developing standards. Standards have been developed only since 2012.

The multiple benefits of energy efficiency improvements in IEA countries

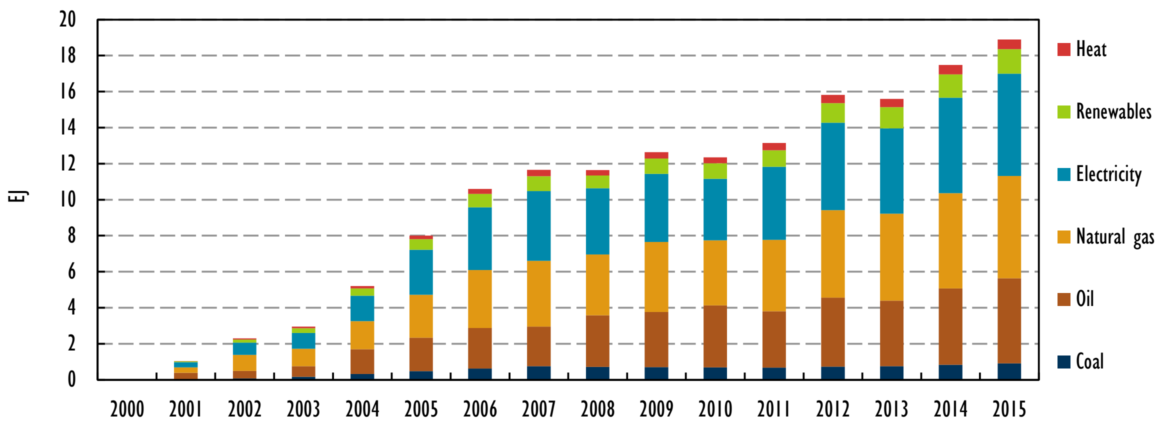
The following section builds on the decomposition analysis by assessing the energy savings of energy efficiency improvements as well as their associated *multiple benefits*. Energy saved through efficiency produces numerous energy-related benefits including (but not limited to) avoided energy expenditure, energy imports, GHG emissions and energy supply investments. Wider social benefits, such as reduced air pollution, improved human health, and greater economic growth and development, can also be linked to energy savings.

Measuring these benefits can be done by measuring the energy savings – that is by comparing actual energy use to hypothetical energy use, which does not include the impact attributed to cumulated changes in energy efficiency since 2000 on total energy use. Savings of specific fuel types are estimated based on their share of consumption and savings in each sector.

Energy savings by fuel type

Improving energy efficiency since 2000 saved 19 EJ (451 Mtoe) of energy consumption in 2015 in IEA countries (Figure 1.14). Savings increased by 1.4 EJ (33 Mtoe) in 2015 (8% growth from 2014). While savings since 2000 were the highest in 2015, the year-on-year growth in savings was down from 2014 at 12%. Energy savings across the IEA exceeded the TFC of Japan (12 EJ) in 2015, the second-largest energy consumer in the IEA. Total energy savings represented 13% of TFC in the IEA.

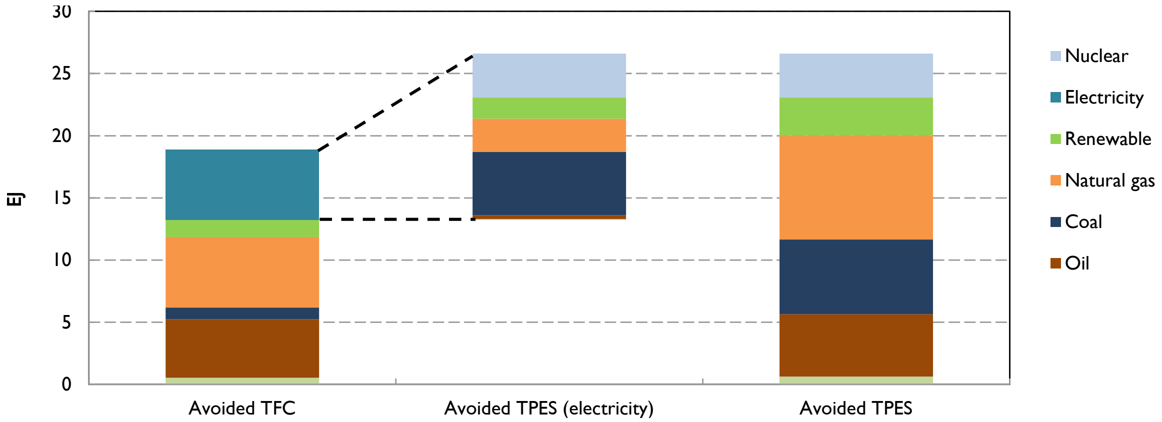
Figure 1.14 Annual avoided TFC, by fuel, from energy efficiency improvements made since 2000 in IEA countries, 2000-15



Fuel savings were spread equally between electricity and natural gas. These two energy carriers showed the greatest savings because the two sectors with the largest savings – services and residential – have the highest shares of electricity and natural gas consumption. Between 2000 and 2015, natural gas savings were 19% of natural gas TFC and electricity savings were 18% of electricity TFC in IEA countries. Such large electricity savings are beneficial because some types of electricity generation have large conversion inefficiencies; reducing the volume of primary energy needed for generation also reduces related GHG emissions. Oil savings were smaller between 2000 and 2015 as transport, the sector accounting for the dominant share of oil consumption, experienced smaller efficiency improvements and comparative energy savings.

Electricity savings lead to primary energy savings, boosting the total energy savings from end-use energy efficiency improvements. Accounting for primary energy savings increases total savings by 41% to 27 EJ (Figure 1.15). The primary energy savings of 13 EJ (319 Mtoe) from electricity savings is equivalent to the primary energy supply of all natural gas combusted for electricity generation in IEA countries in 2014.

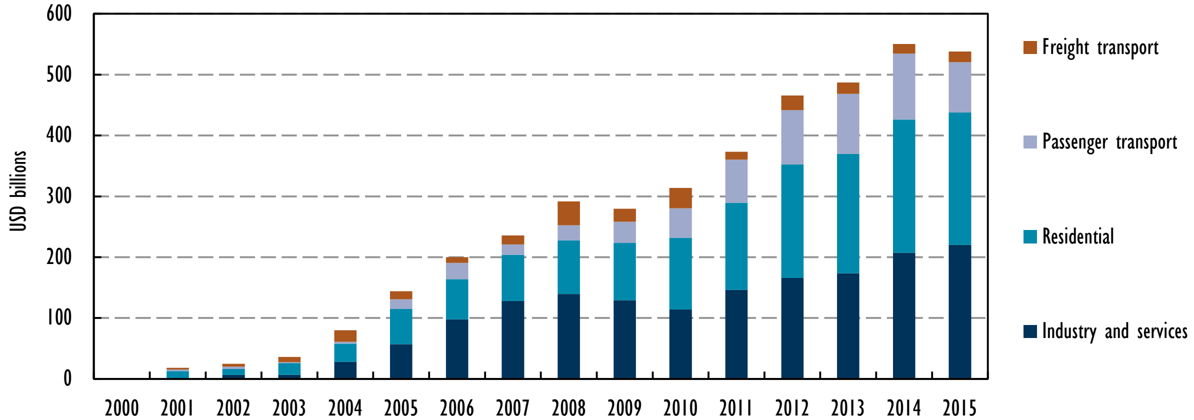
Figure 1.15 TFC and TPES savings from energy efficiency improvements since 2000 in IEA countries, 2015



Avoided expenditure on energy by end users

The 19 EJ of fuel savings highlighted above represent significant avoided expenditure on end-use energy: a total of USD 540 billion across all IEA countries (Figure 1.16). While 2015 energy savings were higher than in 2014, avoided expenditure was down, reflecting important effects from the decline in retail oil prices. At the per-capita level, energy efficiency gains since 2000 reduced the average nominal expenditure on energy by USD 490 in 2015 across IEA countries. The total cumulative savings on energy expenditure between 2000 and 2015 were over USD 4 trillion.

Figure 1.16 Avoided expenditure on end-use fuels in IEA countries by sector, 2000-15

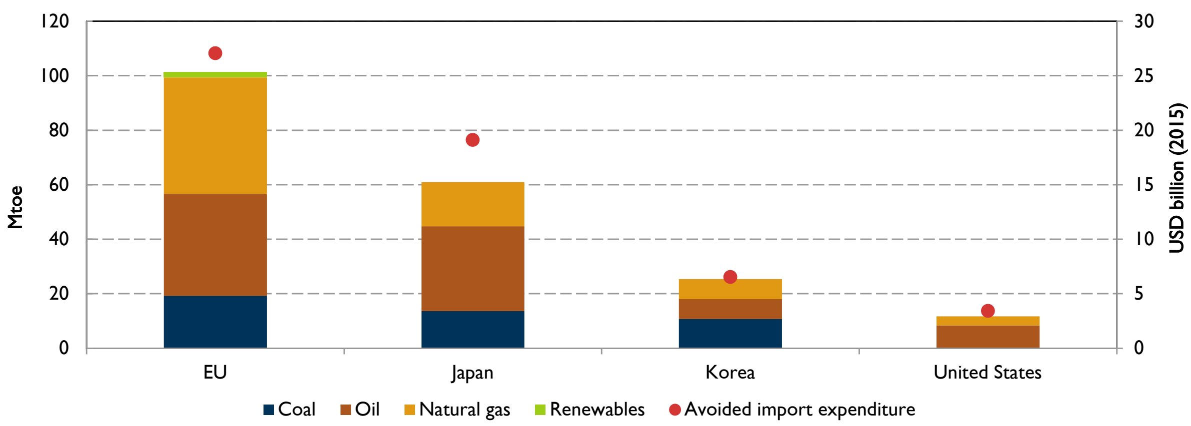


Avoided primary energy imports

For most IEA countries, lower demand for primary energy also decreases the volume of energy imports needed. The IEA estimates the avoided imports from energy savings by allocating savings to specific fuel types. Then, on a country basis, the ratio of domestic production to imports is calculated per fuel. Finally, using this ratio, the fuel savings are apportioned by domestic production and imports. The results likely reflect a conservative estimate of the avoided imports as many energy importing countries do not have the resource capacity to expand domestic production in line with increased demand.

Total avoided imports from energy efficiency improvements since 2000 were 203 Mtoe (8.5 EJ) in 2015 – 7% of total energy imports to IEA countries (Figure 1.17). Crude oil savings were the largest share of avoided imports at 42%, followed by natural gas at 35%. The European Union (EU), the world's largest energy-importing region, represented half of the energy import savings at 101 Mtoe. Avoided imports in Japan were the next largest, at 61 Mtoe, followed by Korea at 25 Mtoe and the United States at 12 Mtoe. Avoided imports in the United States were low because of its large share of domestic production of coal, oil and gas.

Figure 1.17 Total avoided import costs for oil, gas and coal with share of savings by country or region, 2015



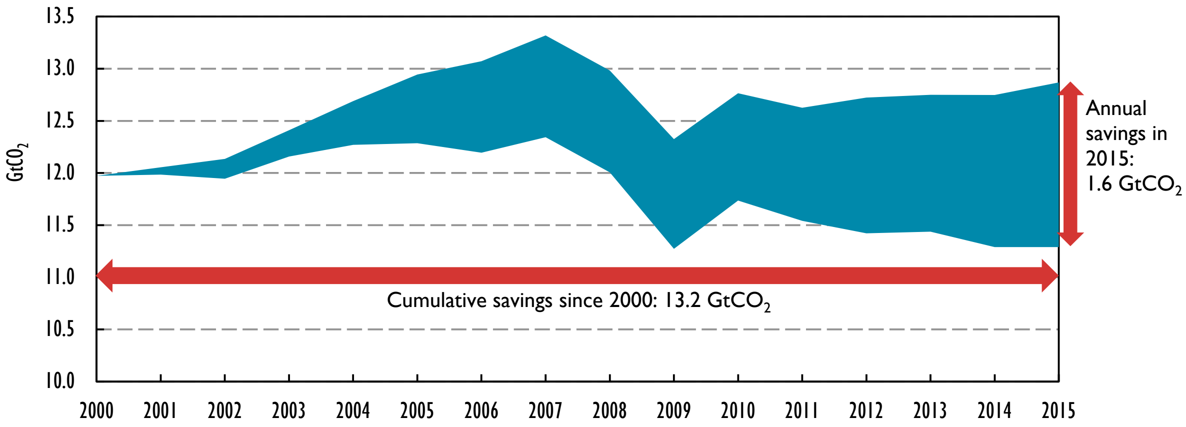
Note: Primary renewable energy imports in this context are biomass.

The impacts of energy efficiency on national trade deficits are significant. Energy savings in 2015 reduced total import bills across the IEA by at least USD 56 billion. In 2015, the European Union spent USD 270 billion on energy imports (Reuters, 2015), the single largest imported good in the region (Eurostat, 2014). Japan spent USD 128 billion on fuel imports in 2015, with avoided imports saving 21% of the country's total imports bill (OECD, 2015). In 2015, energy efficiency improvements reduced the EU import bill by USD 27 billion (10% of total spending on energy imports) and Japan's fuel import bill by USD 19 billion (15%).

Reducing GHG emissions and air pollution

Avoided primary and end-use fuel consumption from energy efficiency improvements also avoids GHG emissions. In 2015, efficiency allowed IEA countries to avoid 1.5 $GtCO_2$, an amount exceeding Japan's total emissions for the same year. Cumulative savings since 2000 were 13 $GtCO_2$ – greater than the 2015 emissions of all IEA countries (Figure 1.18). Over half of these GHG savings came from the industry and services sector. The residential sector accounted for approximately 400 million tonnes CO_2 of avoided emissions. This effect emphasises the importance of seemingly small efficiency improvements such as in appliances and building envelopes; stacked together, they can significantly reduce GHGs over the medium term.

Figure 1.18 Avoided GHG emissions from energy efficiency improvements in IEA countries, 2000-15



Energy efficiency also reduces local air pollution. IEA analysis has shown that existing and planned policies to increase energy efficiency and decarbonise energy supply contribute 40% to a global decline of SO_2 emissions, 35% to a decline in NOx emissions and 60% to a reduction of PM2.5 emissions by 2040.

Avoided investments in power supply

Reducing infrastructure investment requirements in the electricity system is another important benefit of energy efficiency. Energy efficiency improvements since 2000 saved an estimated 1 600 terawatt-hours of electricity consumption in 2015 equal to 15% of total electricity generation in the IEA. Servicing this hypothetical additional demand would have required new power supply.

To estimate the additional generation capacity and investment required, the *Energy Technology Perspectives* energy supply model was used to run a scenario in which electricity consumption is 15% higher in 2015. The model uses a least-cost optimisation, constrained by technical limits and policies, to estimate the mix of new generation that would have been built in 2015 to satisfy this additional demand. The modelling results show that energy efficiency avoided 578 gigawatts of new generation capacity and USD 1.2 trillion in investment across IEA countries.

Decomposing energy intensity and efficiency changes in emerging economies

This year for the first time, the *Energy Efficiency Market Report* includes key emerging economies in its decomposition analysis. The analysis covers IEA accession country Mexico, IEA association countries China,[8] Indonesia and Thailand, and key partner countries Brazil and India. These six countries make up 35% of global TFC. Added to the IEA countries evaluated previously, the full group of countries analysed in *EEMR 2016* covers 70% of global TFC.

Measuring the performance of energy efficiency in emerging economies is more difficult than for IEA countries, due to a relative lack of end-use energy data. As a result, this analysis provides a partial picture of energy intensity improvements, isolated from structural factors. This efficiency effect sheds light on factors that are aligned more closely with energy efficiency improvements. However, because of the high level of aggregation, the analysis is not as refined as for IEA countries and the efficiency effect likely includes some other factors that reduce energy intensity. The energy consumption analysed in this section covers the productive economy (industry, services and agriculture) and both passenger and freight transport but not the residential sector (Box 1.5). The share of TFC evaluated ranges from 59% to 87% of TFC among individual countries and 70% of their combined TFC.

Box 1.5 The efficiency effect in emerging economies: data and methodology

This high-level analysis evaluates passenger and freight transport (using the IEA Mobility Model [MoMo] database) and the industry, services and agriculture sectors using data from the IEA and World Bank (Table 1.2). It is admittedly limited by the availability and quality of data.

Table 1.2 Sectors and data sources in the decomposition of TFC in emerging economies

Sector	Sub-Sectors	Activity data source	Energy data source
Commercial	Industry, services, agriculture	World Bank, GDP	IEA Energy Balances
Passenger Transport	Light commercial vehicles, public transport	IEA MoMo	IEA MoMo
Freight transport	Heavy duty vehicles, rail	IEA MoMo	IEA MoMo

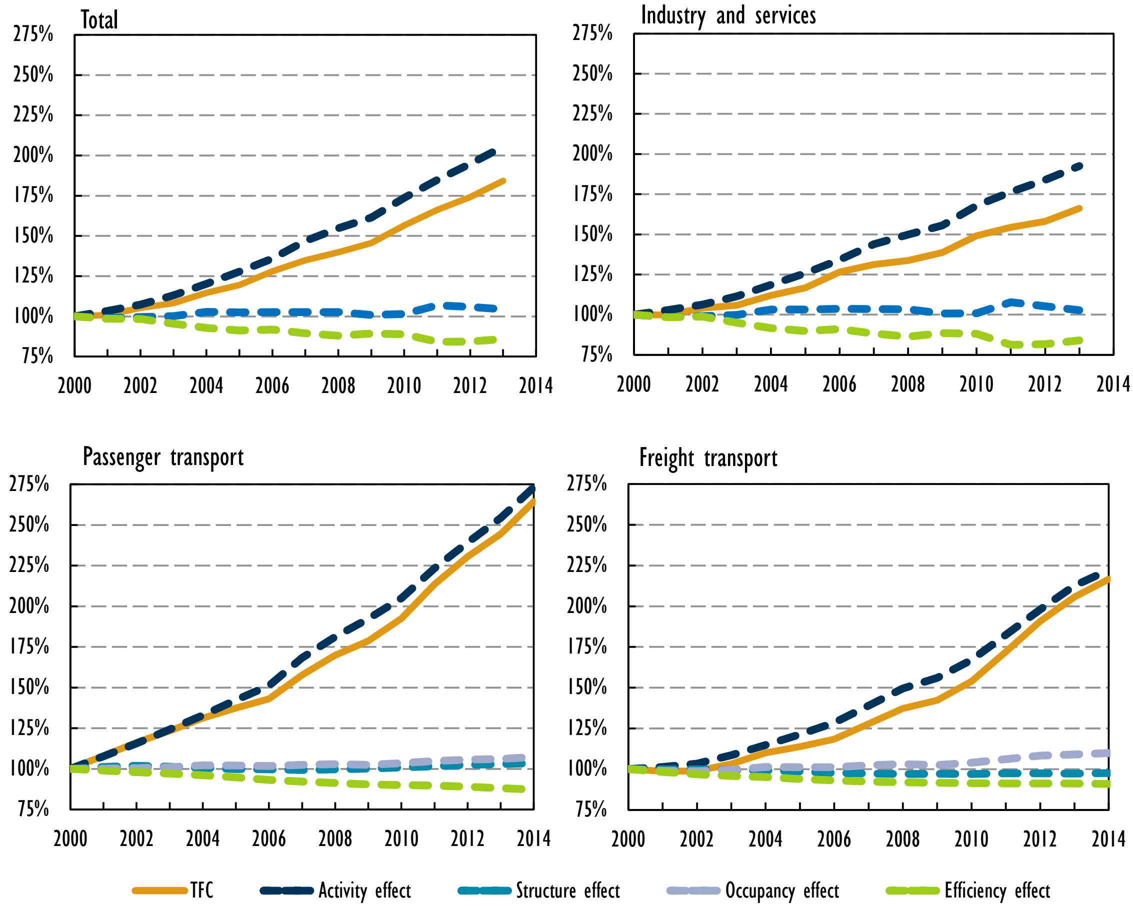
Sources: IEA (2016a), "World energy balances", *IEA World Energy Statistics and Balances* (database), DOI: http://dx.doi.org/10.1787/data-00512-en; IEA (2016b), Mobility Model, 2016 version (database and simulation model), www.iea.org/etp/etpmodel/transport; World Bank (2016c), *World Development Indicators* (database) retrievable from: http://databank.worldbank.org/data/.

Commercial is not broken down into industry, services and agriculture sectors, which limits the ability to draw insights into sector-specific energy efficiency changes. Data in the transport sector are from the MoMo, which includes a combination of real energy indicator data and expert analysis. The residential sector is not included because of the lack of detail on end-use energy consumption. This analysis steps beyond assessing total energy intensity by isolating changes in energy intensity from structural factors in key sectors. It thus provides a better depiction of the scale of intensity and efficiency improvements.

[8] The following chapter is a detailed analysis of energy efficiency in China.

TFC in the sectors of the six emerging countries analysed rose by 84% between 2000 and 2014, which compares to activity levels (GDP, passenger kilometres and freight tonne kilometres) more than doubling. The efficiency effect improved by 14% compared with 2000, with less energy consumption per vehicle-kilometre and improved energy intensity in the agriculture, industry and services sectors (Figure 1.19).

Figure 1.19 Decomposition of energy demand in Brazil, India, Indonesia, Mexico and Thailand by sector, 2000-14



Notes: Energy use decomposed in this analysis includes the agricultural, industrial, services, passenger and freight transport sectors. The efficiency effect depicted in the charts aligns with that for IEA countries; however, end-use energy consumption data are more aggregated than for IEA countries.

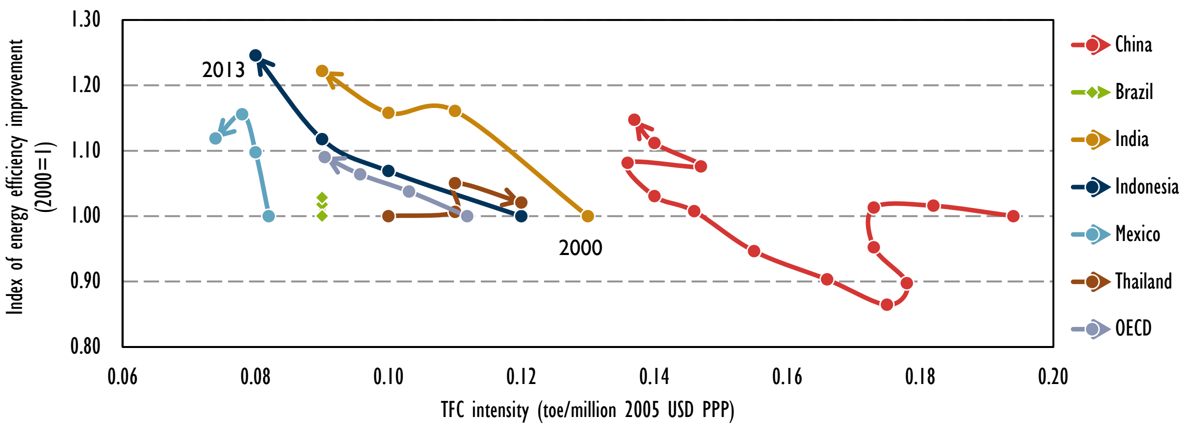
The largest gain in the efficiency effect in these emerging economies was in the industry, services and agriculture sectors, improving by 16% compared with 2000 levels. Structural changes were comparatively smaller and did not notably change between 2000 and 2014. The structural shift after 2010 likely reflects a rebalancing of output and prices in the wake of the global financial crisis. The lack of structural change demonstrates that the growth of industrial output relative to services and agriculture output is not changing. However, because of the high level of aggregation of the industrial sector there is likely more structural change occurring underneath the surface of this analysis.

In the transport sector, once vehicle occupancy is corrected for, increasing activity levels and TFC track each other closely. In passenger transport, TFC rose by a factor of 2.6 while activity rose by 2.7; in freight, TFC and activity both increased by a factor of 2.2. The tight link between TFC and activity shows the small but offsetting effects of structural and occupancy factors on efficiency. Vehicle occupancy rates can affect energy consumption by requiring comparatively more (or fewer) vehicles to move the same amount of passengers or payload. Lowering occupancy and changing structure are important in many emerging economies as growing incomes and preference for personal vehicles over other transport modes creates upward pressure on TFC.

How do changes in the efficiency effect relate to changes in total energy intensity? Figure 1.20 outlines economy-wide energy intensity changes on the x-axis compared to the efficiency effect changes on the y-axis. India and Indonesia had the largest percentage change in energy intensity. Brazil shows only small changes in both total energy intensity and the intensity effect. Thailand became more energy intensive between 2000 and 2013 but has also improved the efficiency effect. Individual country contexts are a key factor. The diverse trends in efficiency development in emerging economies indicates that efficiency improvement is not a given as an economy grows. Rather that improvement requires targeted action and is strongly linked to economic performance, national policy developments and investment.

The greatest absolute change in energy intensity over the period analysed is observed in China, although the percentage change is highest in Indonesia and India, owing to China's markedly higher intensity in 2000. The percentage improvement in TFC intensity in Indonesia (33%), India (31%) and China (30%) all exceed the improvement in OECD countries of 19%.

Figure 1.20 TFC intensity and improvements in the efficiency effect in six emerging economies and OECD, 2000-13



2. ENERGY EFFICIENCY IN CHINA

Highlights

- **Progress in the People's Republic of China (hereafter "China") over the last decade has made it the world's energy efficiency heavyweight.** Between 2000 and 2015, its energy intensity improved by 30%, with energy efficiency gains playing a large role. Efficiency across China's major energy-consuming sectors improved by 19% – a faster rate than efficiency improvements in countries belonging to the International Energy Agency (IEA). Though China started from a relatively energy-intensive position (65% higher than IEA countries in 2000), the prioritisation of energy efficiency in government policy unlocked the significant improvement potential, particularly in the energy-intensive industry sector.

- **The annual energy savings from energy efficiency are equivalent to China's renewable energy supply.** Energy efficiency efforts since 2000 led, in 2014, to annual primary energy savings of 325 million tonnes of oil equivalent (Mtoe), equal to 11% of total primary energy supply (TPES). These savings are greater than the TPES of Germany in 2014.

- **China's energy efficiency gains avoided 1.2 gigatonnes of carbon dioxide (GtCO_2) emissions in 2014**. Overarching framework policies to improve energy efficiency in China, beginning in 2006 with the 11th Five Year Plan (FYP), have been one of the most important actions to reduce global greenhouse gas (GHG) emissions by any country over the past ten years.

- **Most of China's energy demand savings have been in industry.** Since 2006, a mandatory, target-based energy savings programme has been in place for the largest most energy-intensive enterprises. This programme was expanded to over 16 000 enterprises in 2011, and generated net annual savings of 216 Mtoe in 2014. The largest efficiency gains were in the cement, chemicals and the light manufacturing.

- **The slowing growth of China's energy consumption, aided by efficiency, is rippling through global energy commodity markets.** Efficiency gains since 2000 led to annual savings of 350 million tonnes of coal. This was equivalent to 6% of global coal production and 29% of coal exports in 2014. As China is still 50% more energy intensive than IEA countries, energy markets will continue to be affected as China drives to improve intensity over the coming decades.

- **China's efforts on energy efficiency are accelerating**. The 13th FYP (2016-20) targets a 15% energy intensity improvement from 2015 levels by 2020 and 560 Mtoe of energy savings annually by that year. Economic restructuring is planned to make up 65% of the targeted energy savings; energy efficiency and productivity improvements will deliver the balance. Restructuring to this scale will require focused, long-term policy leadership.

- **As its economy continues to expand, China will need to continue to strengthen its commitment to energy efficiency to meet GHG emissions reduction in line with the global 2°C goal.** Between 2015 and 2030, energy intensity would need to improve at a rate of 4.7% per year, a step up over the average annual rate of improvement between 2004 and 2014 at 3.1%. Energy intensity improved by 5.6% in 2015, indicating that this transition is underway, if the rate of improvement remains at this order over the next 15 years.

Introduction

China accounted for approximately half of global energy demand growth between 2000 and 2015 (including 85% of growth in global coal demand). To put this into perspective, the *growth* in China's energy demand between 2000 and 2015 was greater than the *total* energy demand of the European Union in 2015.

Various factors influence energy efficiency potential and its actual achievement in China. The country's legacy of inefficient energy infrastructure and industrial capacity are significant sources of energy efficiency potential. But with per-capita income having more than tripled since 2000 (to 10 000 United States dollars [USD]),[1] demand has sharply increased for modern energy services to support growing use of electronics, appliances and motorised transport. Energy supply per capita in China has more than doubled since 2000, from 0.9 tonnes of oil equivalent (toe) to 2.2, with per capita consumption in the residential sector growing by 30% while transport grew by 163%. This makes the task of evaluating energy efficiency in China difficult as surging energy consumption and demand for end-use services can cloud the role the efficiency is having in restraining energy demand.

This chapter was developed with assistance from the Energy Research Institute of China (ERI), which works within the National Development and Reform Commission, to provide expert advice and policy analysis on energy issues. The ERI is tasked with providing the analytical basis for energy policies and targets in the FYP process, and has collaborated with the IEA to outline key components of the 13th FYP, including the anticipated actions for energy efficiency and the savings they deliver.

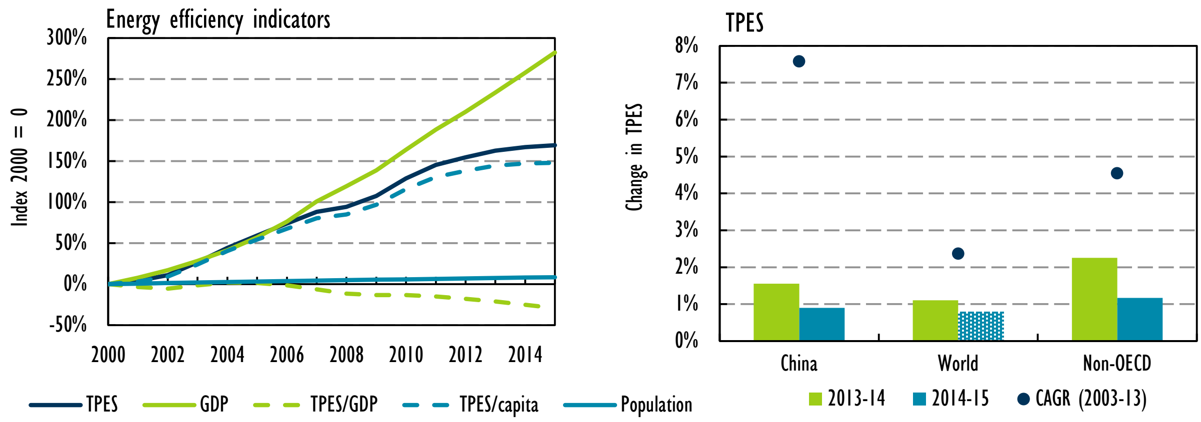
Recent trends in energy intensity and energy demand

China's recent rapid energy demand growth, fuelled by expanding industrial production, appears to be ending. Chinese policy makers are now emphasising a shift to slower overall growth (forecast at 6.5% per year) and to less energy-intensive forms of production. Also, they recognise better the need to balance growth with other objectives such as reducing pollution and shifting towards a consumer-oriented economy. Energy-intensive industrial production is moderating as the government attempts to stimulate rebalancing of output towards services and less energy-intensive (particularly coal-intensive) production. Coal consumption appears to have reached a plateau, at least in the short term. While some sectors still have strong drivers for growth in energy demand, growth in CO_2-intensive fuel consumption appears to be waning.

The transition to a less energy-intensive economy shows early progress. Based on data from the National Bureau of Statistics of China (2016), energy intensity improved by 5.6% in 2015 – faster than the 4.8% achieved in 2014 and well above the 2003-13 annual average of 2.2%. In 2015, for the first time since 1997, total primary energy supply (TPES) growth in China nearly paused, increasing by only 0.9%. Growth in energy demand began to slow significantly in 2014, with growth of primary energy demand at 1.6%, well below the previous decade's compound average annual rate of 7.6% (Figure 2.1, right). Chinese GDP grew by 6.9% in 2015, down from 7.3% in 2014 and the previous ten-year average of 10%.

[1] Based on gross domestic product (GDP) measured on a purchasing power parity basis in constant 2005 US dollars.

Figure 2.1 TPES, population, GDP and major energy efficiency indicators in China



Note: CAGR = compound annual growth rate. Patterned columns represent estimates by the IEA. GDP calculated at 2010 USD using exchange rates. China's TPES growth for 2015 is from the Chinese National Bureau of Statistics.

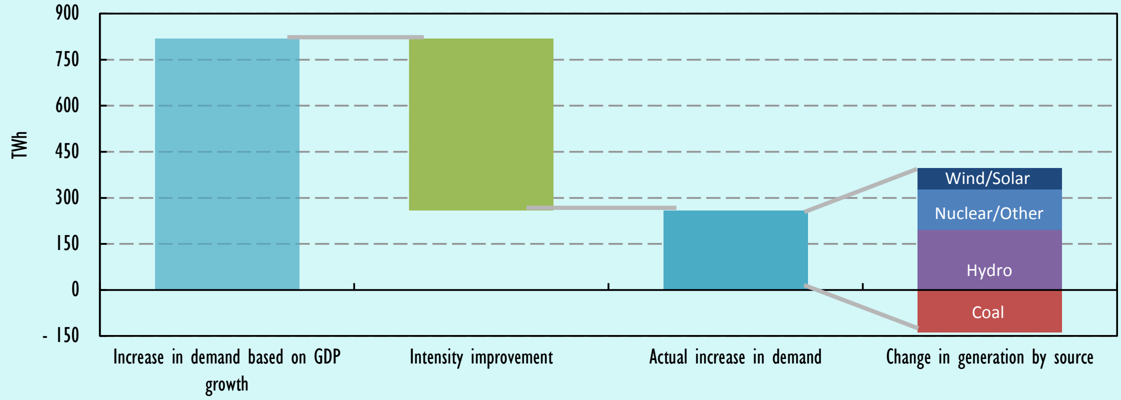
Sources: IEA (2015), *World Energy Outlook*, OECD/IEA, Paris; IEA (2016a), "World energy balances", *IEA World Energy Statistics and Balances* (database), DOI: http://dx.doi.org/10.1787/data-00512-en; National Bureau of Statistics of China (2016), *National Data* (database), retrievable from http://data.stats.gov.cn/tablequery.htm?code=AD0H.

Box 2.1 What factors are driving down coal demand in China?

Energy intensity improvements are having material impacts on energy consumption in China. IEA data show that global GHG emissions slowed in 2015, primarily because growth in Chinese coal consumption paused and has possibly peaked.

What explains this lack of growth in Chinese coal consumption? Energy intensity improvements are the primary factor softening the coal demand in the power sector. Based on the historical relationship between electricity consumption and economic growth, electricity consumption would have grown by more than 800 terawatt-hours (TWh) in 2015; instead, it grew by only 259 TWh (Figure 2.2). Intensity improvements reduced the hypothetical demand for coal-fired generation by 560 TWh; meanwhile renewables and nuclear generation grew by 400 TWh in 2015. The combined effect of improving energy intensity and increased generation from renewables and nuclear worked to reduce coal generation by 140 TWh. This illustrates the importance of energy intensity and efficiency improvements in producing tangible outcomes in the Chinese energy system.

Figure 2.2 Factors affecting reduction in coal power generation, 2013-15



China's most recent FYP (the 13th) set an interim target of reducing energy intensity by 15% below 2015 levels by 2020. If met, this will represent a 44% reduction in energy intensity between 2005 and 2020. This overall improvement will help China achieve its pledge to peak CO_2 emissions by 2030, with a decrease in the carbon intensity of the economy to 60% to 65% below 2005 levels.

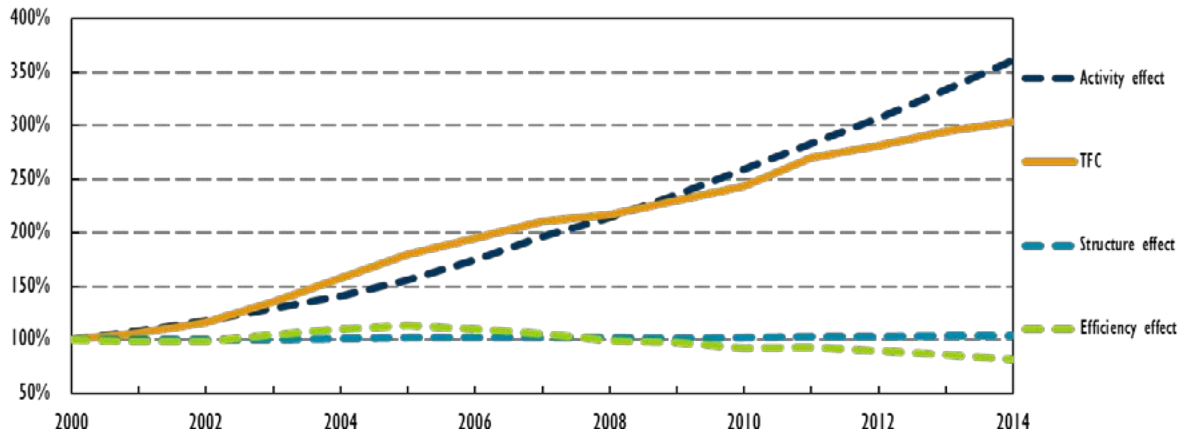
Decomposition of energy demand in China

Energy efficiency improvements are difficult to assess against the immense growth of China's economy and energy system. However, the decomposition of energy demand into activity, structure and efficiency effects helps reveal energy efficiency's role. This analysis uses GDP growth as the "activity effect" in the industry and services sector, and shows it increasing by 260% between 2000 and 2014 in China. By contrast, the activity level in member countries of the Organisation for Economic Co-operation and Development (OECD) from 1990 to 2014 grew by only 14%.That rapid activity growth in China reflects significant pent-up demand for energy services.

China's TFC increased quickly, but not in lock-step with the activity drivers of TFC. On average, TFC in the industry, services and agriculture sector increased by 5% annually from 2006 to 2014 while gross value added increased by 10%. Decomposition analysis indicates that energy efficiency and productivity improvements are the primary factor explaining this growing gap between TFC and activity levels in China.

Across all of China's end-use sectors, energy efficiency improved by more than 19% since 2000 and the pace of change appears to be quickening (Figure 2.3). During the implementation of China's 11th FYP (2006-10) and the 12th FYP (2011-15), energy efficiency levels improved at an average annual rate of 4%.[2] Energy efficiency investments have scaled-up alongside the expansion of energy supply and are now an essential component of China's energy system.

Figure 2.3 TFC in China decomposed by factor, 2000-14



Note: This figure includes the results of the decomposition of energy consumption in three sectors: i) the productive economy in 21 sub-sectors including agriculture, construction, manufacturing and services; ii) passenger and freight transport; iii) residential heating in northern China.

[2] This rate held except in 2011 when efficiency declined by 0.5%. This was largely because energy-intensive industries were revitalised in the framework of China's stimulus plan in the aftermath of the 2008/09 global financial crisis.

Structural change has not been as important a factor to influence Chinese energy demand between 2000 and 2014. The drivers of Chinese energy consumption between 2000 and 2014 can be broken down into three phases. The first phase was worsening intensity between 2000 and 2005 which coincided with a lack of framework policies to reduce energy intensity. The second phase was rapid growth in activity and efficiency. From 2006 to 2010 the activity drivers (GDP population and passenger and freight kilometres) increased by an annual average of 11%. Meanwhile, efficiency increased by an annual average of 4%. The third phase, from 2010 to 2014, saw growth in activity and efficiency improvements and a rebalancing of Chinese economic output away from the production of metals. This structural change with a lower share of metals value-added to total value-added was offset however by increases in the share of cement, chemicals and services leading to only small energy savings from structural factors across the economy.

Box 2.2 Approach to decomposing China's energy consumption

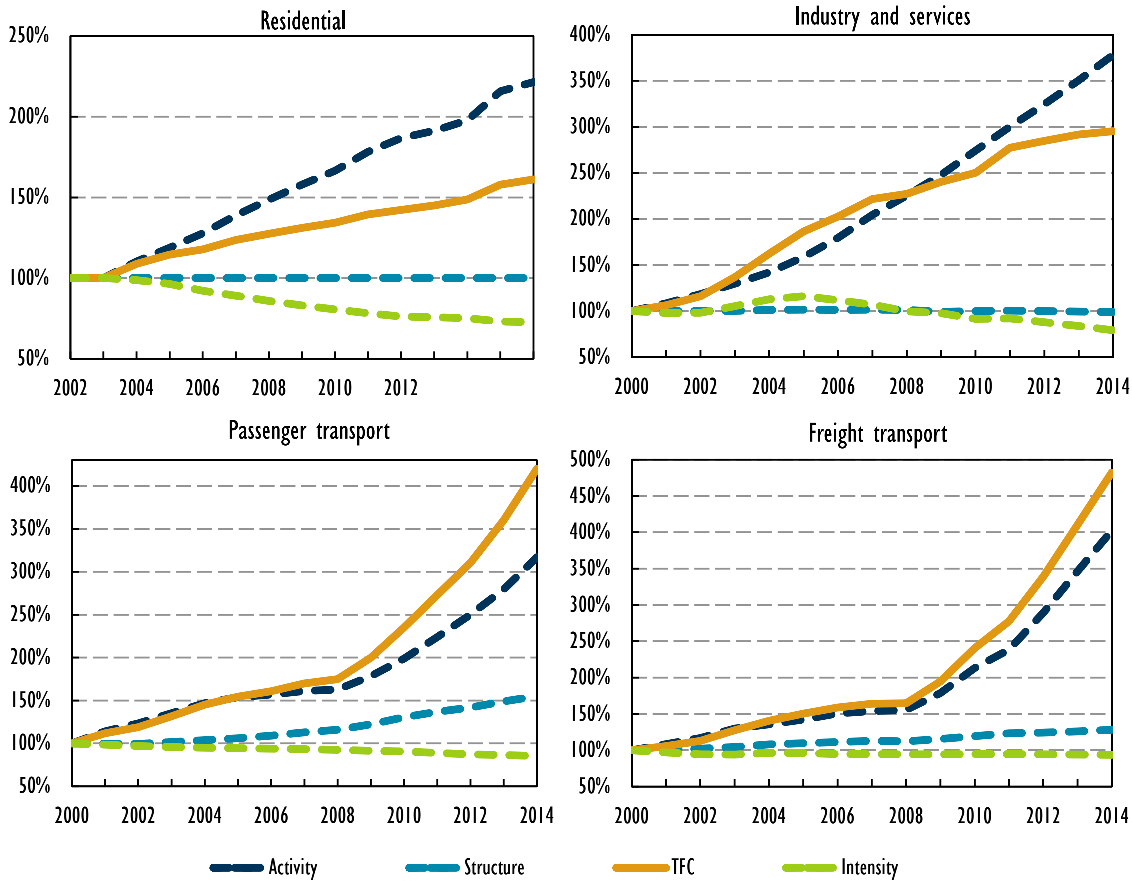
Decomposition analysis allows better isolation of the role of energy efficiency in TFC in China over the period 2000-14. The IEA uses expert analysis and country-level data sources to identify and track key indicators of China's energy system. The level of detail in this study has been chosen on the basis of official data availability, international classification, and consistency between energy data and value-added data.

The energy consumption covered in this analysis represents roughly 87% of TFC in China.* In industry, services and agriculture, the IEA used detailed economic output and energy consumption data published by the NBS to develop a detailed representation of China's economy, structural change and sub-sector energy consumption. Industry comprises 16 sub-sectors,** while the services sector has five.*** The annual growth rate of value added published by NBS was used to estimate the value added in each subsector. For passenger and freight transport, the IEA MoMo database is used for detailed fuel consumption and vehicle travel by mode. Due to data constraints, residential energy consumption covers only urban space heating, representing around 21% of TFC in that sector.

Notes: * The TFC in 2014 covered in this analysis totals 80 096 petajoules (PJ), compared to 92 007 PJ based on the *China Energy Statistical Yearbook 2015*.
**Includes mining and quarrying; food, beverages and tobacco; textiles and textile products; leather and footwear; wood and products of wood and cork; pulp, paper, printing and publishing; coke, refined petroleum and nuclear fuel; chemicals and chemical products; rubber and plastics; other non-metallic minerals; basic metals and fabricated metal; machinery, electrical and optical equipment; transport equipment; manufacturing, recycling; electricity, gas and water supply; and construction. The sub-sector of coke, refined petroleum and nuclear fuel is excluded because it is primarily used for non-energy purposes.
***Includes wholesale; retail trade; hotels and restaurants; financial intermediation; real estate activities and others.

The average national efficiency improvement is the weighted sum of efficiency improvements in each major energy-consuming sector. Decomposition analysis is conducted for four sectors – industry, agriculture and services; passenger transport; freight transport; and residential heating (Figure 2.4). Efficiency of residential heating has improved steadily since 2000. Industry experienced a worsening of efficiency levels from 2000 to 2005 coinciding with the significant growth in the sector and the relative lack of stringent policies to improve energy efficiency in the sector. Since 2006 and the implementation of the 11th FYP, industrial efficiency improved by 19% compared with efficiency levels in 2000. Passenger and freight transport efficiency improvements are less marked; structural changes due to the shift to larger personal vehicles and freight shipped by road vehicles are an increasingly important factor.

Figure 2.4 Sector decompositions of energy use in China



Note: Decomposition of residential energy use focuses on energy consumption for space heating in northern China. As China's official statistics report district heating energy use in the form of primary energy, the decomposition analysis on space heating reflects energy use in the district heating system as a whole, from supply side to demand side.

Table 2.1 Parameters of decomposition of TFC for China

Sector	Service/sub-sector	Activity	Structure	Efficiency effect	Data source
Residential	Space heating*	Floor area	Share of floor area heated by heating system type**	Space heating energy per system type***/ floor area	ERI, Tsinghua University
Passenger transport	Car; bus; rail	Passenger-kilometre	Share of passenger-kilometres by mode and persons per vehicle	Energy/ vehicle kilometre	IEA MoMo

Sector	Service/sub-sector	Activity	Structure	Efficiency effect	Data source
Freight transport	Truck; rail	Tonne-kilometre	Share of tonne-kilometres by mode and tonnes per vehicle	Energy/ vehicle kilometre	IEA MoMo
Industry, agriculture and services	Food, beverages and tobacco; paper, pulp and printing; chemicals; non-metallic minerals; primary metals; metal products and equipment; other manufacturing, service sector, agriculture; construction	Value-added	Share of value-added	Energy/ value-added	IEA, National Bureau of Statistics of China

* In the residential sector, the only end-use data available for decomposition were space heating in northern China, which represents 25% of China's total residential energy consumption.
** The structure effect in residential space heating is considered an efficiency improvement in this analysis, with the structural change being the replacement of coal stoves with more efficient district heating systems.
*** Space heating energy per system type evaluates the intensity of different heating systems by fuel type relative to the floor area that those systems heat. This measures both the improvement in building efficiency and the efficiency of new heating systems.
Sources: IEA (2016a), "World energy balances", *IEA World Energy Statistics and Balances* (database), DOI: http://dx.doi.org/10.1787/data-00512-en; IEA (2016b), Mobility Model, 2016 version (database and simulation model), www.iea.org/etp/etpmodel/transport; National Bureau of Statistics of China (2016), *National Data* (dataset), retrievable from http://data.stats.gov.cn/tablequery.htm?code=AD0H; Tsinghua University (2015), *2015 Annual Report on China Building Energy Efficiency*, Tsinghua University Building Energy Research Center, Beijing.

Industry, agriculture and services sectors

Savings from energy productivity and efficiency in China's industry, services and agriculture sector are the largest in magnitude because of its dominant share (58%) in TFC in China. Overall productivity levels (energy consumption per unit of value-added) in the sector improved by 19% between 2000 and 2014. The improvement in efficiency is pronounced in several sectors: energy intensity declined by 53% in the pulp and paper sector, by 35% in cement, by 34% in services and by 20% in chemicals. Due to the impacts of changing prices, the energy intensity per unit of value-added could decrease even though energy intensity per unit of physical output improves. Some commodity industries, such as steel, are particularly sensitive to the price impact.

Structural change (shifts in relative value-added among 20 sub-sectors in this analysis) has had comparatively little impact on energy consumption in China. The rising shares of output value in cement, chemicals and services subsectors have contributed to increasing energy consumption, while these impacts have been almost offset by the decline in proportion of output value in other sectors, including metals and agriculture. Overall, the economic restructuring over the period of 2000-14 has not achieved significant effects on energy consumption. The Chinese government has set policy objectives to shift the economy away from energy-intensive industry sectors towards more productive and higher-value sectors and to the services sector. This structural change is expected to become an important factor influencing energy use in the 13th FYP, accounting for 65% of the planned energy savings.

It is important to note that energy intensity in these sectors can improve without efficiency investments. If firms become more profitable with the same energy-using equipment, for example by reducing other input costs, their energy intensity improves. However, analysis suggests that efficiency investment has been the driving force behind intensity gains. Between 2000 and 2005, energy productivity in Chinese industry declined by 18%. Intensity began to improve in 2006, when the 11th FYP set ambitious energy efficiency policies, which were supported by improved implementation and significant investments.

Industry and service sector efficiency policies improving energy efficiency

The Chinese government enacted (from 2006 to 2010) a mandatory energy savings programme, called the Top 1 000 Program, for the 1 000 largest enterprises in nine energy-intensive sectors. In 2005, the enterprises subsequently regulated accounted for 33% of the country's TFC and 47% of industry TFC. Energy efficiency targets were incorporated into performance evaluations for managers in these companies. In addition, a differentiated electricity pricing system was applied to the cement and aluminium sectors, along with a surcharge for poor energy performance (China State Council, 2013). Finally, an energy efficiency fund was created to support the enterprises concerned.

Overall, the programme led to 105 Mtoe of annual savings, 1.5 times more than the original target (NDRC, 2011). Based on the success, in 2011 the scope of the programme was extended to the top 10 000 enterprises. A total of 16 078 enterprises, across almost all sectors, are now required to meet energy savings targets. Between 2011 and 2014, the Top 10 000 programme saved 216 Mtoe annually – over 20% more than the revised target of 175 Mtoe (NDRC, 2015).

During the same period, inefficient industrial plants were also decommissioned, leading to overall sector energy productivity improvements. During the 11th FYP, production capacity closures were substantial in three key industries: 122 million tonnes (Mt) of iron production capacity, 70 Mt of steel production capacity and 330 Mt of cement production. During the first four years of the 12th FYP, further decommissioning (78 Mt of steel production capacity, 600 Mt of cement production capacity, 150 Mt of glass production capacity, and 23 630 megawatts [MW] of power production capacity) has allowed newer, more efficient plants to improve the average intensity of the sector.

Heating in the residential sector in northern China

China's rapid urbanisation has expanded the area of residential buildings requiring heating by a factor of more than 2.2. Since 2000, approximately 5 billion square metres (m^2) of residential floor space was heated in 2000, increasing to 12 billion m^2 in 2014. The energy consumed in space heating increased by a factor of only 1.6. As a result, residential space heating shows a significant improvement in energy efficiency – a 27% reduction compared with 2000.[3]

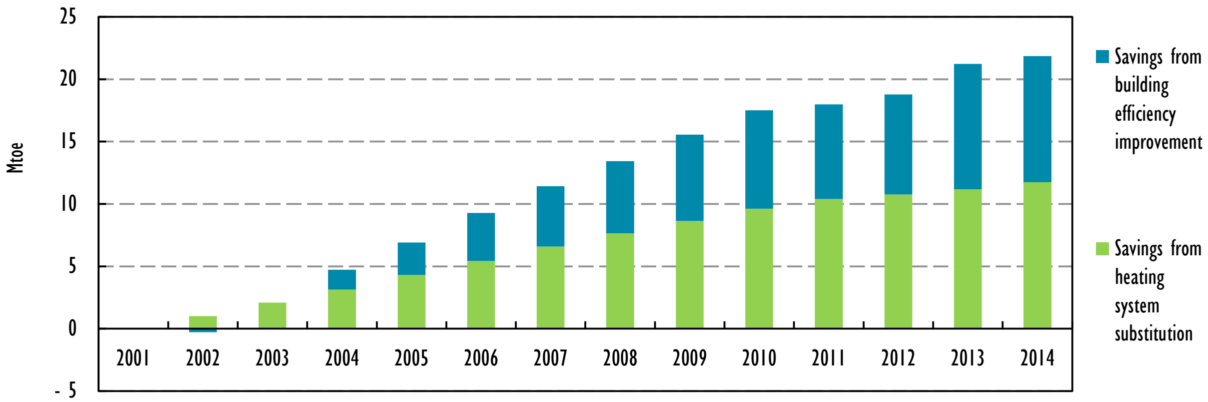
Both energy and environmental challenges prompted China to pursue a series of actions to improve energy efficiency in the residential sector. The combination of co-generation,[4] switching to gas boilers, recovering industrial waste heat, identifying distributed solutions, and strengthening demand-side measures through building energy management and consumption-based billing has led to China's northern urban region becoming the world's largest and fastest-growing user of district heating. China has seen a considerable shift from coal-powered, heat-only boilers to large co-generation. Co-

[3] This analysis of the residential sector focuses on urban district heating use, which represents approximately 21% of total residential energy consumption in China.

[4] *Co-generation* refers to the combined production of heat and power.

generation boilers currently provide 42% of total heating area, up from 26% in 2000. Substitution away from small coal stoves and boilers towards large boilers and co-generation systems saved 12 Mtoe in the residential sector over the past 15 years (Figure 2.5). The switch to district heating was also assisted by increasing urbanisation and densification of urban areas.

Figure 2.5 Energy savings from efficiency improvements in China's residential sector



In addition to switching to more efficient heating systems, China also took steps to improve the efficiency of those systems and of the building stock, saving a further 10 Mtoe (Figure 2.5). In 2007, the government launched a building retrofit and heat-metering reform programme with the goal of improving the energy efficiency of 150 million m^2 of building area. China issued its first mandatory national building energy efficiency (BEE) standard for new residential buildings in cold regions in 1995. This standard (referred to as the 50% BEE standard) required new buildings to achieve a combined 50% improvement in energy efficiency over buildings constructed on standard designs of the early 1980s. Since August 2010, a 65% BEE standard has become mandatory for new construction in China's cold climate regions.

Despite progress to date, multiple split incentives remain – on both supply and demand sides of district heating systems – that prevent the scale-up of energy efficiency projects. Reforms to commoditise heat are not fully adopted. Heat billing is largely based on a flat energy cost per square metre, regardless of the amount of energy consumed or level of comfort desired. Many employers pay the heat bills for their employees, as part of the social welfare system. When energy efficiency gains cannot cover the infrastructure improvement investments, heat companies may lose the investment incentive. More efforts are still required to supply low-temperature heat networks, integrate renewable heat sources and connect to smart electricity grids (IEA, 2016).

While this analysis focuses on space heating, China has also developed a suite of policies to improve the efficiency products for other residential end uses such as appliances, electronics, lighting and space cooling. As China's per capita income has increased, so has demand for modern energy services from such devices. China has a long history of implementing minimum energy performance standards (MEPS) on appliances (see Chapter 3). In 2005, it also introduced a mandatory energy labelling system that now covers 28 appliance types. Grants and subsidies are also available for the purchase of energy-efficient appliances. In 2012, a total of USD 4 billion was spent to promote energy-efficient air conditioners, refrigerators, washing machines, televisions and water heaters. To further encourage energy conservation, the government also introduced tiered rates for electricity, in which the price of a unit of electricity rises with the quantity of electricity consumed.

Transport sector

In China's passenger transport sector, energy efficiency by 2014 improved by 15% relative to 2000 levels. The improvement was driven by a move toward more efficient standards for personal vehicles. However, as China continues to develop, a shift toward more energy-intensive modes of transport could depress overall efficiency improvements. In addition, lower vehicle occupancy will increase the energy intensity of passenger vehicle travel. Sales of passenger light-duty trucks in China have increased by 72% since 2011 and now make up 33% of new vehicles sold in 2015 (compared with 28% in 2010). The appeal of these vehicle types is increasing and is expected to continue rising in the coming years.

Efficiency standards will help stem efficiency losses from the move to larger vehicles. China first introduced vehicle fuel economy standards in 2005. New standards were phased in starting in 2012 that, critically, shifted to a corporate average fuel efficiency approach, such that efficiency gains are measured and achieved over the whole new vehicle fleet. This better compensates for the shift to larger vehicles. The current standard aims to reduce the average fuel consumption of Chinese passenger vehicles to approximately 5 litres per 100 kilometres (km) by 2020. A fuel economy labelling requirement, implemented in 2010, requires all new light-duty vehicles to be labelled with fuel consumption estimates.

The Chinese government also uses tax instruments to achieve energy efficiency objectives. Vehicle taxes, such as consumption tax and acquisition tax, have been reformed to promote small-engine cars. Additionally, the government has used subsidies to actively promote the adoption of energy-efficient vehicles and electric vehicles. Since 2010, the scheme subsidised up to a maximum of USD 8 000 for plug-in hybrid electric vehicles and USD 9 600 for battery electric vehicles.

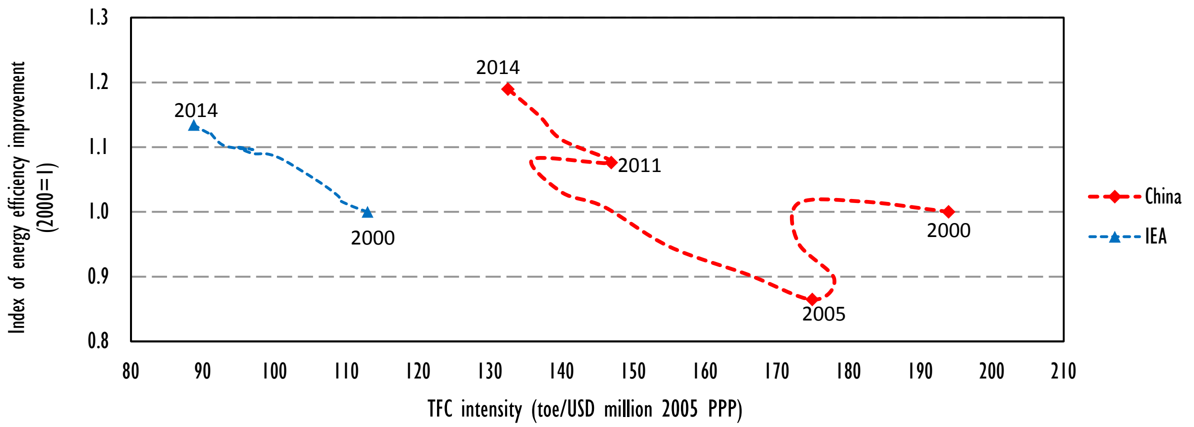
China has the world's longest high-speed rail network, with more than 19 000 km of track in service as of January 2016 (more than the rest of the world's high-speed rail tracks combined). Many cities have developed public transport projects. Between 2006 and 2011, the total distance covered by metro tracks increased 174% while the total number of metro passengers increased by 293%. Despite significant expansion of public transport systems, the preference for personal vehicles has not abated. The share of passenger kilometres travelled via personal vehicles increased from 4% in 2000 to 20% in 2014. The impact of this structural change puts an upward pressure on energy demand and has more than offset the sector-wide gain in energy efficiency. As a consequence, TFC for passenger transport quadrupled between 2000 and 2014, while total kilometres travelled increased by a factor of 3.2.

Putting Chinese energy efficiency improvements in context

China's 19% improvement in energy efficiency since 2000 is a significant achievement. By contrast, IEA countries improved by 14% between 2000 and 2015 (Figure 2.6).[5] At the start of the period (2000), energy intensity in China was around 65% higher than the average intensity of IEA countries. While efficiency gains in both regions improved intensity in both regions, more substantial gains in China reduced the intensity difference in 2014 to 50% higher.

[5] Based on aggregate decomposition analysis of IEA countries.

Figure 2.6 Efficiency improvements and energy intensity in China and IEA countries



Notes: PPP = purchasing power parity. China's significant efficiency improvements are the result of several factors: sustained political will and support, personal accountability for meeting quantitative targets, decades of building up technical and institutional capacity, a deliberate shift from a centrally managed administrative strategy toward a more market-oriented framework, a policy portfolio that includes both incentives and penalties, and a governance strategy that prioritises efficiency gains across multiple layers of government and industry.

Multiple benefits of energy efficiency in China

This section estimates some of the multiple benefits of energy efficiency improvements in China. Gains in energy efficiency and intensity help avoid energy consumption and reduce energy bills, lower GHG emissions, and avoid energy import requirements.

Energy savings and reduced emissions from energy efficiency

Energy efficiency improvements in China since 2000 avoided 250 Mtoe of TFC in 2014 (Figure 2.7). Scaling the end-use savings in electricity to savings in primary energy for avoided electricity generation increases the energy savings to 326 Mtoe.[6] An estimated 76% of the primary energy savings was avoided coal consumption, at 350 Mtce. The primary energy savings from efficiency in China since 2000 were as large in scale as the country's total renewable energy supply in 2014, and greater than the TPES of Germany.

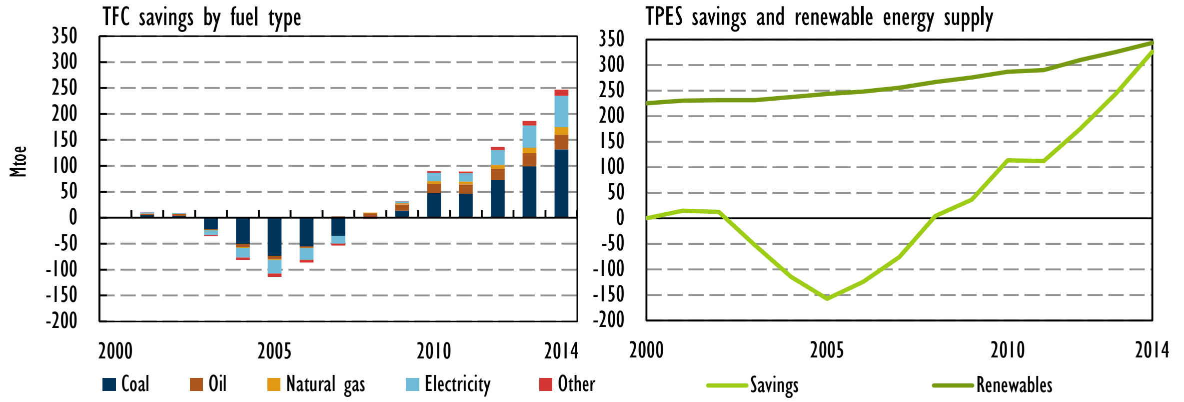
The average CO_2 emissions intensity of primary energy consumption in China increased by 21% between 2000 and 2013. By contrast, in 2014-15, growth in Chinese coal consumption stalled, as did associated CO_2 emissions. Energy efficiency has been an important driver in reducing the intensity of energy consumption (supplied mostly by coal) that would have otherwise been required to fuel China's growth. Energy efficiency has stemmed the increase in emissions intensity of China's energy system and avoided significant additional GHG emissions and air pollution (such as nitrous oxides).
Without energy efficiency improvements, Chinese energy-related CO_2 emissions would have been 13% higher in 2014. Efficiency improvements over 2000 levels saved 1.2 $GtCO_2$ annually by 2014.[7] The avoided emissions from efficiency are equivalent to the total energy-related emissions of Japan, the world's fifth-largest emitter of CO_2 from fuel combustion. Policies put in place by the Chinese

[6] Primary energy savings are calculated by converting estimated electricity savings into primary energy inputs, based on the average conversion efficiency for each fuel input in the year of the savings.

[7] This analysis assumes no change in the annual emissions intensities of Chinese energy consumption in the hypothetical "no energy efficiency" scenario compared with actual GHG intensities as observed.

government to improve efficiency have been one of the most important factors in limiting the growth of energy-related CO_2 emissions anywhere in the world over the past decade.

Figure 2.7 TFC savings by fuel type, TPES savings since 2000 and renewable energy supply in China



Note: Negative savings implies that efficiency worsened compared with the base year, resulting in additional energy consumption.

Energy expenditure and cost declines for Chinese industry

Energy efficiency improvements have generated sizeable benefits for energy consumers in China. The immense demand for resources to feed China's economic growth was a driving force in the increase of global commodity prices over the past decade. Chinese development ran in parallel with surging energy prices: between 2001 and 2013, international markets saw substantial increases in the prices of crude oil (by a factor of 3.5), coal (1.6) and liquefied natural gas (LNG) (2.4). Nevertheless, the burden of increasing energy costs was one factor that prompted policy makers to pursue energy efficiency as a means of alleviating the impact on firms and workers.

Table 2.2 Energy intensity improvements, energy savings and energy expenditure savings for selected industrial outputs

Sector output	Energy intensity improvement, 2010-14	Output, 2014*	Energy savings (Mtoe)	Energy expenditure savings (USD millions)
Cement	7.5%	2 492	48.6	7 547
Thermal power	4.5%	4 234	44.5	6 905
Raw steel	3.4%	822	11.7	1 815
Aluminium oxide	11%	52	2.3	358
Plate glass	21%	831	2.1	322
Crude oil refining	11%	211	1.7	265
Caustic soda	18.4%	31	1.6	249
Ethylene	9.0%	17	1.0	150
Synthetic ammonia	1.7%	57	0.9	143
Sodium carbonate	4.5%	25	0.3	41
Calcium carbide	0.8%	22	0.1	21
Total			**115**	**17 825**

*Output is measured for thermal power in TWh, plate glass in 1 million weight cases, and all others in sectors in millions of tonnes.
Source: ERI analysis and State Statistics Bureau (2015), *China Statistical Yearbook 2015*.

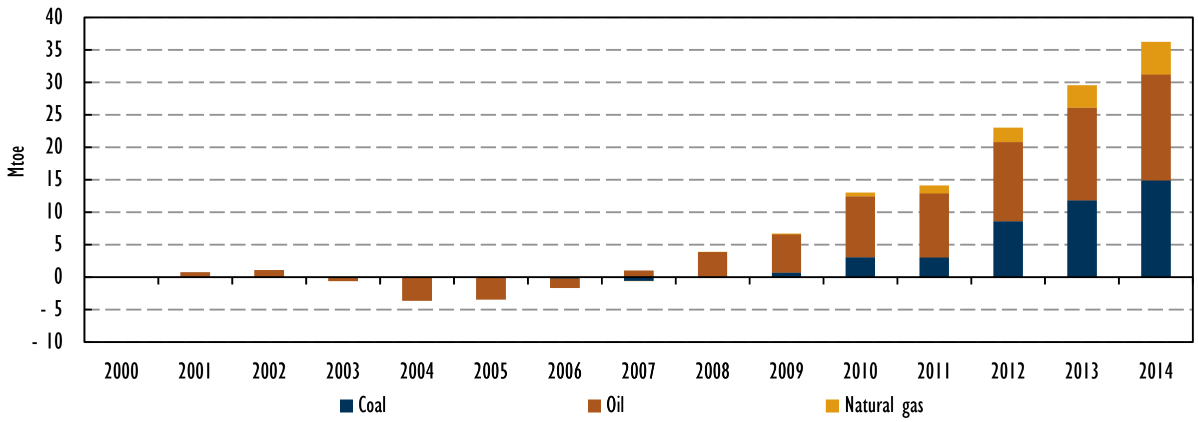
Thanks to energy savings measures in the industry sector, energy consumption per unit of industrial output has declined across several key sectors. In the first four years of the 12th FYP (between 2010 and 2014), energy consumption per unit of crude steel decreased by 3.4%, and by 7.5% for cement. Unit energy consumption is also down for aluminium oxide, plate glass and other products. Compared with industrial energy intensities in 2010, by 2014 efforts saved around 115 Mtoe of industrial energy consumption across 11 key industrial products.

The reduction in energy intensity in the industry sector also generated sizeable savings in energy expenditure. Assuming an average energy price of USD 109/toe in industry,[8] savings in energy expenditure in selected large industry sectors in 2014 were USD 18 billion. Avoided costs in thermal power generation (from efficiency investments in power plants) were USD 6.9 billion, and USD 10.9 billion in manufacturing industries. These savings represent 48% of the government financing for energy conservation during the first four years of the 12th FYP.[9]

Avoided imports

Chinese energy imports grew by a factor of four between 2001 and 2013. Coal imports increased by a factor of 26 between 2001 and 2013, with imports now making up 9% of total coal consumption, up from 1%. Crude oil imports increased by a factor of 3.7 and natural gas by a factor of 17. The amount of avoided imports of energy commodities as a result of energy efficiency is moderated by two factors: i) Chinese primary energy consumption is dominated by coal, making up 66% of primary energy; and ii) most (94%) consumed coal is produced domestically. In 2014 the estimated avoided energy imports from efficiency were 36 Mtoe, a relatively small amount of total primary energy savings of 326 Mtoe, reflecting that imports make up only 15% of Chinese primary energy supply (Figure 2.8). Energy efficiency reduced China's spending on imports by USD 10 billion in 2015.[10]

Figure 2.8 Avoided energy imports from energy efficiency, 2000-14



Note: Negative avoided imports implies that efficiency worsened compared with the base year, resulting in additional imports being required.

[8] Assumes a price of USD 84 (525 Yuan renminbi) per 5.5 kilocalories of coal at the end of 2014.

[9] Based on World Bank commodity price data for West Texas Intermediate (WTI) crude oil, Australian coal and LNG prices in Japan

[10] This analysis assumes that the additional primary energy demand in the hypothetical "no energy efficiency" scenario would be imported at the same ratio of imports to domestic production as observed in each historical year. This is a conservative estimate as the ability of countries to scale up domestic energy production for certain energy commodities depends on the available reserves of those commodities.

Avoided investment in power supply

If the savings generated from energy efficiency improvements are considered a fuel source, then how do they affect investment in other types of energy supply? Energy efficiency gains in China since 2000 avoided an estimated 702 TWh of electricity consumption by 2014. If efficiency had not improved, and China hypothetically needed that amount of additional generation, what additional investment would have been required?

The *Energy Technology Perspectives* energy supply model is used to model a scenario in which Chinese electricity consumption is 15% higher, reflecting the additional electricity consumption in a hypothetical "no energy efficiency" scenario. The model develops a least-cost investment pathway based on existing policy commitments, investment costs and technical limitations. In the scenario with additional electricity consumption, the amount of generation capacity increases by 273 gigawatts (22%), comprising coal (38% of new capacity), hydro (24%), wind (12%) and solar (10%), with natural gas, nuclear and bioenergy making up the balance. The additional investment required to build this new capacity would be USD 230 billion.

Policy in China is driving expansion of the market for energy efficiency

China's suite of energy efficiency policies and programmes are among the most comprehensive and aggressive in the world. In fact, they have been a key driver of global investment and improvement in energy efficiency (IEA, 2014).

11th and 12th FYPs

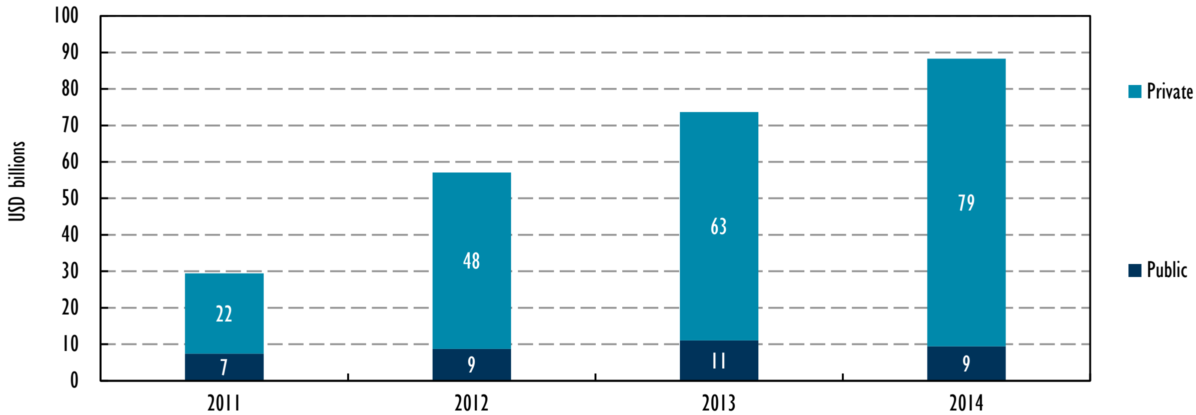
Before the 11th FYP, the Chinese government set energy efficiency policy on a sector-by-sector basis without an overarching framework. For example, while efficiency standards were implemented for a number of consumer products, few standards or other meaningful efficiency policies existed in industry and transport. When both industry and transport sectors significantly expanded after 2000, energy efficiency worsened in industry and did not improve in transport until 2005.

In 2006, the government set its first high-level and mandatory national energy intensity targets within the 11th FYP. The targeted energy intensity improvement was 20% below 2005 levels by 2010, which would produce energy savings of 441 Mtoe by 2010 based on a fixed intensity baseline. The target defined the scope and effort of the country's energy conservation activities, from which regional, local and sectoral authorities set more detailed policies. The Chinese national government reviews interim savings targets on an ongoing basis. If firms or subnational governments are at risk of missing targets, the national government intervenes to ensure compliance. The 11th FYP provided over USD 20 billion in public subsidies and investment, leveraging an additional USD 100 billion in private funding.

In the 12th FYP (2011-15), China aimed for similar energy savings and expanded the scope of the policy action. The intensity target was a 16% reduction from 2010 levels by 2015, which would produce energy savings of 469 Mtoe (based on a fixed intensity baseline). The number of industrial firms with targets grew by a factor of ten, and greater focus was placed on improving the efficiency of residential and commercial buildings. The government also funded technical research and promoted energy-efficient technologies through demonstration programmes and information campaigns.

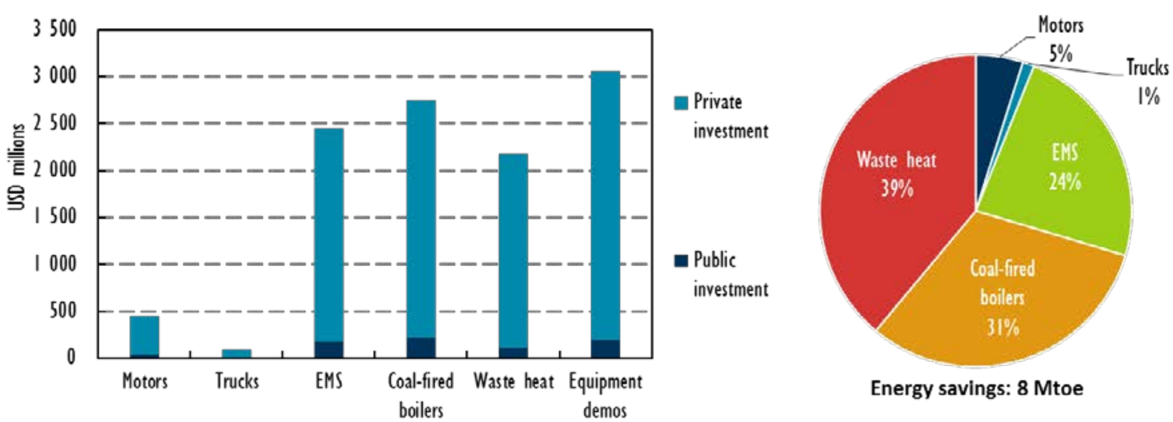
Total public and private investment in energy efficiency was USD 249 billion in the first four years of the 12th FYP. The breakdown of this four-year total investment was USD 29.8 billion (12%) from the central government, USD 6.9 billion (2.8%) from regional governments and USD 211.8 billion (85%) from the private sources. The amount of investment rose year-on-year between 2011 and 2014 (Figure 2.9). The ERI estimates that this investment resulted in savings of 199 Mtoe. Energy efficiency measures were responsible for 47% of the progress towards the reduction in energy intensity.

Figure 2.9 Financial investment in energy efficiency by source, 2011-14



In 2015, the central government spent USD 6 billion on energy efficiency policies and programmes, down from USD 9 billion in 2014. This decrease signals that China is shifting from government incentives towards private-sector investment. A snapshot of the types of projects that received investment in 2013 (the year for which project-level data were available) also reveals the amount of energy savings the projects generated (Figure 2.10). Efficient equipment demonstrations received the highest total investment, followed by upgrades to coal-fired boilers. Waste heat projects generated the most energy savings. Energy management systems were also a significant part of the investment portfolio.

Figure 2.10 Breakdown of energy savings and investments in energy savings projects, 2013



Notes: Motors = motor systems; trucks = trucking; EMS = energy management; equipment demos = equipment demonstrations.

Recent energy efficiency policy developments

Besides setting and enforcing high-level energy savings targets, the Chinese central government also implements and manages specific policies and programmes to improve energy efficiency in key focus areas. Recent policy developments include the following:

Guidelines for sustainable development: With a goal to promote "ecological civilisation" the government has issued five principles, three of which are particularly relevant to energy efficiency: reorienting urban development patterns to limit sprawl; improving resource use and efficiency; and promoting technical innovation and structural change in the Chinese economy. To achieve the principles, the government has detailed actions such as shutting down inefficient industrial capacity and prohibiting the resale and transfer of inefficient technologies to less-developed regions of China.

Promoting high-efficiency boilers and eliminating low-efficiency coal boilers: Seven Chinese ministries and departments have prepared a joint plan to boost the share of high-efficiency large coal boilers from 5% to 40%, while also eliminating low-efficiency coal boilers. By the end of 2015, the Beijing, Tianjin and Hebei urban areas had eliminated all inefficient coal-fired boilers.

Top Runner programme: China is implementing a Top Runner programme similar to the one in Japan. It aims to achieve long-term energy efficiency improvements by implementing efficiency benchmarks, shortening schedules to achieve the standards and providing other policy incentives. The "top runners" are the highest-efficiency product models in three categories: end-use products, energy-intensive sectors and public institutions. These top runners set the benchmark that others in the category need to achieve over a given period. As of July 2016, 16 top runner standards have been proposed for industrial production, including for ethylene, synthesis ammonia, cement, plate glass and electrolytic aluminium.

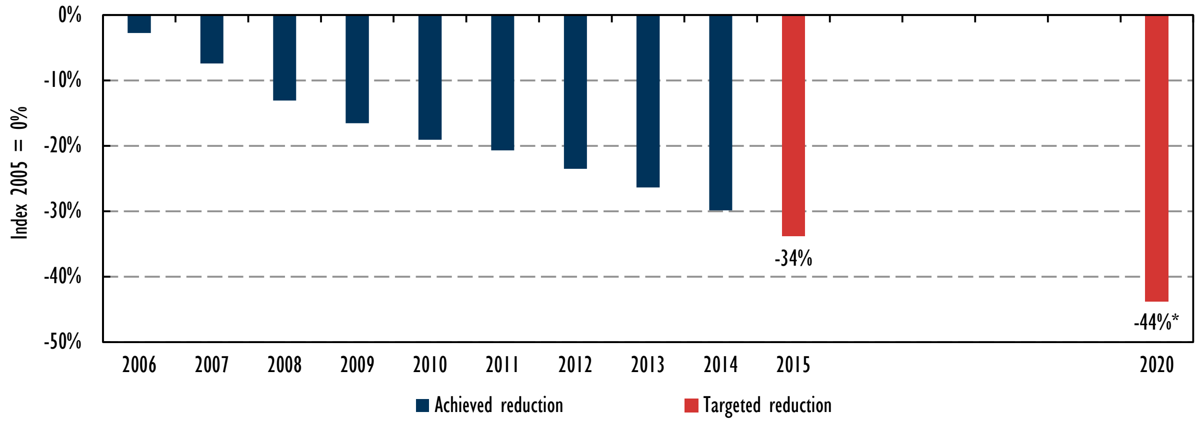
Increasing the efficiency of coal-fired power: In autumn 2014, the central government announced the Coal Power Energy Conservation and Emission Reduction Upgrade and Renovation Action Plan, which will phase out inefficient coal plants. The plan sets an emissions target of 300 grammes of coal-equivalent per kilowatt-hour (gce/kWh) for all new coal-fired power, with the average of all coal power generation reaching 310 gce/kWh by 2020. For generating units larger than 600 MW, the average performance will be lower than 300 gce/kWh. The plan is part of the larger strategy to reduce emissions and pollution from coal-fired power in China.

Waste heat recovery: In 2015, the government announced that by 2020, it will replace 50 Mt of coal for district heating with low-grade waste heat energy. The government will provide financing support to local governments to identify and harness waste heat energy sources for new buildings.

13th FYP

The 13th FYP aims to set, for the first time, a cap on energy consumption in China of 3 500 Mtoe. In addition, China wants to reduce energy intensity to 44% below 2005 levels by 2020 – a 15% reduction between 2015 and 2020. China succeeded in lowering energy intensity in each of the previous two FYPs, by 19% in 2010 and 34% in 2015 (Figure 2.11). Energy savings based on a fixed intensity baseline over the five-year period to 2010 were 441 Mtoe, rising to 469 Mtoe over the five-year period to 2015. The target is 560 Mtoe over the period to 2020.

Figure 2.11 Achieved and targeted reductions in energy intensity in China since 2005

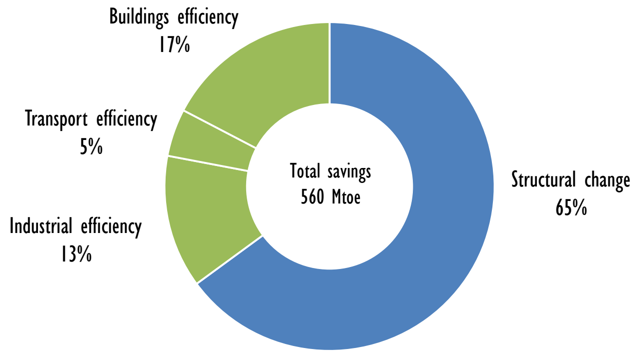


* 2020 target is calculated as 15% below 2015 levels.

The new efficiency measures in the 13th FYP include commitments to promote energy conservation by demonstrating and incentivising efficient technology and practices. Specific instruments have and will continue to include energy efficiency labels, MEPS, financial incentives, pricing and government procurement. Financial tools include direct funding of energy efficiency projects in industry and buildings, subsidised loans, and loan and credit guarantees. China plans to shift away from direct government subsidies for energy-efficient investment and towards market-based approaches such as ESCOs, risk guarantees for ESCO financing, and mainstreaming energy efficiency lending through dedicated credit lines. The plan also indicates that the Chinese government will pursue metering and management systems in the buildings and industry sectors. In addition, the government will advocate for behavioural change in terms of consumer purchases and lifestyle habits.

The investment required to achieve China's 13th FYP targets is estimated at USD 270 billion, which would save approximately 560 Mtoe annually by 2020 (Figure 2.12). The bulk of the savings will come from two shifts in economic structure: the first from industry to services, the second within industry from high-intensity manufacturing (such as chemicals and steel) to lighter manufacturing (such as consumer products). Conservation measures in high-energy-consumption industries will also play a part, as will improving the efficiency of building heating.

Figure 2.12 Energy savings by measure as forecast in China's 13th FYP



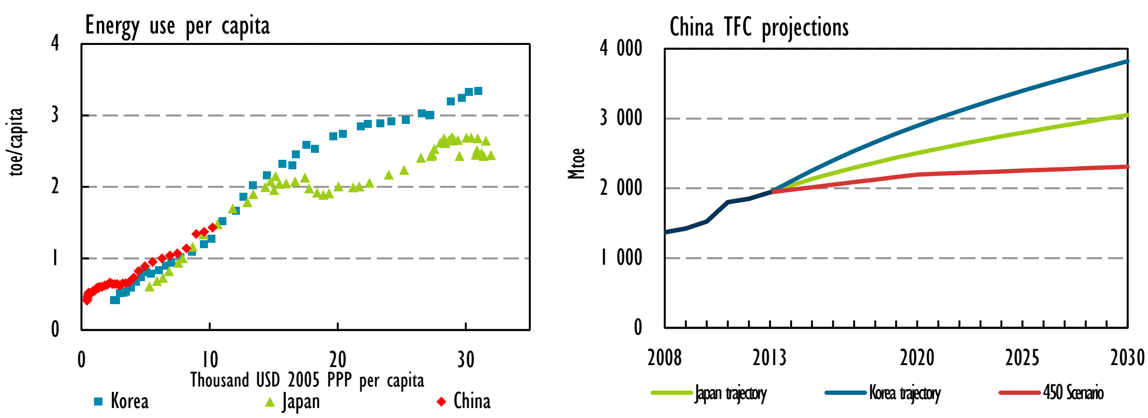
Possible pathways for energy demand and energy efficiency in China

As China's pace of development is on course to more than double per capita income by 2030, the future trajectory of energy intensity improvements and energy demand is globally relevant. Achieving the commitments of China's Nationally Determined Contributions submission as the minimum threshold would, in many respects, rewrite the outlook for energy intensity improvement in other countries in similar situations. A "well-below" 2°C pathway would require even greater improvements.

This section evaluates how China's development may impact future energy demand if it follows the trajectories of development and expanding energy supply similar to those of its east Asian neighbours, Japan and Korea. Unless China achieves significantly greater intensity improvements from both structural change and greater efficiency compared with the historical trends in Japan and Korea, the economy's per capita income growth will prompt higher energy demand than is projected by the 450 Scenario.[11]

China's current income per capita of USD 10 000[12] is on par with that of Korea in 1989 and Japan in 1968. At present, industry in China is 44% of GDP, similar to the levels of Japan (44%) and Korea (38%) when their per capita income was at China's current level. Based on these starting points, it is possible to examine the trajectory of economic growth, structural change and energy intensity improvements in Japan and Korea to develop insights into China's future energy intensity improvements.

Figure 2.13 Energy use per capita, GDP per capita, and TFC trajectories for China



Since 1968, the energy intensity of Japan's TFC has declined by 45%. Industry's share of the economy has shrunk from 44% to 26%. In parallel, Japan has been a leading nation for implementing mandatory energy efficiency standards and improving energy intensity. This has served to limit growth in Japan's TFC to 96% over 1968 levels and only 3% over 1990 levels.

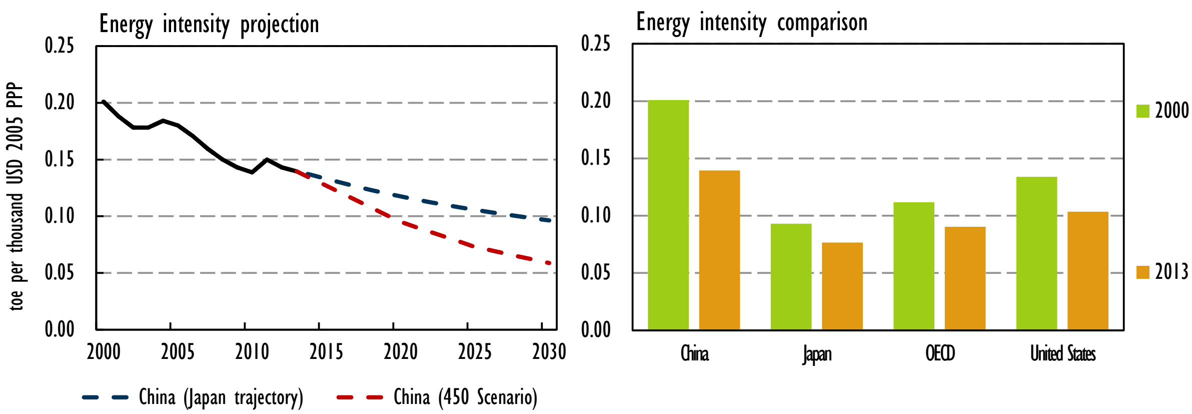
[11] The 450 Scenario sets out an energy pathway consistent with the goal of limiting the global increase in temperature to 2°C by limiting concentration of GHGs in the atmosphere to around 450 parts per million of CO_2.

[12] Converted using real USD 2005 based on PPPs.

Growth expectations for China are markedly different from historic growth levels in Japan. Given China's robust economic growth targets, if it follows Japan's trajectory of energy intensity improvements and economic restructuring, TFC will grow to 3 050 Mtoe in 2030, increasing from 2013 levels by a factor of 1.6 at an average annual growth rate of 2.7%.[13] This level of TFC surpasses the New Policies Scenario by 21% and the 450 Scenario by 32% by 2030.

If China followed Japan's trajectory, the energy intensity of TFC in 2030 would be 0.096 toe/1 000 2005 USD PPP, which is 31% lower than intensity levels in 2013 and only slightly higher than the OECD average of 0.090 toe in 2013. To follow Japan's track, the energy intensity of China would need to decrease by 2.2% per year to 2030 – in line with the 2.1% annual improvement Japan achieved during years of strong economic growth. For all OECD countries, the average annual reduction in intensity was 1.8% over the last four decades. In the 450 Scenario, the energy intensity of TFC declines to 0.059 toe, 58% lower than energy intensity in 2013. In the 450 Scenario, the energy intensity of TFC in China improves by 5% annually.

Figure 2.14 Current and projected energy intensity improvements in China, 2000-30



Note: the "Japan trajectory" is based on the historic energy intensity trends experienced in Japan applied to the Chinese context.

China's energy intensity will also improve as its economy changes structure toward the less energy-intensive services sector. Japan also underwent considerable structural change over the previous four decades, yet the majority of its energy intensity improvements were achieved from efficiency improvements. The IEA estimates that 31% of Japan's intensity improvement between 1970 and 1996 resulted from structural change, while 69% was from energy efficiency and productivity improvements. One reason for the smaller role of structural change is that it can cut both ways. While Japan reduced the relative role of industry in its economy, structural changes in residential demand (a move towards larger homes) and transport (more personal vehicles) worked to offset the intensity improvement from economic structural change.

China's strong annual GDP growth over the past three decades was largely driven by high levels of fixed asset investment, heavy industry expansion, and exports from manufacturing industries. This model of growth cannot continue indefinitely. Since 2013, the government has decided to steer China's economic strategy to a "new normal", emphasising services, innovation, and improving

[13] Based on an assumed economic growth rate of 5.4% by OECD between 2010 and 2030.

income inequality and environmental sustainability. This would bring significant structural change, driving investments in services and higher value-added manufacturing while also rebalancing the economic engine towards domestic consumption.

How can China achieve this paradigm shift, and to what extent will this structural change affect the country's energy consumption? This economic reorientation will be massive in scale and will create new rounds of winners and losers. It could come with important short-term costs such as higher unemployment and lower growth, which would act as a brake on the shift to a new normal. In the case that China is unable to significantly rebalance toward less manufacturing output, energy consumption will be considerably higher.

The Korea trajectory signals what energy demand growth could be if China does not significantly alter the structure of its economy. The structure of Korea's economy has become more energy-intensive since 1990, with the share of manufacturing increasing from 25% in 1990 to 30% in 2014. By contrast, Japan's manufacturing share shrank from 26% to 19% over the same period. If China follows Korea's trajectory, energy consumption would be 3 824 Mtoe in 2030, an increase of 1 830 Mtoe. This is more than five times the increase in the 450 Scenario (310 Mtoe) and more than the entire energy consumption of IEA countries in 2015.

Policy makers in China have indicated that they will not follow Korea's structural trajectory. The share of Chinese service sector GDP increased from 40% in 2000 to 48% in 2014. In addition, China already has a more energy-intensive structure than Korea, which is one of the most industrialised economies among OECD members in terms of industry (38%) and service share (59%) of GDP. While structural effects in China have not yet produced meaningful energy savings in the decomposition analysis, it is cautiously expected that the structural effects will become much stronger in the near future.

To achieve China's role in the global 450 Scenario, the government needs to successfully manage the structural change of its economy and continue to promote and mandate energy efficiency improvements across all sectors. The level and scale of efficiency improvements would have to occur at more than double the rate that Japan and other OECD countries previously achieved. By reaching the 450 Scenario, China would firmly assert itself as the global leader in energy efficiency.

3. POLICY DRIVERS OF THE ENERGY EFFICIENCY MARKET

Highlights

- **Efficiency policy is the most important tool to shape national energy markets and has delivered substantial energy savings.** In particular, mandatory standards and targets have achieved significant energy savings over the past three decades. Vehicle fuel economy standards, implemented as early as 1978, saved 2.3 million barrels per day (mb/d) of oil consumption worldwide in 2015. Energy savings from appliance standards were equivalent to 7% of final energy consumption in the United States and 4.5% of primary energy demand in the European Union in 2015.

- **In 2015, mandatory energy efficiency policies (performance standards and mandatory targets) covered 30% of the world's energy consumption, up from 11% in 2000.** The highest sector coverage (37% of energy consumption) is in industry – led by mandatory targets covering 82% of industrial energy consumption in China and 37% in India. The most dramatic increase in the coverage of standards is in lighting jumping from 2% of lighting energy consumption in 2000 to 63% in 2015. One-third of the world's building energy use is subject to standards, via building energy codes (BECs) and minimum energy performance standards (MEPS) on equipment. Vehicle standards now cover three-quarters of new car sales worldwide and over 50% of the energy consumption of the global light-duty vehicle (LDV) fleet.

- **Mandatory policies on appliances, equipment and vehicles worldwide have strengthened by an average of 23% since 2005.** The greatest strengthening (as measured by increasing mandated performance levels) was in space and water heating equipment in the residential sector. Standards affecting demand for space heating in particular have strengthened by more than 40% since 2005.

- **The new IEA Efficiency Policy Progress Index (EPPI) measures the rate of improvement in efficiency policies by combining changes in mandated performance levels with changes in the share of final consumption covered by mandatory policy**. Globally, the EPPI has improved by 7.3% since 2005. At 15%, the residential sector showed the largest EPPI improvement, driven by improved standards for space heating and cooling, water heating, and appliances. Yet, the most influential single policy on the increase in the EPPI since 2005 was China's Top 10 000 program for industrial energy consumption.

- **Substantial potential exists for mandatory measures to save even more energy.** If vehicle efficiency standards were expanded to all countries, and standard performance levels had increased to a rate equivalent to the best-performing current standards over the past ten years, energy savings in 2015 would have almost doubled to 4.3 mb/d. Best-in-class energy performance standards on air conditioning, space and water heating, and lighting would have saved 13 exajoules (EJ) of energy, or 14% of global residential energy consumption.

Introduction

To anticipate the future direction of energy efficiency investments, we need to better understand how the key drivers of energy efficiency investment are evolving. Policies are essential to stimulate demand for investment in energy efficiency, largely by overcoming the lack of awareness of efficiency benefits and addressing complex decision-making barriers (which often overvalue up-front costs and undervalue future energy savings). Policies can also create new markets for efficiency through mechanisms such as energy taxes and energy efficiency obligations, or provide direct financial incentives, such as rebates or tax breaks for efficient equipment.

In general, five broad categories of instruments are used by policy makers to meet efficiency targets: i) mandatory standards (e.g. MEPS and BECs); ii) mandatory energy savings targets and obligations (e.g. white certificate schemes or mandatory energy targets in Chinese industry); iii) labelling and information (e.g. labels certifying that products meet a given performance level or consumer awareness campaigns); iv) financial incentives (e.g. subsidies for energy-efficient products or practices, auctions or tendering schemes); and v) financial disincentives (e.g. energy taxes or carbon prices).

This chapter first reviews important new energy efficiency policy developments around the world in 2015, with a focus on the agreement reached at the 21st United Nations Framework Convention on Climate Change Conference of the Parties (COP21) in Paris. The chapter then analyses how national mandatory policies, including energy efficiency standards and targets, have expanded and improved over the past decade. It does this by quantifying what portion of energy use is covered by mandatory energy efficiency standards and evaluating how the performance level requirements of those standards have increased. Introduced for the first time in the *Energy Efficiency Market Report (EEMR)* series is the IEA EPPI, which tracks the expansion of coverage and the improvement of performance levels for policies around the world.

Energy efficiency and COP21 commitments

The Paris Agreement reached at COP21 in December 2015 was the key global development that will affect the future energy efficiency market. This agreement has seen 189 countries submit 162 Nationally Determined Contributions (NDCs)[1] which set out high-level intentions, goals, targets and prescriptive actions to reduce greenhouse gas (GHG) emissions. The NDCs cover 95% of global energy-related GHGs. The NDCs start in 2020 and typically run to 2030. This section reviews how the NDCs address energy efficiency and what their impacts are likely to be.

Energy efficiency is recognised as one of the lowest-cost options to reduce emissions. Climate mitigation scenarios with higher levels of energy efficiency show lower total costs. In an analysis of the costs of climate mitigation, Fraunhofer ISI (2015) demonstrated that a scenario with significant energy efficiency adoption was at least 2.5 trillion US dollars (USD) less costly by 2030 than other more energy-intensive mitigation scenarios. This sets the stage for greater prominence of energy efficiency in the policy mix as governments work to achieve their contributions to the Paris Agreement.

The climate change mitigation targets and goals outlined in the NDCs focus on reducing GHG emissions. However, while most NDCs acknowledge the role of energy efficiency measures in achieving GHG targets, only a handful of countries set specific targets for energy demand, intensity and efficiency targets. Of the 162 NDCs submitted, 143 mention energy efficiency, but few indicate any additional policy measures to be undertaken (Box 3.1).

[1] There are fewer NDCs than countries covered because the European Union submitted one Intended Nationally Determined Contribution for all 28 member states.

In most cases, when NDCs refer to energy efficiency, they mention either existing policies and funding or areas of focus for future efficiency improvements. Among the NDCs evaluated, buildings and transport were the sectors most often mentioned for energy efficiency. Energy efficiency is also generally more prominent in submissions from emerging and developing countries. An overview of the emissions reduction targets of some IEA member countries, accession candidates, association countries and key partner countries provides some insights into what role (if any) the NDC gives to energy efficiency (Table 3.1).

Table 3.1 Summary of NDC targets and energy efficiency for selected countries

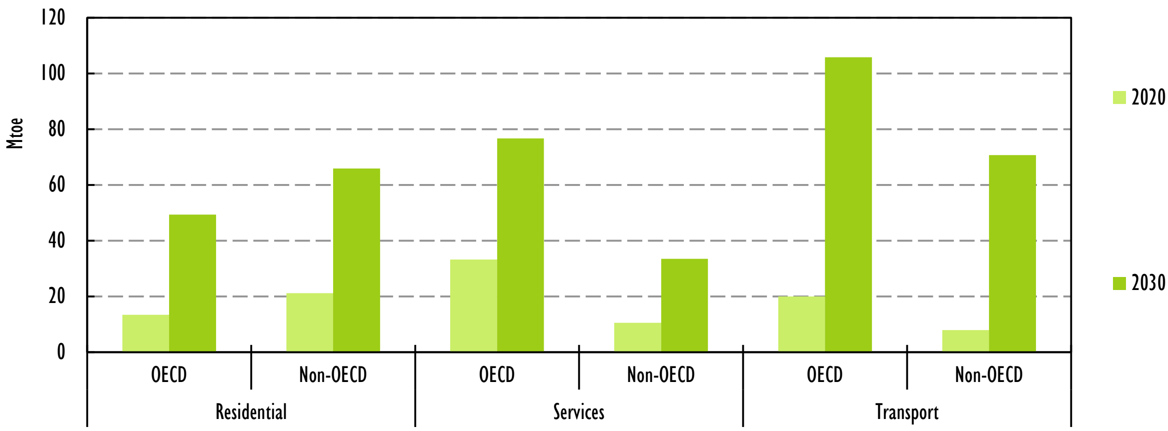
	GHG reduction target	Target year	Baseline year	Energy efficiency mention or action
Australia	26-28%	2030	2005	Existing policy measures in place to improve energy efficiency.
Brazil	37%	2025	2005	NDC targets 10% efficiency improvements in the power sector; new energy efficiency standards in industry and transport sectors.
Canada	30%	2030	2005	More than USD 10 billion in funding for green infrastructure, energy efficiency, clean energy technologies, cleaner fuels and smarter grids.
Chile	Reduce GHG intensity by 30%	2030	2007	Reducing inefficient and polluting cars.
China	Peak emissions; reduce GHG intensity by 60-65%	2030	2005	Multiple mentions of energy efficiency including continuing to improve and invest in energy efficiency across the economy. Specific mention of efficiency in industry, buildings and cities, and of new financing options.
European Union	40%	2030	1990	Emissions savings associated with the existing EU policy framework.
India	Reduce GHG intensity by 33-35%	2030	2007	Multiple mentions of energy efficiency including existing action plans under the Energy Conservation Act. Promotes energy efficiency in industry, transport, buildings and appliances.
Indonesia	29%	2030	BAU	Improving energy efficiency and consumption patterns.
Japan	26%	2030	2013	Multiple references to efficiency in power generation, buildings, industry, transport, lighting, appliances and energy management systems.
Mexico	25%	2030	BAU	No specific mention, but efficiency likely to be a component of the Energy Transition Law approved in December 2015.
New Zealand	30%	2030	2005	Improving energy efficiency above BAU levels.
South Africa	Target: Peak (2020-25), plateau (2030) and decline (2030-beyond) carbon emissions	2030	-	Energy efficiency improvements in the power sector, lighting, electric motors and appliances.
Thailand	20%	2030	BAU	Multiple mentions of energy efficiency including achieving existing energy efficiency targets in the Energy Efficiency Plan.
Turkey	(up to) 21%	2030	BAU	Increasing energy efficiency in industry with financial incentives and regulations for energy-efficient buildings.
United States	26-28%	2025	2005	Continuing to update energy efficiency standards on appliances and buildings.

Notes: BAU = business-as-usual. Intensity targets refer to reducing the GHG emissions intensity of gross domestic product (GDP) rather than an absolute reduction in GHG levels. Chile, Indonesia and Mexico have both unconditional and conditional targets. Unconditional targets are straightforward commitments by the country itself. Conditional targets predominantly depend on financial support from other countries; they are typically more ambitious than unconditional targets. Baseline year refers to the year against which future emissions levels will be measured. Countries with a BAU baseline will reduce emissions compared with BAU.

Impacts of NDCs on energy efficiency investment

Although many NDCs lack specific details on the role of energy efficiency in achieving stated targets, IEA analysis indicates that efficiency will be a central strategy to achieve NDC targets. The INDC Scenario[2] in the IEA (2015) *World Energy Outlook (WEO)* combines specific actions mentioned in NDCs and an assessment of feasible, cost-effective pathways to achieve NDC targets. The scenario projects global energy consumption at around 600 million tonnes of oil equivalent (Mtoe) (1.6%) less in 2030 than under the Current Policies Scenario (CPS). This is approximately three times the current annual consumption of Canada. In addition, the INDC Scenario suggests that annual savings of around 200 Mtoe will occur before the NDCs take effect in 2020 as programmes are ramped up to cost-effectively achieve their goals (Figure 3.1).

Figure 3.1 Energy savings in the INDC Scenario



Note: Energy savings are calculated as the difference in TFC between the *INDC Scenario* and the CPS.
Sources: IEA (2015a). World Energy Outlook. OECD/IEA: Paris. IEA (2015b). World Energy Outlook Special Report: Energy and Climate Change. OECE/IEA: Paris.

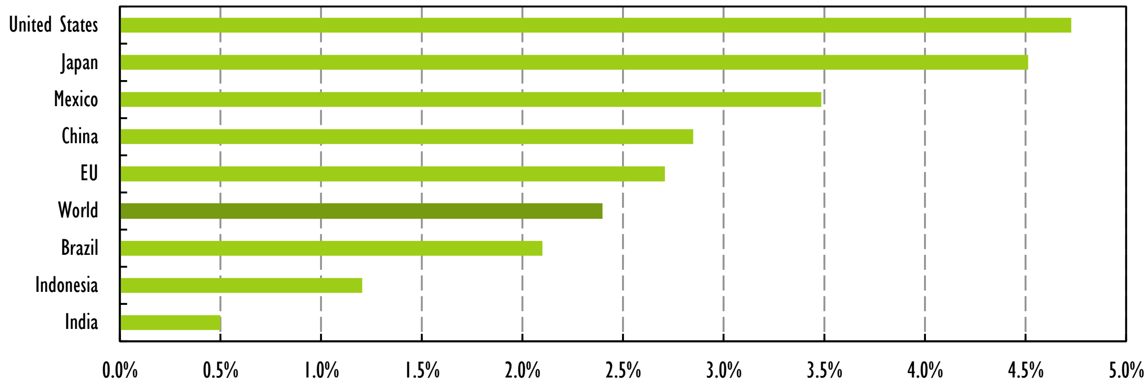
In the INDC Scenario, energy demand in buildings declines strongly in all major world regions (Figure 3.2), with country declines greatest in the United States, Japan and Mexico. If governments take action to meet their NDC targets, markets should anticipate increased focus on building efficiency investments between now and 2020.

How the Paris Agreement will change the business case for energy efficiency policies and investments will depend on the specific countries, sectors, technologies and developments happening elsewhere in national energy systems. However, it is clear that energy efficiency will be key in achieving the necessary energy savings inherent in the NDCs, which will significantly expand the market for energy efficiency if the necessary policies are implemented. According to the Energy Transition Commission (ETC, 2015), energy efficiency provides 24% of the GHG emissions reductions by 2030. Should countries work to limit climate change to 2°C, efficiency would have to provide more than 40% of total GHG emissions reductions based on the IEA 450

[2] In the 2015 *World Energy Outlook*, the term "INDC Scenario" is used to refer to all climate pledges, i.e. Intended Nationally Determined Contributions submitted for the Paris Agreement, including those that have acquired the status of an NDC by countries that have formally joined the agreement.

Scenario. This means that as the NDCs evolve in ambition towards the long-term goal of the Paris Agreement, the emphasis on efficiency will be strengthened.

Figure 3.2 Energy savings in the buildings sector in the INDC scenario, 2020



Note: Energy savings are calculated as the difference in TFC between the *INDC Scenario* and the *Current Policies Scenario*.
Sources: IEA (2015). World Energy Outlook. OECD/IEA: Paris. IEA (2015b). World Energy Outlook Special Report: Energy and Climate Change. OECE/IEA: Paris.

Recent energy efficiency policies

A range of new policies have been announced or implemented since the beginning of 2015 to promote energy efficiency investment. Some key examples include China's 13th Five-Year Plan (FYP), new standards in the United States, strengthened and widened coverage of buildings standards in Japan, and new strategic initiatives in the European Union and Mexico. In India, the government's new industrial policy could open significant new markets for efficiency investment.

Australia: National Energy Productivity Plan

Australia announced that from 1 July 2017, it will lower the threshold of the Commercial Building Disclosure programme from 2 000 to 1 000 square meters (m^2). This measure means that owners or managers of an additional 1 000 commercial buildings will now have to disclose the energy efficiency level when selling or leasing a property. In addition to helping inform purchasers and tenants of building energy costs, this will deliver more than USD 38 million in energy savings, and around 3.5 million tonnes (Mt) of emissions reduction by 2021.

Additionally, Australia will pursue significant energy savings on six priority product categories through the Equipment Energy Efficiency programme. These products include: lighting, non-domestic fans, swimming pool pumps, commercial refrigerated storage and display cabinets, air conditioning, and domestic refrigerators and freezers. These changes will deliver significant energy savings along with emissions reductions of up to 29 Mt by 2030. Together, these measures will help to achieve the Australian government's target of increasing national energy productivity by 40% between 2015 and 2030.

Canada: Increased funding for energy efficiency

In its 2016 budget, Canada announced funding of up to USD 2.3 billion by 2021 to address climate change and air pollution. As part of this funding, USD 102 million was allocated to Natural Resources Canada for energy efficiency policies and programmes. Additional energy efficiency policies and programmes could be part of other federal government funding envelopes, including the Low Carbon Economy Fund and various funds for clean technology research and development.

As well, in 2016 the government of Canada committed to work with the provinces and territories to implement a pan-Canadian framework for clean growth and climate change by early 2017. This framework will enable Canada to meet or exceed its international emissions reduction targets and transition to a stronger, more resilient low-carbon economy.

China: 13th FYP

China is committed to reducing the carbon dioxide (CO_2) and energy intensity of its economy. In Paris, China pledged that its CO_2 emissions would peak by 2030. The peak will trigger a corresponding decrease in the economy's CO_2 intensity of as much as 60% to 65% below 2005 levels. In China's 13th FYP, the government set an interim target (2020) of 48% below 2005 levels. If met, this target would represent an 18% reduction in energy intensity between 2015 and 2020. For a more detailed description of the 13th FYP and efficiency policies in China, refer to Chapter 2.

European Union: Heating and cooling strategy and review of the EU energy efficiency legislation

The EU has developed a strategy to improve the efficiency of heating and cooling services, which account for about half of the energy consumed in the region. The strategy identifies district heating and cooling, co-generation,[3] waste heat and waste cold recovery, thermal storage, smart systems, and smart buildings as important policy areas for further analysis, work and action. The strategy is anticipated to feed into reviews of the Energy Efficiency Directive and the Energy Performance of Buildings Directive, including a Smart Finance for Smart Buildings Initiative, the New Electricity Market Design and the revision of the Renewable Energy Directive in 2016.

France: Energy Transition for Green Growth

Under the Energy Transition for Green Growth law adopted in 2015, France aims to reduce final energy consumption by 50% below 2012 levels by 2050. A separate goal for buildings sets a precedent for mandatory retrofits. The CO_2 price increases under the law – applied to final consumption of transport and heating fuels and rising from 56 euros (EUR) per tonne (t) by 2022 to EUR 100/t by 2030 – will also boost efficiency investment.

Germany: National Action Plan on Energy Efficiency

In May 2016, Germany launched an ambitious energy efficiency package under the umbrella of the National Action Plan on Energy Efficiency, comprising new promotional programmes and a comprehensive public awareness campaign. The campaign (*Deutschland macht's effizient*) targets energy consumption in all sectors. Important new promotional programmes include:

[3] *Co-generation* refers to the combined production of heat and power.

- Electricity-saving measures via the competitive tendering Step Up! pilot programme.
- Improving recovery of waste heat and promoting efficient technologies in industry.
- A pilot programme for digital energy services, focused on consumer energy savings.
- Incentives to improve the efficiency of building heating systems including for heat pumps.

The action plan allocates USD 19 billion of financial incentives until 2020 to improve the energy efficiency of the German economy.

Japan: Updated Building Energy Conservation Law

Japan has updated its Building Energy Conservation Law with the aim of reducing energy consumption in both residential and non-residential buildings. This law is enforced in two parts: labelling and incentives from 1 April 2016, and new performance-based building standards from April 2017. The building incentives will reward energy efficiency performance improvements for new buildings and building retrofits with eased restrictions on building size, allowing developers to construct buildings with more floor space. The incentive programme will also introduce a building energy labelling system that will allow energy-efficient building owners to advertise and include the label in contracts.

The building regulations will revise mandatory standards for both new and retrofitted non-residential buildings over 2 000 m^2 and residential buildings larger than 300 m^2. This standard updates the 2009 performance regulations and increases the minimum energy performance level of buildings. The new standards take a whole-building approach to energy savings, requiring that all energy-using equipment in the building comply with performance levels. Overall, improving the energy performance of buildings is estimated to save a cumulative 330 Mtoe between now and 2030.

Mexico: Energy Transition Law

Mexico's Energy Transition Law requires the government to develop clear energy efficiency and clean energy goals for the next 15 and 30 years. The medium-term goal will be updated every three years, based on progress. While detail is still lacking on what specific actions the Mexican government will take, the law simplifies the administrative mechanisms and jurisdiction for energy efficiency policy. The law does specify that funding will focus on energy-efficient appliances and equipment, and building retrofits.

Philippines: Energy Efficiency Action Plan

The Philippines Department of Energy approved the short-term Energy Efficiency Action Plan 2015-20 in December 2015. It follows the Energy Efficiency Roadmap 2014-30 published in July 2014. Based on the roadmap, the action plan sets out a series of 39 initiatives for all sectors, including initiatives to strengthen the institutional framework, build capacity of the finance sector, and establish a monitoring framework.

United States

Commercial air-conditioner standards

In 2016, the United States updated standards for commercial building conditioning including chillers, air conditioners, heat pumps and warm air furnaces. By 2023, new air conditioners will have to be approximately 30% more efficient than the 2010 standard. Cumulative savings from the standards over the next 30 years are estimated at 15 600 PJ – a 24% annual energy consumption savings compared with a reference case. The net present value of these savings is estimated at between USD 15 billion and USD 50 billion. The standards are estimated to reduce GHG emissions by 77 Mt compared with the reference case.

Phase 2 heavy-duty vehicle standards

In 2015, the US Environmental Protection Agency proposed new regulations under Phase 2 of its GHG emissions standards for heavy-duty vehicles (HDVs). The regulations, which will be implemented in 2018 and extend to 2027, will deliver between 0.5 mb/d and 1 mb/d in oil consumption savings between 2035 and 2050 – equivalent to 2.5-5% of current US daily oil consumption. Consumers would save up to USD 170 billion in fuel costs by 2050, and avoided fuel costs would pay back vehicle owners in only two years (ICCT, 2015).

Uruguay: National Energy Efficiency Plan

The National Energy Efficiency Plan 2015-24, approved in August 2015, calls for implementation of a national energy efficiency certificate programme. The overall goal is to reduce energy consumption by 5% by 2024 compared with a BAU scenario, thereby achieving cumulative energy savings of 1 690 thousand tonnes of oil equivalent over the period 2015-24, an amount equivalent to 45% of energy consumption in 2012. Most energy savings are expected to come from the residential (45%) and transport (30%) sectors.

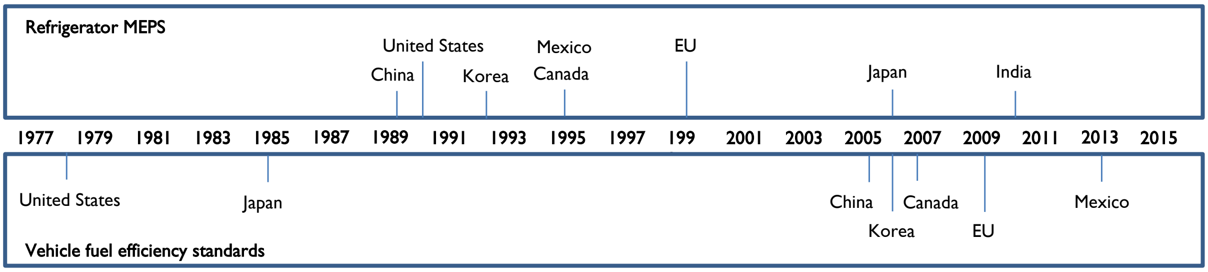
Tracking mandatory energy efficiency policies

This section tracks the progress of mandatory energy efficiency policies around the world. Mandatory policies include MEPS and targets requiring energy savings from efficiency. Mandatory policies are not the only policy mechanism that can improve efficiency but they have been one of the most widely used tools to improve efficiency by governments. They can also be tracked and quantified as first done by the IEA (2015a) in the *WEO*. This section updates and builds on the *WEO* analysis.

Many countries began to implement energy performance standards in the 1970s. Most have since expanded the number of end uses regulated (coverage) and reduced the allowable quantity of energy consumed to provide a given unit of service (performance level) (Figure 3.3). Well-designed standards (i.e. standards that are feasible and cost-effective and increase performance levels over time) accelerate the natural tendency of the market to create more efficient vehicles, buildings and other end-use equipment. Standards also push the least efficient equipment out of the market. In the absence of mandatory standards, market forces also improve efficiency, but the pace of improvement is often slower and increased technical efficiency may be diverted into providing more powerful or larger equipment.[4]

[4] In the vehicles market, efficiency gains have been converted into increases in engine power, mostly negating the savings. It was not until specific standards mandated performance levels in terms of energy per distance travelled that vehicle efficiency gains improved.

Figure 3.3 Timeline of standards for refrigerators and vehicles for selected countries



This analysis does not include subnational mandatory standards and targets, which can be important drivers of efficiency improvement. Subnational governments, including state and provincial governments and municipalities, can have significant impacts on the pace and scale of efficiency improvements. The IEA *Energy Technology Perspectives 2016* explores in detail the role of urban and subnational policies for sustainable energy transition (IEA, 2016).

Coverage of energy consumption by mandatory energy efficiency policies

This analysis quantifies the amount of energy consumption in building heating and cooling systems, lighting, large appliances, vehicles, motors, and other energy-consuming equipment that is subject to mandatory policies. To do this, the IEA identified the implementation dates of mandatory standards and targets around the world, and then estimated the volume of equipment sold since policies and standards were implemented and their associated energy consumption (Box 3.1). This energy consumption is considered to be "covered" by mandatory energy efficiency policies.

Between 2000 and 2015, the share of global TFC subject to mandatory energy efficiency standards and regulations grew from 11% to 30%, bringing the absolute total to 115 EJ of TFC (Figure 3.4). In fact, the growth in energy use subject to mandatory policies is outpacing growth in TFC: the TFC covered by standards grew on average by 9% per year, compared with 2% for global TFC during the same period. Most recently, the share of energy consumption covered by standards grew 1 percentage point from 29% in 2014 to 30% in 2015 (6.3 EJ).

Box 3.1 EEMR approach to tracking the coverage of mandatory energy efficiency policies

To assess how much energy use is covered by mandatory policies, EEMR uses the following approach:

1. Track all significant mandatory policies, including energy efficiency standards and energy savings targets, and their implementation dates, around the world.
2. Estimate the amount of technologies that have been adopted since implementation of the standards, accounting for the retirement of stock and changing adoption rates.
3. Calculate the energy use of technologies and energy-using stock adopted since mandatory policies were implemented.
4. Calculate the amount of energy consumption that is subject to sector-wide energy savings targets in the industrial sector.

Box 3.1 EEMR approach to tracking the coverage of mandatory energy efficiency policies (continued)

In the industry sector, some countries, notably China and India, have implemented broad mandatory targets for a large share of the sector's energy consumption. Mandatory obligation schemes exist in other sectors, such as white certificates in Europe, but the amount of energy consumption these policies affect is difficult to track. Double counting of standards on technologies and obligation schemes is also likely. While this analysis tracks only mandatory savings targets in industry, voluntary agreements in industry have been used in 18 countries (of which 9 are in Europe) (Rezessy et al., 2005; Price, 2005).

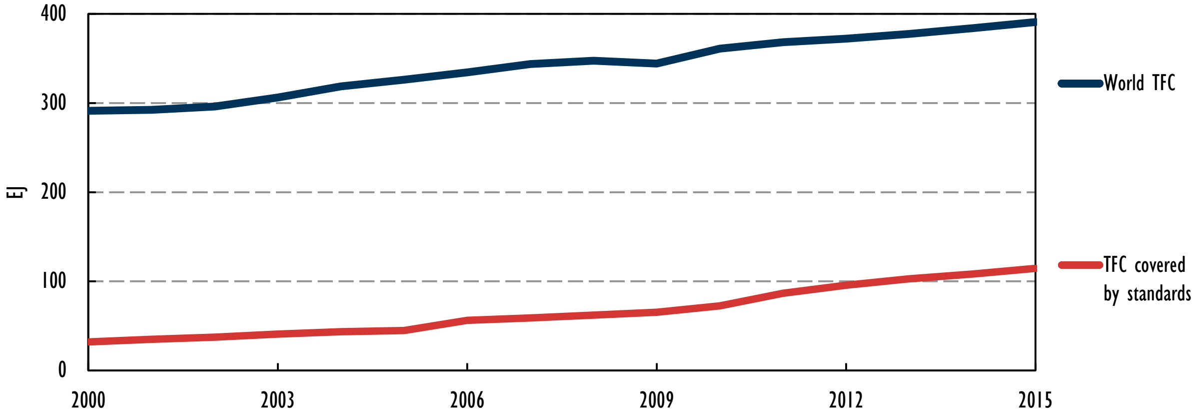
Analysis of mandatory policies on all significant energy end uses in all major regions enables the creation of policy timelines (Figure 3.3) which, taken together, give a comprehensive overview of energy use covered by energy efficiency standards. The sectors and policies tracked in this analysis are listed in Table 3.2. Appliances are separate from buildings because of the large number of standards enacted in various countries.

Table 3.2 Sectors and policy types included in the coverage analysis of mandatory policies

Sector	Subsector	Policy types included
Appliances	Refrigerators and freezers, dishwashers, clothes washers, clothes dryers, televisions	MEPS and other appliance efficiency regulations
Industry	All industries	Electric motor MEPS Mandatory energy savings targets
Residential and non-residential buildings	New building construction Existing building retrofit Heating and cooling systems, water heating, lighting	BECs BECs for renovations MEPS
Transport	Light-duty vehicles (LDVs) HDVs	Corporate average fuel economy or carbon standards on passenger vehicles Carbon or efficiency standards on road freight

Sources: Energy data based on IEA (2015) *World Energy Outlook*, (2016a) *Energy Technology Perspectives*, and (2016b) Mobility Model.
Policy data based on analysis from IEA 4E Technology Collaboration Programme, IEA (2016c) Policies and Measures (database), retrieved from: www.iea.org/policiesandmeasures/. CLASP (2016). CLASP Global S&L Database retrieved from: http://clasp.ngo/en/Tools/Tools/SL_Search.aspx. Maia Consulting (2014). Energy Standards and Labelling Programs throughout the World in 2013. Australian Department of Industry: Adelaide, retrieved from: www.iea-4e.org/document/343/energy-standards-labelling-programs-throughout-the-world-in-2013. IEPD (2016), Industrial Efficiency Policy Database, retrieved from: http://iepd.iipnetwork.org/. Building Codes Assistance Project (2016), Code Status (database), retrieved from: http://bcapcodes.org/code-status/. GBPN (2016), Databases and Tools retrieved from: www.gbpn.org/databases-tools. Enerdata (2016). Odyssey-Mure (database), retrieved from: www.odyssee-mure.eu/. Siemens AG (2015), Minimum Energy Performance Standards: MEPS regulations worldwide. Munich. Retrieved from: www.industry.siemens.com/drives/global/en/motor/low-voltage-motor/efficiency-standards/Documents/meps-regulation-en.PDF. ICCT (2016) ICCT (2016). TransportPolicy.Net (database), retrieved from: http://transportpolicy.net/index.php?title=Main_Page..

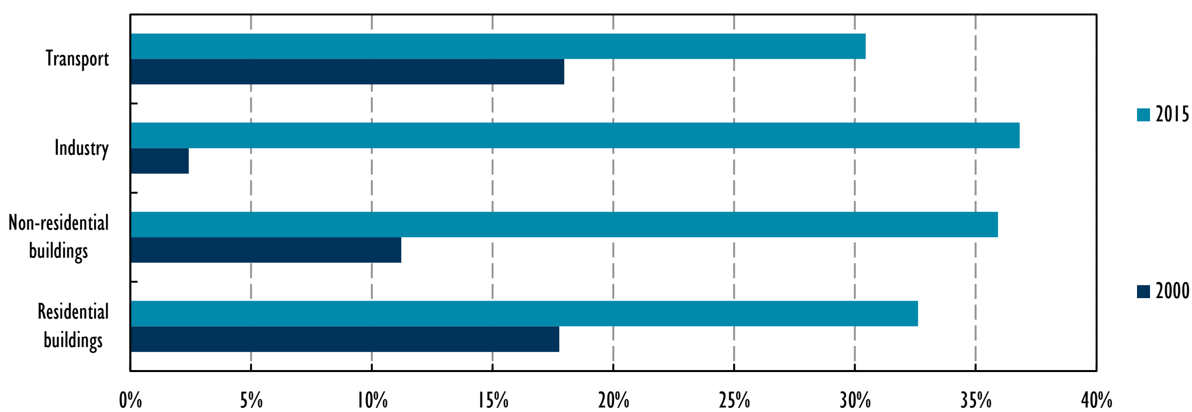
Figure 3.4 World TFC and TFC covered by mandatory energy efficiency standards and targets



Note: TFC includes energy consumption in agriculture and the use of energy commodities for non-energy purposes.

The largest increase in energy consumption covered by standards has been in industry (Figure 3.5), associated with a sudden increase in coverage in 2005 when China's 11th FYP placed mandatory targets on industry (as highlighted in Chapter 2). This one policy action had a significant impact on the coverage of standards. India's Perform, Achieve, Trade (PAT) programme, implemented in 2012, also covers industry and further increased the amount of energy consumption covered in the industry sector. Policy coverage of non-residential buildings energy consumption exceeds that of residential buildings. This is a result of the importance of the United States as a share of the global non-residential sector and the prioritisation by many developing countries of regulating the non-residential sector before the residential sector.

Figure 3.5 Share of global TFC covered by mandatory energy efficiency standards and regulations by sector, 2000 and 2015

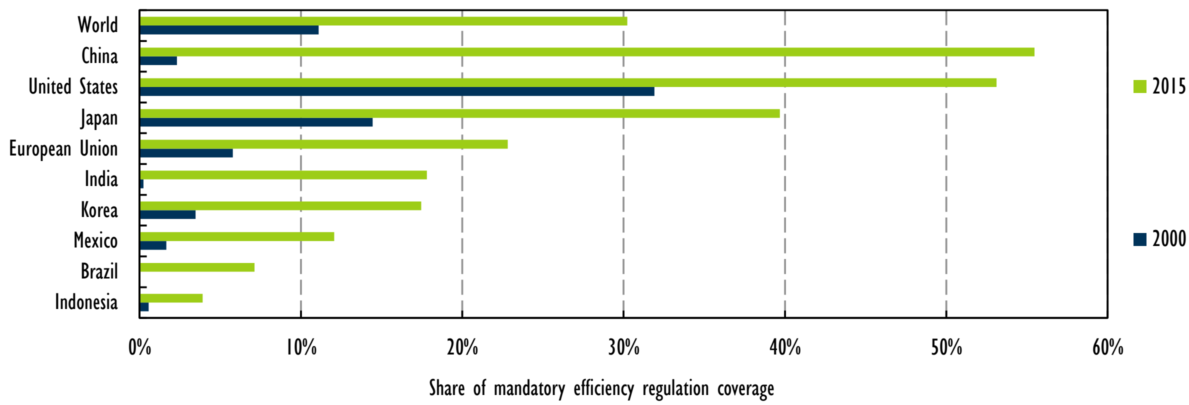


Coverage of mandatory energy efficiency standards and regulations by country

China is responsible for the largest increase in policy coverage since 2000, with implementation in 2005 of a sector-wide energy savings policy framework for industry (previously, relatively few mandatory standards or regulations were in place). The roll-out of these policies coincided with a 72% growth in the country's industry energy consumption between 2005 and 2014. Taking account of the rapid growth in industry consumption, the implementation of policy has significantly increased the share of world TFC covered by regulations.

Many other countries and regions have significantly expanded the role of standards and regulations. In 2000, India, Brazil and countries in the Middle East had no energy efficiency standards and regulations. By 2015, 17% of Indian TFC was covered by regulations, 8% in Brazil and 15% in the Middle Eastern countries. While the expansion of standards in these regions is noteworthy, progress on increasing the coverage of standards still lags. By contrast, the European Union has more than doubled the share of energy covered by regulations in the 2000s through measures to both improve energy efficiency and co-ordinate policies across member states. The United States is notable for implementing standards well before 2000. As vehicle efficiency and appliance standards, along with building energy codes, have been implemented since the 1970s and 1980s, much of the US stock of energy-using products is covered by standards (Figure 3.6).

Figure 3.6 Share of TFC covered by mandatory energy efficiency standards and regulations



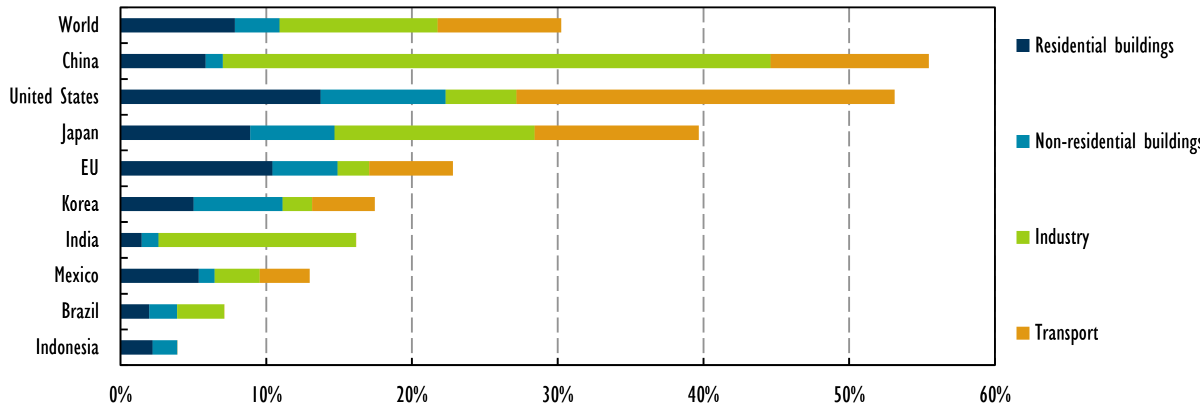
Sources: Energy data based on *Energy Technology Perspectives*, *World Energy Outlook* and the IEA Mobility Model. Policy data based on IEA PAMS databases (2016), CLASP (2016), EES and Maia Consulting (2014), IEA 4E TCP (2009-2015), IEPD (2016), BCAP (2016), GBPN (2016), ISIS and Enerdata (2015), Siemens (2015) (electric motors) and ICCT (2016).

Coverage of mandatory energy efficiency standards and regulations by sector

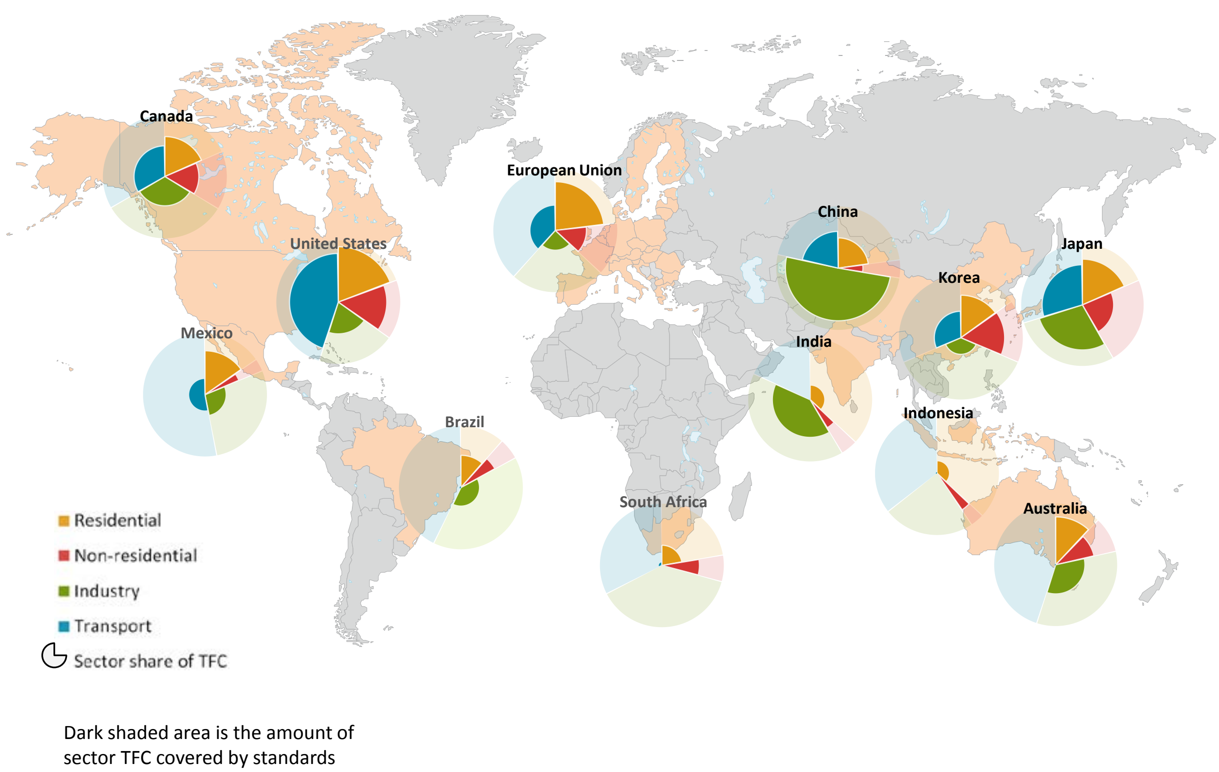
At the global level, coverage of mandatory standards and regulations is roughly even among transport, industry and buildings. However, sector coverage differs across countries. In China and India, industry makes up the largest share of TFC covered (Box 3.2). In the United States and the European Union, industry accounts for a smaller share than other sectors because there are fewer mandatory standards and targets in industry. Conversely, virtually all of the US passenger vehicle fleet is covered, as standards have been in place since the 1970s. In the European Union, mandatory vehicle standards were implemented only in 2009 (Figure 3.7) (Map 3.1).[5]

[5] Prior to 2009, voluntary agreements on vehicle efficiency were reached between various EU member states and vehicle manufacturers. These were effective in achieving vehicle efficiency improvements, but do not qualify under the definition of mandatory standards and regulations.

Figure 3.7 Share of TFC covered by mandatory energy efficiency policy by sector



Map 3.1 Energy use covered by mandatory energy efficiency standards for selected countries, 2015



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Box 3.2 China's Top 10 000 and India's PAT programmes

The biggest growth in the coverage of energy consumption by mandatory policies over the last ten years has been in the industry sectors of China and India. This is because of the implementation of the Top 10 000 programme (and the prior Top 1 000 programme) in China and India's PAT programme. Each of these two programmes sets a mandatory energy intensity target to be achieved by the largest industrial energy consumers. In the policy mapping analysis in this chapter, these programmes are treated as covering 85% of China's and 40% of India's industrial energy consumption in 2015.

Top 10 000 programme

The Top 10 000 programme was implemented with the 12th FYP in 2011, building on the Top 1 000 programme that had been in place since 2005. The industry sector is the largest end-use sector in China. The programme covers two-thirds of Chinese TFC and around 16 000 individual companies. It sets a total energy savings target of 250 million tonnes of coal equivalent by 2015. The savings make up 37% of China's total energy savings target in the 12th FYP.

The energy savings target is apportioned across 31 provinces and large cities. Local governments are responsible for implementing policies that achieve their quota of energy savings. They set targets for individual firms and monitor their progress, and they are also empowered to conduct mandatory energy audits and even to mandate efficiency improvements for firms that do not voluntarily meet their targets. The central government supports the programme through training and capacity building, fiscal and financial incentives, and by supporting energy service companies (IIP, 2016).

PAT

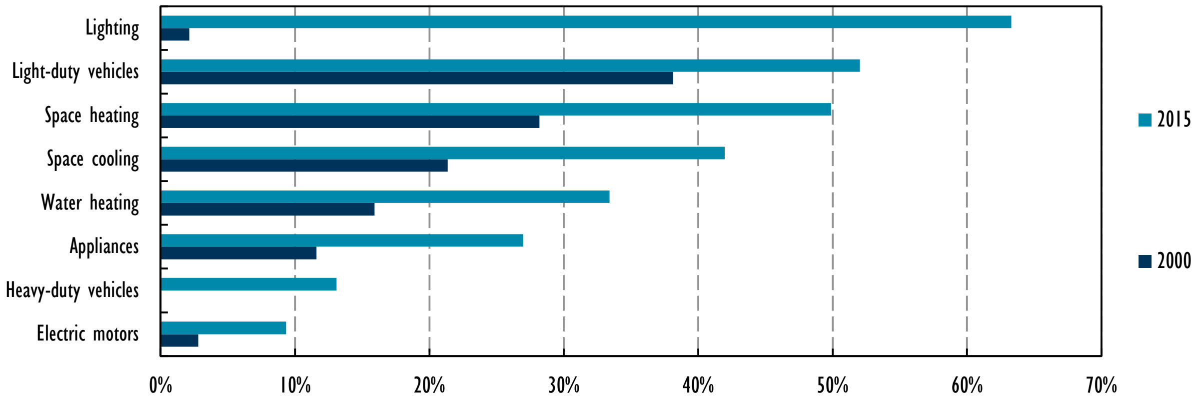
India launched the PAT programme in 2012, setting energy consumption targets for 478 of the most energy-intensive industrial enterprises. The first cycle of the PAT programme (2012-15) aimed to reduce energy consumption on average by 4.1% in eight industry subsectors that made up 36% of total industrial energy consumption (2009-10 levels). The majority of the estimated annual savings were expected to come from power generation, followed by iron and steel and cement. Firms could comply with the targets by achieving their own energy savings or by generating energy savings certificates that could be exchanged with other firms on a trading market. The latest assessment of 427 industrial enterprises under the first cycle shows the original target was surpassed with energy consumption reduced by 5.3%, resulting in annual emissions reductions of 31 million tonnes of CO_2 ($MtCO_2$).

The second cycle (2016-19) will expand the PAT programme across 900 to 950 industrial enterprises, representing a share of 50% of industrial energy consumption (2009-10 levels). It will continue to cover those firms in the first cycle while adding others such as refineries, railways and state distribution companies.

Coverage of mandatory energy efficiency standards by end use

Traditionally, mandatory efficiency standards and regulations targeted a fairly narrow range of end uses: LDVs, space heating, space cooling and water heating. Between 2000 and 2015, coverage was expanded substantially to include all end uses. The largest increase was for lighting, while coverage doubled for space heating, space cooling and water heating (Figure 3.8). Coverage of electric motor standards remains limited, even though most countries have implemented electric motor standards in the past ten years. This is because standards have only recently been implemented and the turnover of existing motors is slow. At present, almost nine out of ten electric motors sold are covered by standards; as the existing stock of motors is replaced, this should lead to a steep increase in coverage. Coverage of HDVs remains very low; only four countries have implemented mandatory policies for this end use.

Figure 3.8 Share of global end-use energy consumption covered by mandatory energy efficiency policies, 2000 and 2015



Note: Only energy end uses that achieved notable expansions in policy coverage are presented in this chart. Industrial processes, cooking, 2- and 3-wheelers, non-road transport, agricultural equipment, and non-energy use are not included.
Sources: Energy data based on *Energy Technology Perspectives*, *World Energy Outlook* and the IEA Mobility Model. Policy data based on IEA PAMS databases (2016), CLASP (2016), EES and Maia Consulting (2014), IEA 4E (2009-2015), IEPD (2016), BCAP (2016), GBPN (2016), ISIS and Enerdata (2015), Siemens (2015) (electric motors) and ICCT (2016).

Five of the eight major end uses have more than 30% global coverage (Figure 3.8). Electric motors have the lowest coverage of this group, but the rate should change quickly with recent uptake of standards in several countries. Other end uses not included in the eight – such as non-road transport, cooking, industrial processes and agriculture – still have important roles to play.

Tracking improvements in the performance levels of mandatory policies

The performance level of mandatory policies plays a large role in determining actual energy savings. This section evaluates how the performance levels of standards have been increased over the past decade and the potential to push for more ambitious targets. To track the increase in performance, *EEMR* calculates the percentage improvement in the technical requirements of mandatory standards for each sector and end use, in 2005 and 2015. For example, if a country's regulation sets minimum water heater efficiency at 80% in 2005 and 90% in 2015, the policy strengthened by 13%.

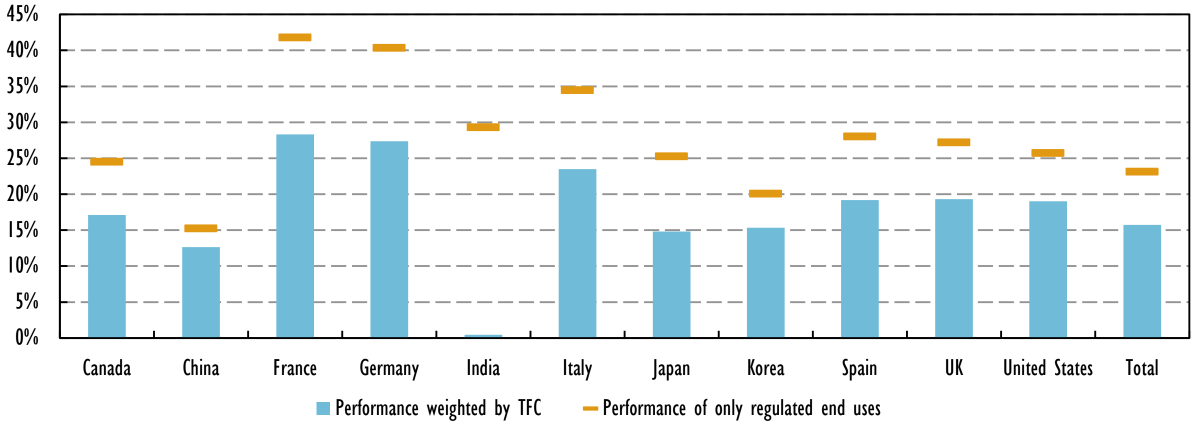
Performance level increases have been evaluated in 11 countries representing 60% of global energy consumption. The end uses included in this analysis (Table 3.3) cover around 60% of global TFC. In each country, sufficient detail was available on standards and the efficiency of the existing stock of technologies in the transport, building and industry sectors. For countries that did not have a standard in 2005 but had implemented one by 2015, the analysis uses the difference between the estimated average efficiency of the installed stock of technologies in 2005 and the performance level of the new standard. The total performance level increase is weighted by the share of end-use energy attributed to each sector and country.

Table 3.3 Sectors and end uses included in the performance level analysis

Sector	End use	Performance level metric
Buildings	Space heating and cooling	Increase in expected building performance or shell U-value for new building energy codes Increase in efficiency of heating system standards (boilers, furnaces) Increase in the energy efficiency ratio (EER) of space cooling standards
	Water heating	Increase in MEPS for water heating
	Products and appliances	Weighted increase in MEPS for refrigerators, dishwashers, clothes washers, freezers, clothes dryers, lighting
Transport	LDVs	Increase in vehicle fuel economy or GHG standards for passenger vehicles
	HDVs	Increase in fuel economy or GHG standards for light commercial, medium- and heavy-duty vehicles
Industry	Motor-driven systems	Increase in MEPS for electric motors based on average motor size
	Other industrial energy use	Energy savings from mandatory targets compared with total sector energy consumption

Across the countries evaluated, the performance level of mandatory policies increased by 23% between 2005 and 2015 (indicated by the yellow bars in Figure 3.9). France, Germany, Italy, Japan and the United States had the greatest increases in strength for the end uses covered. In Germany, for example, building energy codes in 2014 were approximately 45% more stringent than the corresponding code in 2005. In the United States, the 2008 update to vehicle fuel economy standards increased performance levels by 23% and led the overall increase in performance levels. Performance level improvements in EU countries were driven by updated building energy codes and heating systems standards.

Figure 3.9 Increase in performance level of mandatory energy efficiency policies, 2005-15



Notes: These results are based on performance data complemented with published technical policy documents on MEPS and BECs. Prescriptive BECs have a weighted average calculation of building components, based on fixed size single- and multi-family houses and their shares in the building stock.

Sources: Energy data based on *Energy Technology Perspectives*, *World Energy Outlook* and the IEA Mobility Model. Policy data based on IEA PAMS databases (2016), CLASP (2016), EES and Maia Consulting (2014), IEA 4E TCP (2009-2015), IEPD (2016), BCAP (2016), GBPN (2016), ISIS and Enerdata (2015), Siemens (2015) (electric motors) and ICCT (2016).

This analysis also weights performance level increases by TFC (Figure 3.9). When performance level improvement is weighted by TFC, improving standards on more common energy end-uses has a greater effect. Countries with large shares of energy use that are not regulated by standards or did not increase the strength of standards on common end-uses will have a comparatively lower performance improvement. This is the case in India: as most energy use is not yet covered by standards, the strengthening by 29% of existing standards on refrigerators and air conditioners had little impact on the overall performance increase.

IEA Efficiency Policy Progress Index

To track the progress of mandatory energy efficiency policies, the IEA has developed the Efficiency Policy Progress Index (EPPI). The EPPI measures progress in both coverage and strength of mandatory energy efficiency policies. In the EPPI, improvements in the performance level of policies are linked to the energy consumption covered by mandatory standards and targets in 2015 (Box 3.3). The EPPI is weighted by TFC, country, sector and end use to create a common baseline for comparison and to boost visibility of countries that implement policies on larger sources of energy consumption.

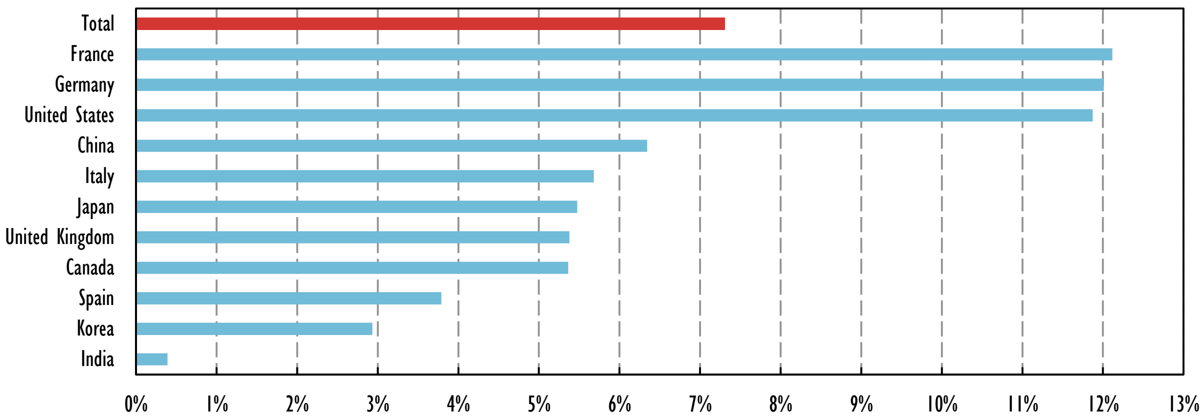
Box 3.3 Method to calculate the Efficiency Policy Progress Index

To track progress of mandatory energy efficiency regulations, the EPPI uses the following steps:

- Establish a list of relevant end uses for which sufficient data are available on coverage and performance levels.
- Calculate the amount of energy consumption by end use covered by mandatory standards consistent with the methodology in Box 3.1.
- Calculate the performance level increase of mandatory standards by energy end use.
- Multiply the energy consumption by coverage and the performance-level improvement over the period analysed.
- Weight the energy use by end use, sector or country, depending on the desired scope. For example, the EU refrigerator MEPS requires a minimum energy efficiency index of 95 in 2005 and 42 in 2015, an improvement of 56%. The European Union has had refrigerator MEPS since 1999, so almost 100% of the refrigerator stock is covered. Hence, all EU refrigerator energy use is included, leading to an EPPI of 56%*100% = 56%. Weighted for a specific EU country, refrigerators in Germany use around 34 PJ, which is 1.1% of German TFC covered by mandatory standards. This adds 1.1%*56% = 0.6% to the German EPPI.

From 2005 to 2015, the EPPI increased by 7% on average across all countries evaluated (Figure 3.10). France, Germany and the United States saw the largest increases in their national EPPI. Progress in France and Germany was marked by an expansion of buildings-focused efficiency policies. Mandatory standards for heating systems and retrofits in France and Germany, in particular, drove progress. In the United States, the largest gain in the EPPI was driven by the updated LDV standards in 2012.

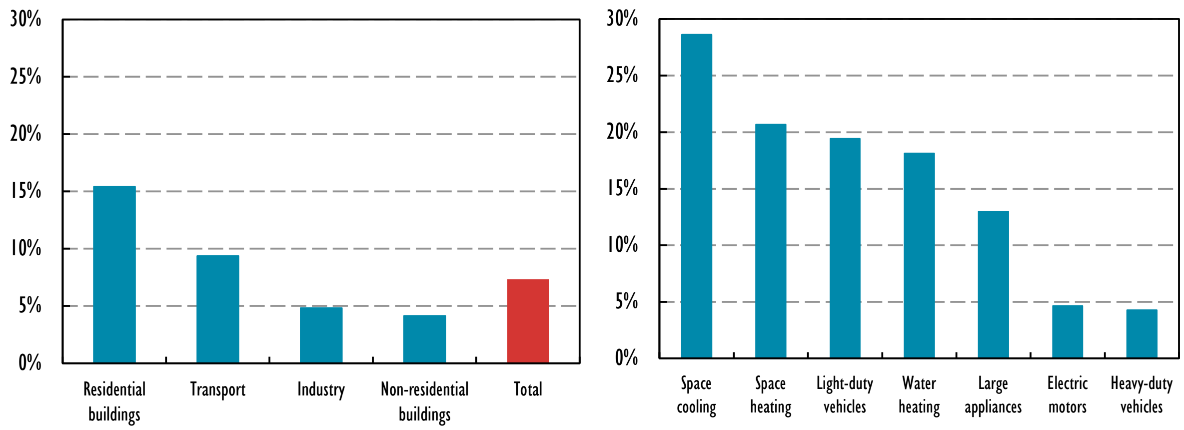
Figure 3.10 Efficiency Policy Progress Index, 2005-15



At world level, the residential sector shows the greatest EPPI improvement at 15%. This was driven by improvements in standards for space heating and cooling, water heating, and appliances. Transport had the second-highest EPPI improvement, driven by fuel efficiency standard tightening in the United States, the European Union and Japan. In non-residential buildings, BECs are being strengthened in the United States and Europe; however, progress was slower compared with other sectors (Figure 3.11).

On an end-use basis, the largest gain in the EPPI was achieved in space heating and space cooling standards. This reflects a strong focus over the last decade by policy makers on strategies to implement both energy performance codes for buildings and minimum performance standards for heating and cooling equipment.[6] Increases in end-use performance level standards were highest on space cooling (29%), space heating (21%) and LDVs (18%) over the last decade (Figure 3.11).

Figure 3.11 Efficiency Policy Progress Index increase by sector and end use, 2005-15



[6] The performance level improvement in space heating and cooling is calculated as the percentage increase in BEC performance multiplied by the increase in the standards on heating and cooling systems. This approach weights the improvement in standards for heating and cooling equipment by the increase in BECs. When a country implements ambitious BECs and heating system standards, the strength increase is not the sum. Rather, there is a multiplier effect as the new standards on heating systems will further influence the reduced energy load from new BEC standards.

As standards become more ambitious and equipment becomes more efficient, it often becomes more difficult and costly to increase the performance further. This effect is evident in the case of electric motors, which show a lower strength increase than other end uses. In most cases, average efficiency motors are already around 90% efficient and standards seek to increase performance towards 95%. At present, the performance of motor standards is limited by their scope, which is typically constrained to the efficiency of the motor itself, not the motor system. Expanding the scope of policies to include other components of motor systems – for example by incentivising variable speed drives and improving operations of motors to maximise efficiency – would drive significant gains in the EPPI for motors.[7]

Energy savings from mandatory energy efficiency policies

Analysis in this chapter so far demonstrates that the coverage and performance levels of mandatory energy efficiency policies worldwide, as measured by the EPPI, have increased by a weighted average of 7.3% since 2005. But what impact has this had on energy consumption? By examining in more detail the standards on LDVs and appliances, this section analyses how expanding standards and improving performance levels save energy.

Energy savings from vehicle fuel economy standards

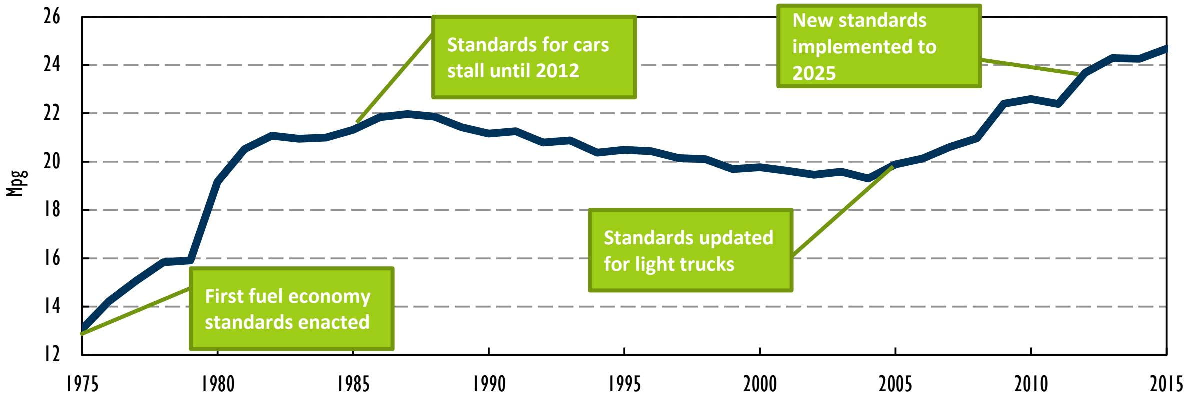
Mandatory fuel economy standards now cover more than 74% of global vehicle sales and have gradually increased the fuel economy of the LDV fleet. To evaluate the energy savings from vehicle fuel economy standards, a counter-factual scenario needs to be developed where standards are not implemented in order to estimate what the efficiency of the vehicle fleet would be in the absence of standards.

The United States has the longest-standing experience using vehicle fuel economy standards. In the US vehicle market, corporate average fuel economy (CAFE) standards[8] improved fuel economy by 39% as far back as between 1975 and 1985 (Figure 3.12). Action on fuel economy standards for vehicles then stalled. After strong sales of light trucks in the 1990s and 2000s, the standards were updated in 2005. In 2010, a comprehensive revision of the standards affected all LDV categories in the 2012-16 period. A subsequent rule was enacted in 2012, aiming to improve fuel economy by a further 45% between 2016 and 2025. The fuel economy of the new vehicle fleet improved until 2014, but the collapse in oil prices has prompted a shift to larger, less-efficient vehicles, and thus curtailed improvements in 2015. The following chapter discusses this issue in greater detail.

[7] For a detailed discussion and analysis of energy efficiency in electric motors please see the the IEA *WEO* published in November 2016.

[8] CAFE standards do not regulate the efficiency of specific vehicle models. Instead, vehicle manufacturers must comply with a minimum average efficiency of all vehicles sold in a given year. This gives manufacturers flexibility to sell high and low efficiency vehicles while still achieving average efficiency improvements over the fleet of new vehicles purchased by consumers.

Figure 3.12 Average fuel economy of passenger vehicles sold in the United States



Notes: Mpg = miles per gallon. Context boxes were added to this figure by the IEA. Vehicle fuel economy presented in this chart is the average of all cars and trucks sold based on their adjusted combined fuel economy value. This value combines the fuel economy of city and highway driving in order to adjust vehicle efficiencies to real-world duty cycles.
Source: United States Environmental Protection Agency (2015). 2015 FE Trends Report. Appendix D: Fuel Economy Data Stratified by Vehicle Type. Office of Transportation and Air Quality. Retrieved from: www3.epa.gov/fueleconomy/fetrends/1975-2015/420r15016-appendix-d.xlsx

This analysis assumes that vehicle efficiency does not change unless standards are implemented and continuously strengthened. The counter-factual scenario assumes that countries did not implement standards and that the baseline average vehicle efficiency is frozen at the year that a country or region had historically implemented vehicle efficiency standards. This reflects the experience of the United States after 1985 where standards stagnated and the average vehicle efficiency did not improve.

The difference in global oil demand from the counter-factual scenario with no vehicle standards is 2.3 million barrels of oil equivalent per day in 2014. In other words, vehicle efficiency standards saved 2.5% of global oil demand or 6% of energy consumption in the global road transport sector. For countries that have implemented standards, these savings represent 9.7% of fuel consumption in the road transport subsector. Savings from vehicle fuel economy standards were approximately one-third of the volume of tight oil production in the United States in 2015, illustrating the potential of energy efficiency as an alternative means of meeting energy demand.

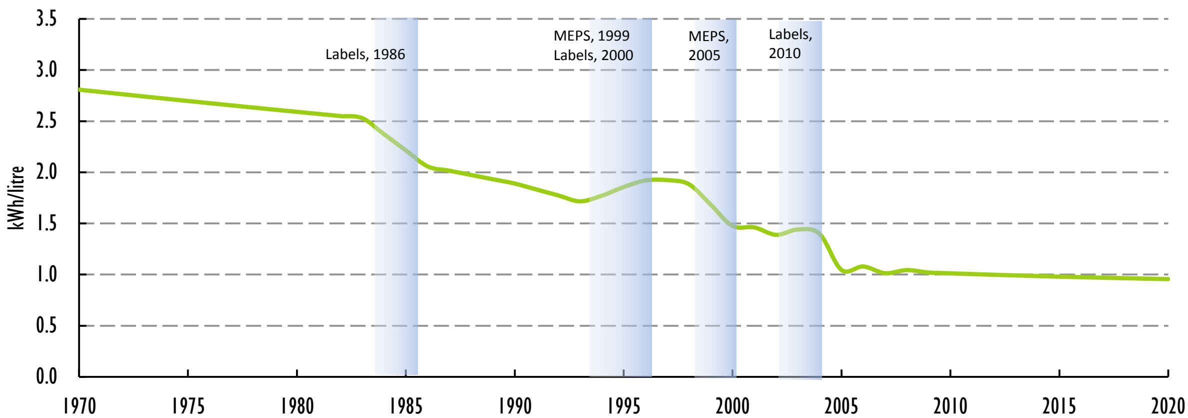
Mandatory standards and regulations in appliances

What has been the impact of the expansion and increasing strength of standards on the efficiency of appliances and other products? The average total efficiency improvement over the last ten years of the specific products to which standards and labels have been applied in IEA member countries and key emerging economies was:

- 16% for refrigerator-freezers
- 26% for lighting products (lamps)
- 21% for washing machines
- 23% for room air conditioners.

In one example, after Australia launched a labelling programme, the efficiency of refrigerators improved by 18% between 1986 and 1999. After the first efficiency standard for refrigerators was developed in 1999, efficiency improved by 40% to 2010 – an average annual rate of 4.5% (Figure 3.13).

Figure 3.13 Energy efficiency of refrigerator capacity in Australia and policy developments, 1970-2020

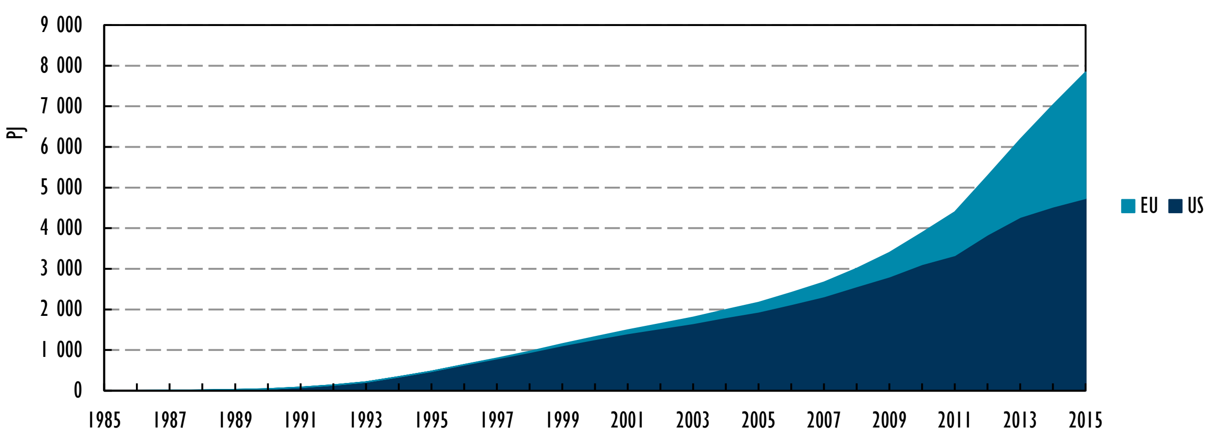


Note: kWh = kilowatt-hours.
Source: IEA 4E TCP, 2015.

Energy savings from appliance and product standards

The United States and the European Union are two of the largest consumer product markets in the world and energy savings from standards and labels have proven to be sizeable. In the United States, more than 65 product types are regulated. In 2015, standards in the two regions combined saved 4.7 EJ, or 57% of US and EU appliance energy use. This represented USD 63 billion in avoided energy expenditure, approximately 15% of total expenditure on energy in buildings. By 2030, cumulative energy expenditure savings associated with energy efficiency standards are estimated at USD 2 trillion, reflecting a demand reduction in excess of one year of US energy consumption (US DOE). In the European Union, policies enacted between the 1990s and 2015 (Ecodesign and energy labelling) resulted in 3.1 EJ of primary energy savings in 2015, representing 4.5% of EU primary energy demand. Cumulative primary energy savings since 1990 are 13 EJ (Figure 3.14).

Figure 3.14 Energy savings from appliance standards in the United States and the European Union



In Mexico, energy efficiency standards resulted in annual electricity savings of 11.8 terawatt-hours (TWh) in 2014. The standards have helped deliver energy cost savings to residential consumers equivalent to a cumulative USD 5.5 billion or USD 46 per capita since 1996. As electricity tariffs are subsidised, standards also generated a cumulative saving for the Ministry of Finance of USD 11 billion, saving taxpayers approximately USD 93 per capita. The combined savings between 1996 and 2014 would amount to USD 139 per capita. The emissions reduction benefit was 50 $MtCO_2$ for the period (CONUEE, 2016a).

Energy savings potential of expanding coverage and strengthening policy

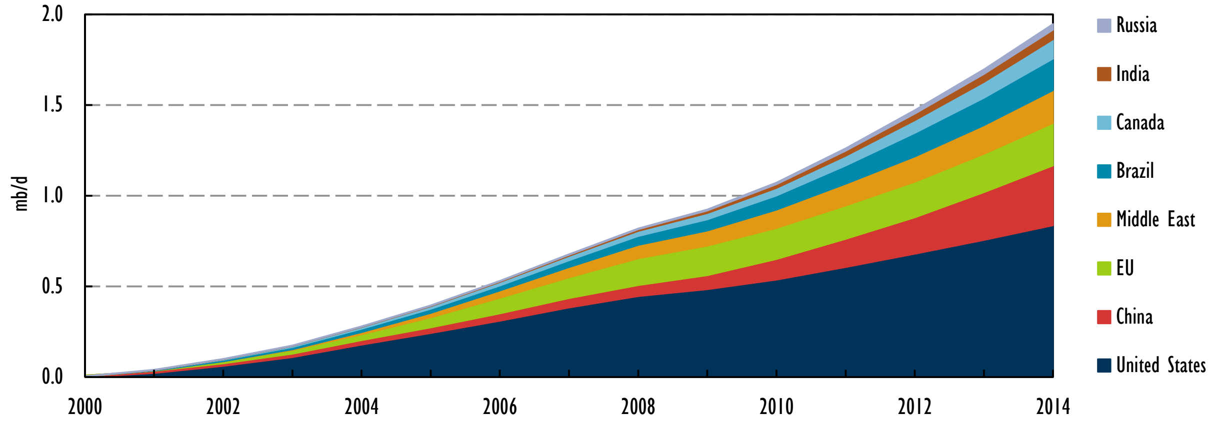
The evidence is clear that mandatory energy efficiency policies have been both expanding and strengthening. But as previous sections highlight, a still significant share of energy use is not yet subject to these types of policies and the strength of policies varies widely across regions. To estimate the energy saving potential of broader application of mandatory policies, this section evaluates scenarios in which policy coverage is extended worldwide and efficiency standards are strengthened to match the most ambitious examples currently in place.

Energy savings potential of expanding vehicle energy efficiency standards

Vehicle efficiency standards offer a significant source of energy efficiency potential. Approximately 30% of the global new vehicle fleet is not subject to energy efficiency standards, and standards in place vary significantly in strength.

Japanese standards have improved the average efficiency of the new vehicle fleet by 33% since 2000. If every major vehicle market (both with and without standards) had set this target over the same period, the additional oil savings would have been 2 mb/d in 2014 (Figure 3.15).

Figure 3.15 Additional energy savings from applying Japanese performance improvements to other major vehicle markets



Source: IEA Mobility Model.

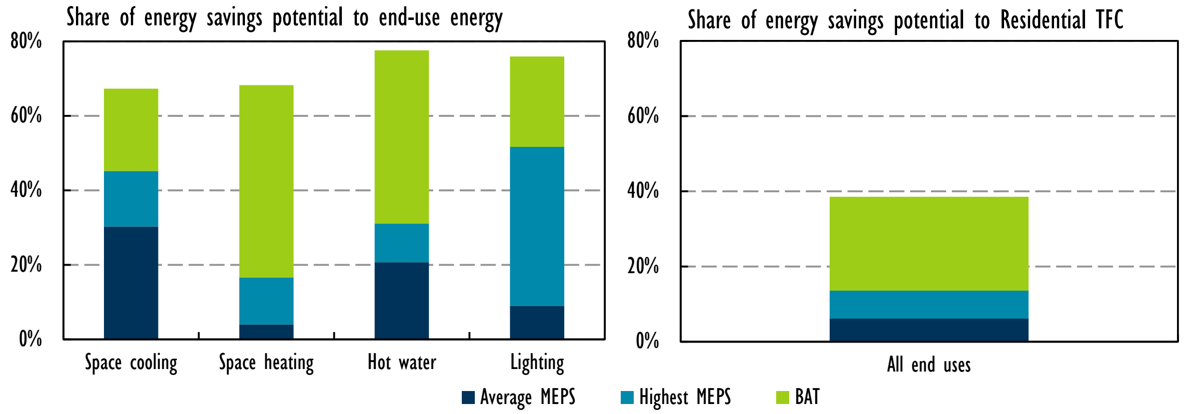
This analysis accounts for the makeup of the vehicle market in each region in the year 2000 and then assumes a 33% improvement in efficiency. Although vehicle markets differ by region, technical efficiency improvements as observed in Japan can be made to any vehicle type through a combination of light-weighting, drivetrain improvements, aerodynamic and rolling resistance improvements, and other measures.

Energy savings potential of expanding and strengthening energy efficiency standards for equipment in buildings

Two-thirds of global buildings energy use is still not subject to MEPS. This section analyses the scale of energy savings that could have been achieved in 2015 if building technologies met three different levels of standards: i) global average standards; ii) global best-in-class standards; and iii) new standards that achieve best available technology (BAT) level performance. The global average standards level represents the average value for existing standards for each building technology type with MEPS. The global best-in-class standards level represents the current most efficient standard for a given building technology type, such as minimum performance based on the performance of fluorescent lighting. The new BAT-based standards level limits all technology to BAT, such as minimum performance based on the performance of light-emitting diode (LED) lighting.

Had average MEPS been implemented for space cooling, space heating, hot water and lighting, the energy savings in 2015 would have been on the order of 6 EJ, or 6% of global residential energy use.[9] Implementing the highest MEPS globally would have saved 14% of global residential energy use (13 EJ). The largest potential is in space heating, where a large gap remains between average and best MEPS. Lighting savings in the highest MEPS scenario would have tripled as extending the highest MEPS would ensure the use of LED and compact fluorescent lighting for all global lighting. This unmet potential demonstrates that existing MEPS for lighting are still far from best-in-class and that strengthened standards could potentially save 52% of lighting TFC.

Figure 3.16 Energy savings if all installed stock met higher standards, 2015



[9] To estimate the energy savings potential in 2015, *EEMR* used the *Energy Technology Perspectives* buildings model to calculate the energy intensity for each end use and each of the three levels of standards. This analysis is based on the existing stock being completely rolled over by 2015 and on 2015 energy demand characteristics, such as population size and building floor area.

Most standards regimes set a minimum performance level for energy-using equipment, but these levels are often far from the BATs. In space heating, for example, BAT is heat pumps, which can be five times more efficient than existing standards. If BATs had been adopted since 2000, resulting energy savings would have equated to almost 38% of global residential TFC (Figure 3.16). Importantly, the potential depicted in Figure 3.16 is in 2015; in coming decades, the share of energy consumption by different end uses is expected to change. Space cooling energy demand is projected to grow the fastest of any building energy end use, more than doubling by 2030. As a result, the potential of global standards for space cooling will be significantly greater in 2030 than in 2015.

Trends for standards

Over the medium term, several countries are set to strengthen the performance levels and expand coverage of standards, often as part of periodic updates that reflect reviews of BAT and the economic feasibility of market transformation. Expected developments in efficiency standards in the next few years will deliver more energy savings and perhaps prompt similar action by others (Table 3.4).

Table 3.4 Medium-term developments in efficiency standards

Country	Developments
United States	The Appliance and Equipment Standards Program sets standards for more than 70 types of appliances and equipment.10 The Program has two goals: i) by 2025, to reduce by 20% the energy intensity of the buildings sector, from the 2010 level; and ii) by 2030, to reduce by 30% the average energy use per square foot of US buildings. Over the medium term, the programme will develop or update standards for 60 types of appliances and equipment. The Department of Energy will review the standards in late 2016 and early in 2017 include room and central air conditioners, clothes dryers, dehumidifiers, ovens and cooktops.
China	A fuel efficiency standard for heavy-duty vehicles is an important upcoming policy. It will match the first schedule of standard increases set by the United States, which calls for three phases of increases to 2040. Analysts expect large savings in China, where medium- and heavy-duty vehicles consume two-thirds of transport energy.11 China also recently announced a 'Top Runner' programme to promote energy conservation. The programme will provide technical guidance to managers of heavy industrial plants, light manufacturing plants and public buildings, encouraging them to 'run after' the most efficient ('top') achiever.
EU	Under the EU Ecodesign Directive, the European Commission sets MEPS for 23 categories of products sold in Europe. The Commission is currently considering revising or developing standards for the following product groups: air heating products, cooling products and process chillers, enterprise servers and data storage products, machine tools and welding equipment, smart appliances, taps and showers, lighting products, household refrigeration, household washing machines and dishwashers, computers, standby power consumption, water heaters, pumps and vacuum cleaners. Further, under the Energy Performance of Building Directive, there is a continuous tightening of national minimum energy performance requirements in line with the cost-optimal methodology.
Japan	Japan will continue its Top Runner programme, under which the government sets the efficiency of the most efficient product in a given category as the standard. Manufacturers and importers are required to comply with the new standard within three to ten years. As of 2015, the programme covered 31 categories of products.12 Products included in the programme are commonly used, consume high amounts of energy or are particularly inefficient.

[10] See http://energy.gov/sites/prod/files/2016/02/f29/BTO%20Multi-Year%20Program%20Plan%20-%20Final.pdf.

[11] See http://energyfuse.org/u-s-and-china-in-agreement-on-fuel-economy-standards-for-heavy-duty-trucks/.

[12] See www.enecho.meti.go.jp/category/saving_and_new/saving/data/toprunner2015e.pdf.

4. ENERGY PRICES: AN ENERGY EFFICIENCY MARKET DRIVER?

Highlights

- **As end-user gasoline prices have fallen, recent trends toward more driving and the purchase of larger less fuel-efficient vehicles have accelerated in the United States.** In 2015, vehicle-kilometres jumped by 3%, motor gasoline consumption increased by 2.7% and sales of light-duty trucks reached a record level of more than 9.5 million.
- **Policy has shielded efficiency from much of the potential impact of the 60% fall in the Brent crude oil price between 2014 and 2015.** Outside the United States, gasoline prices typically fell by only 10% to 25%, largely because of higher rates of fuel taxation. In jurisdictions with new vehicle standards, the fuel economy of new vehicles continued to improve. In the United States, where gasoline prices fell by around 40%, progress on fuel economy slowed to an average annual 1% between 2013 and 2015, down sharply from 1.8% per year between 2005 and 2013.
- **In China, the world's largest new passenger vehicle market, fuel economy gains accelerated between 2013 and 2015, with an average annual gain of 2.3% despite a 26% drop in retail gasoline prices.** This improvement was driven by the phasing in of China's first corporate average fuel consumption (CAFC) standards.
- **Household energy prices softened slightly in 2015, but energy efficiency investment in buildings rose**. While natural gas prices fell by around 10% in countries belonging to the Organisation for Economic Co-operation and Development (OECD) between 2014 and 2016, electricity prices remained at levels close to historic highs. Investment levels continue to be driven less by price and more by retrofit policies and performance standards for buildings and appliances.
- **Policy makers must hold their nerve and continue to broaden the coverage and increase the strength of energy efficiency policies.** If climate goals are to be met cost-effectively efficiency improvements must step up over current levels beginning immediately. High energy prices cannot be relied on as a main factor driving investments in energy efficiency. Equally, low prices do not diminish the case for efficiency to be at the forefront of national energy policy. Efficiency policies will need to continue to expand and strengthen even at a time when the short-term pressure to act may be diminished.

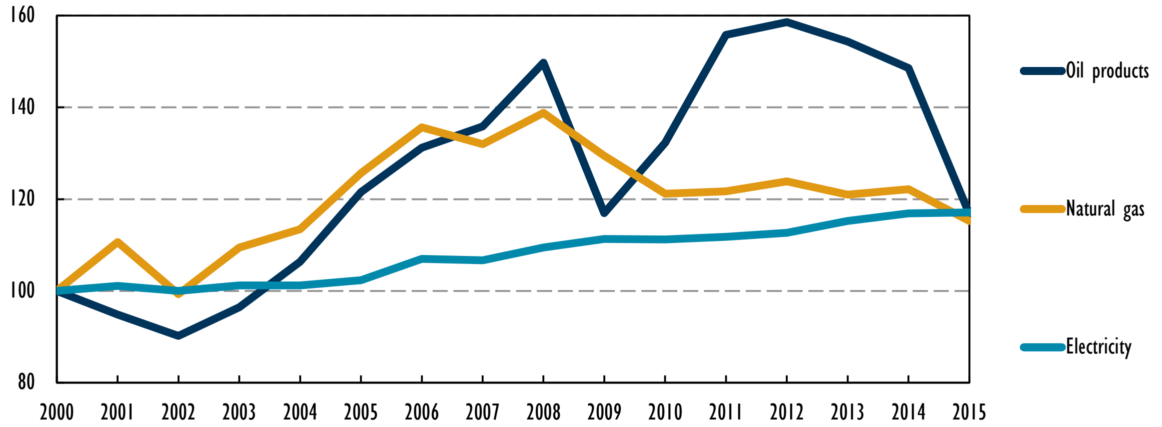
Introduction

The much lower energy commodity prices seen since mid-2014 have sent shock waves throughout the global economy, raising questions about how changes in energy prices have affected energy efficiency. How have consumer prices changed? And how important are those changes to the energy efficiency market, given the sensitivity of consumers to energy prices, rising gross domestic product (GDP) and policies in place to drive efficiency gains? This chapter outlines recent trends in household energy prices and reviews the evidence of their impact on energy demand and energy efficiency investment.

End-user energy prices have fallen, but less sharply than headline energy commodity prices

Dollar-denominated crude oil prices fell by 60% between Q2 2014 and Q4 2015, dropping further before recovering somewhat during 2016. Commodity prices of natural gas also fell by between 55% and 65% over the two years to Q4 2015.[1] Prices paid by consumers, however, have declined much more moderately, and with substantial variation across both countries and end-use fuels. In some sectors and in some countries, end-user energy prices have barely been affected by changes in upstream prices. In others, and most notably in the transport sector, significant end-use price decreases have quickly followed drops in the price of crude oil. Indeed, the biggest declines have been seen in oil products, where prices were around 30% lower on average in 2015 than in 2014, with the largest reductions seen in the United States. Household natural gas prices also fell in 2015, although less significantly and with a time lag; price reductions have continued into 2016. Over the same period, the average household retail price of electricity has stabilised at the historically high prices reached in the last two years (Figure 4.1). Despite these divergent price movements, the average prices across all three product groups in the OECD were between 15% and 17% higher in 2015 than in 2000.

Figure 4.1 Indices of real household retail energy prices in OECD countries, 2000-15



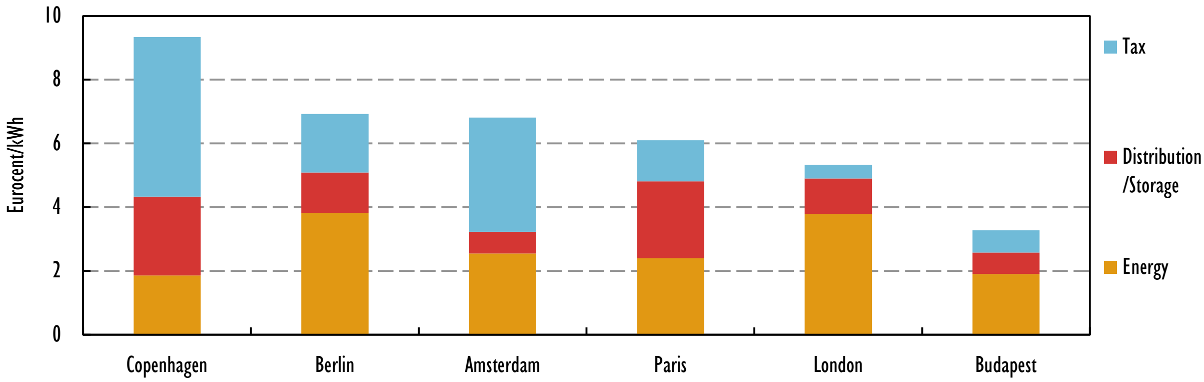
The extent to which decreases in energy commodity prices feed through to end users varies by country and product. Between Q2 2014 and Q4 2015, the US dollar appreciated by 10% to 30% against other OECD country currencies, dampening the impact of the dollar-denominated headline

[1] Across spot markets in Europe, Asia and the United States (Henry Hub, National Balancing Point [NBP], Asian liquefied natural gas spot, Brent, Title Transfer Facility [TTF]).

price decline in many countries. Impacts can also take time to work their way through to end-user prices, particularly in the household sector, where electricity and natural gas contracts often fix prices for periods of two years (or longer in some cases).

In addition, end-user prices comprise a number of other elements besides upstream fuel costs, such as shipping costs, transmission, distribution and tax. Considerable variation exists in the relative significance of these costs across jurisdictions. For example, natural gas wholesale costs made up only 20% of the average household retail price in the first half of 2016 in Copenhagen (Denmark), while taxes made up 54% of the total price. By contrast, in London (United Kingdom), wholesale natural gas costs made up 71% of the average household retail price and tax made up just 8% (Figure 4.2).

Figure 4.2 Composition of household retail natural gas prices in selected European cities, 2016



Note: kWh = kilowatt-hours.
Source: European Commission analysis of VaasaETT data, European Commission, Directorate-General for Energy, Market Observatory for Energy, 2016.

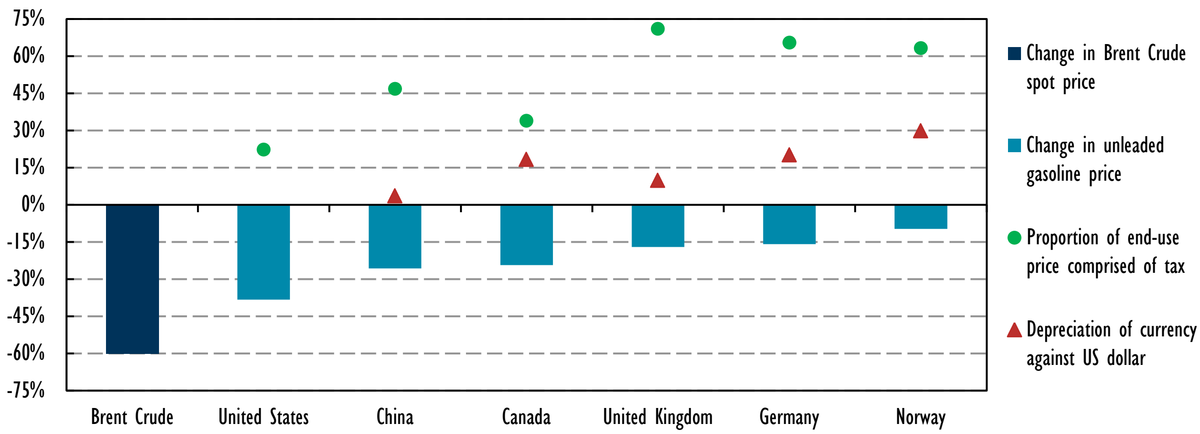
As these other elements become proportionately more important in determining the prices paid by end users, changes in underlying commodity prices have less impact on the percentage change seen by consumers. In this respect, tax reduces consumer exposure to commodity price fluctuations while also insulating the energy efficiency market at times of falling prices. This effect can be seen most clearly in the transport sector.

Energy price falls have been most significant in the transport sector

While oil prices fell by 60% between Q2 2014 and Q4 2015, the prices paid by consumers of oil products for transport fell considerably less. End-user prices fell most in the United States, where unleaded gasoline prices were 38% lower over the 18-month period. The percentage price reduction in the United States was more than twice the average seen in other OECD countries, with decreases ranging from 24% in Canada to 10% in Norway. Variations in tax rates and the depreciation of local currencies against the US dollar strongly affected the reductions in different countries. Currency depreciations against the US dollar of between 10% and 30% across countries belonging to the International Energy Agency (IEA) dampened the fall of oil commodity prices in local currencies. The much higher fuel tax rates outside North America meant that commodity cost reductions were passed through to consumers in a much smaller proportion of the end-user price. In China, where the exchange rate for the Chinese Yuan renminbi dropped by only 4% against the US dollar, regulated gasoline prices fell by 26% over the period. In Q4 2015, taxes made up just 22% of US and 34% of Canadian unleaded gasoline prices. In Europe, taxes ranged between 56% of the end-user price in Luxembourg and 71% in the United Kingdom. In China, 47% of the gasoline price was made up of tax (Figure 4.3).

The impacts of taxation policy on efficiency outcomes work through two channels. First, higher levels of fuel taxation lead to higher end-user prices, boosting incentives for investment in more efficient vehicles. This limits consumer incentives to invest in efficiency. Second, as can be seen in the current situation, during periods of falling commodity prices, higher tax rates have a dampening effect on end-user price changes. In addition, there is evidence that taxes have more impact on behaviour than underlying price changes, owing to the greater salience of taxes to consumers and the perception that they are more likely to be persistent than equivalent increases in tax-exclusive prices (Li, Linn and Muehlegger, 2014).

Figure 4.3 Change in crude oil and end-use gasoline prices between Q2 2014 and Q4 2015, proportion of end-use price comprised of tax, and depreciation of currency against the US dollar

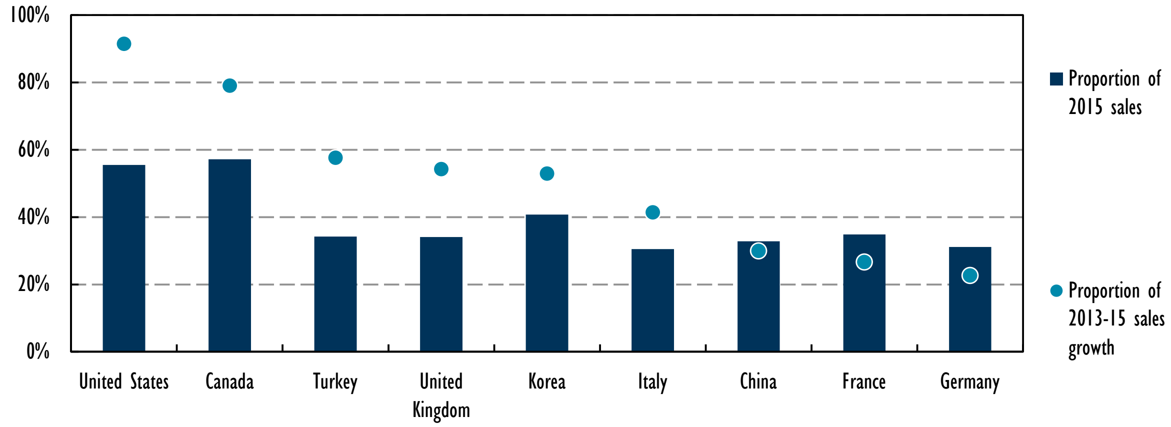


Note: unleaded gasoline prices are for premium unleaded Research Octane Number (RON) 95 in national currencies. The changes are between nominal prices. The proportion of the end-use price that was tax is for Q4 2015.
Sources: IEA analysis, NDRC (2016) and OECD (2016).

What have been the effects of the fall in end-user transport fuel prices?

In the medium to long run, the impact of the fall in transport fuel prices will be evident through changes in vehicle purchasing patterns. Less efficient vehicles bought during periods of lower prices will consume more fuel per kilometre (km) travelled over their lifetimes (typically 15 years in OECD countries and probably more than 20 years in non-OECD countries). Recent trends towards the purchase of light-duty trucks (sport utility vehicles, pickup trucks, minivans, crossovers and light-duty commercial vehicles), which typically consume more fuel per kilometre, intensified during the recent fall in fuel prices. This trend was particularly noticeable in North America, where price falls have been relatively strong and the large share of light-duty trucks in the new passenger fleet is already well established, exceeding 55% in 2015. In the United States, light-duty trucks accounted for 90% of the growth in new passenger vehicle sales between 2013 and 2015. In other growing vehicle markets, the picture was more mixed with strong growth of light-duty trucks in the share of sales in Turkey, the United Kingdom and Korea, but small declines in the shares in France and Germany (Figure 4.4).

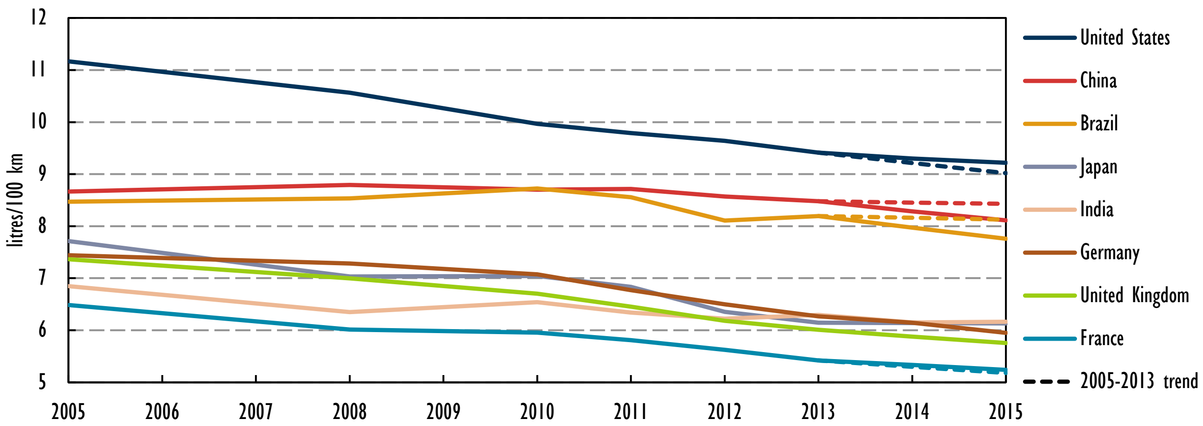
Figure 4.4 Share of light-duty trucks in new passenger vehicles sales



Source: IHS POLK

While light-duty trucks may provide consumers with different services than the cars they are replacing in the fleet (for example, those associated with their size and perceptions of safety), they tend to come with a fuel economy penalty. As most new light-duty trucks have worse fuel economy than other new vehicles, an increasing share of such vehicles in the fleet will slow progress towards fuel economy targets. This can be seen when comparing the relative fuel economy of the new passenger vehicle fleet in different countries and the rate of progress on fuel economy during the recent period of falling prices (Figure 4.5).

Figure 4.5 New passenger vehicle fuel economy in selected countries, 2005-15



Note: Fuel efficiency calculated on the basis of the Worldwide Harmonised Light Vehicles Test Procedure (WLTP).
Source: IHS POLK

Over the last six years as the US economy has recovered from recession, sales of new passenger vehicles have grown every year. Initially, increases in sales were seen across both cars and light-duty trucks. With the fall in fuel prices during 2014 and 2015, however, the continued increase in passenger vehicle sales was concentrated in light-duty trucks. In 2015, both sales of light-duty trucks (9.5 million) and their share in total sales (56%) set record highs.

The considerably lower transport fuel prices in the United States are also affecting demand for fuel through increases in kilometres travelled. After five years of declining or moderate growth, US passenger vehicle travel picked up in 2014, increasing by 1.8% to levels last seen in 2007, and jumping by 3% in 2015 to a record 13.8 million km per day. Meanwhile, motor gasoline consumption increased by 2.7% in 2015 and is projected to rise by a further 1.6% in 2016 to a record level of 9.3 million barrels per day (mb/d), despite improvements in vehicle fleet fuel economy. This is driven by a further 2.3% increase in kilometres travelled (US EIA, 2016).

In emerging economies such as Brazil, China and India, the rate of improvement in the fuel economy of new passenger vehicles picked up during the period of falling oil prices. China has the world's largest market for new passenger vehicles, with sales growing at more than 10% per year since 2008. In this large and rapidly growing market, the fuel economy standards phased in from 2012 have helped to drive average gains of 2.1% annually between 2013 and 2015, despite lower fuel prices. This rate of improvement was significantly higher than the rate achieved between 2005 and 2013 (0.3% per year). Over the next five years, the rate of improvement will need to increase again, if China is to meet its proposed target for light-duty vehicles. The decline in the CAFC limit value implies an average annual rate of improvement of 5.0% per year over the period to 2020.

Policy shields efficiency from much of the potential impact of falling energy prices

There is evidence that policy is helping to mitigate the impact of falling energy prices. While the introduction of CAFC standards in China has caused the rate of improvement in fuel efficiency to accelerate, it is also interesting to note that, without corporate average fuel economy (CAFE) standards, the slowdown in efficiency gains in the United States would have been much greater. Light-duty trucks tend to be both larger and more powerful than cars; in 2015, the average fuel economy of cars sold in the United States was 7.8 litres per 100 km (L/100 km) and that of light-duty trucks was 10.4 L/100km. Thus, a relatively large shift in sales from cars to trucks would be expected to reduce overall efficiency of the new vehicle fleet. However, driven by CAFE standards, the average fuel economy of light-duty trucks sold in the United States has improved, from 10.9 L/100 km in 2013 to 10.4 L/100 km in 2015. During the recent fall in fuel prices, this improvement outweighed the shift in sales to trucks from cars. Indeed, had the average efficiency of light-duty trucks sold in 2015 remained at the 2013 level, the average fuel economy of the US new passenger vehicle fleet would have declined by 0.4% annually; instead, it improved by 1.0% per year. Since the introduction of standards in the late 1970s, vehicle efficiency gains have led to savings of 1.7 mb/d in US oil products consumption, dwarfing the 320 000-barrel-per-day increase in gasoline consumption seen over the 2013-15 period.

Box 4.1 Corporate average fuel economy standards drive efficiency gains

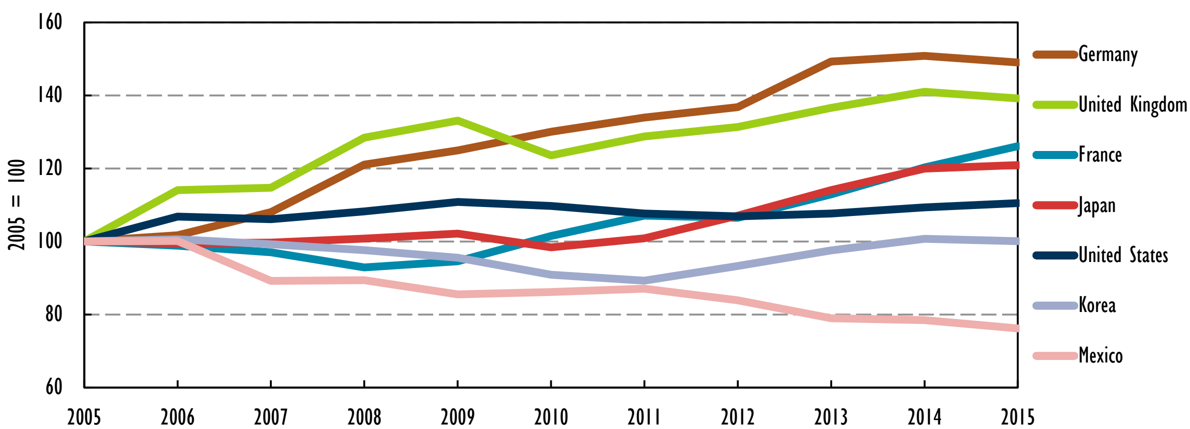
Corporate average fuel economy (CAFE) standards assign targets to vehicle manufacturers to improve the average fuel economy of the new vehicles they sell without prescribing particular technological solutions. Even though allowances are made for shifts in consumer purchases between vehicle size classes, the design of the policy incentivises manufacturers to curb how lower energy prices influence fuel economy in two ways. In the short run, manufacturers can reduce the price of the most efficient vehicles within each class to increase the likelihood of them being sold (Leard, Linn and McConnell, 2016). In the longer run, manufacturers can invest more in improving the fuel economy of the largest vehicles, which are subject to an upper limit on fuel economy independent of their size (IEA, 2016).

Household energy prices remain close to ten-year highs

Household energy prices have risen across most OECD countries over the last decade. In Germany, real electricity prices rose by 50%, while elsewhere in Europe prices rose by between 25% and 40%. In OECD Asia, electricity prices remained stable in some places but rose by up to 20% in others (Figure 4.6). In OECD Americas, US prices increased by 10%, while Mexico saw a drop of more than 20%.

Between 2013 and 2015, the rise in household electricity prices was arrested in most jurisdictions, although there were no significant falls in retail prices in 2015. In most cases, reductions in generation costs were countered by rising network investment costs and policy costs. The high prices paid for electricity are becoming relatively more significant in terms of household energy consumption. In 2005, global residential consumption of electricity and natural gas were on a par at around 16.1 petajoules (PJ) each. In 2015, the residential sector consumed around 20% more electricity than natural gas, driven primarily by growth in electricity demand in non-OECD countries.

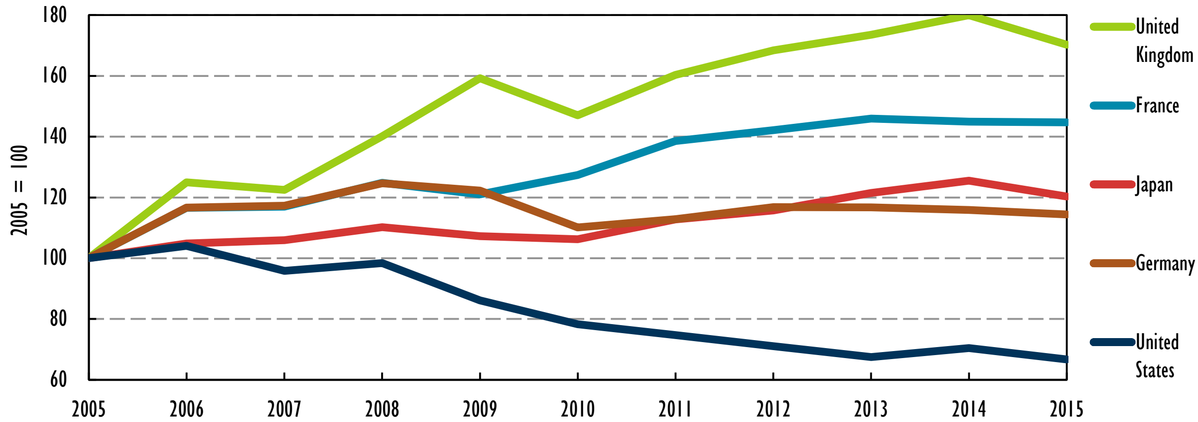
Figure 4.6 Indices of real household electricity prices, 2005-15



Household natural gas prices rose significantly over the last decade, particularly in Europe. In Q1 2016 natural gas prices were 70% higher than in Q1 2005 in the United Kingdom, which imposes a very low rate of taxation on household gas consumption (a reduced rate of 5% value-added tax). In other significant residential European gas markets, natural gas prices were between 15% and 45% higher. In Japan, household natural gas prices were around 20% higher. Exceptionally, year-on-year prices have been falling in the United States, owing to the increase in domestic shale gas production (Figure 4.7).

The impact of the large falls in natural gas prices seen across global commodity markets did not filter through to household prices to a significant extent during 2015. Prices do look to be softening in 2016 – at least in Europe and Japan – from historically high levels

Figure 4.7 Indices of real household natural gas prices in selected countries, 2005-15



Given the relatively modest falls in household natural gas and electricity prices seen during 2015, it is too early to identify an impact on energy efficiency. Investment in energy efficiency in the buildings sector continued to increase in 2015 (see Chapter 5) and there are reasons to expect that lower prices in the future would have a relatively benign impact. Studies that examine how changes in energy prices affect investment in energy efficiency in buildings suggest that the impact is small, i.e. that investments are inelastic with respect to energy prices (Rapson, 2014; Jacobsen, 2015), and that price increases elicit stronger investment responses than equivalent price reductions. This asymmetric response may be explained by lower transaction costs and better information being available for investments in technologies that are new or recently developed during the period of price increase. As the technologies mature, they become less costly investments and are thus less affected by a fuel price decrease than an equivalent increase (Boonekamp, 2007). Policy measures, particularly performance standards for energy-consuming technologies and buildings, play a vital role in this respect. Improvements over time in the minimum efficiency of products available on the market effectively remove technologies that could become economic at lower fuel prices (Box 4.2).

Box 4.2 The interaction of policy and falling household prices for natural gas and electricity

Policy already plays a key role in driving energy efficiency investment in the buildings sector, which will become increasingly important if prices do fall significantly. The key policies used to stimulate efficiency (standards, rebates, taxes, labelling and market-based instruments) all interact with price changes in different ways. In the case of building energy standards, many authorities have adopted strong efficiency requirements for new build. As a result, when energy prices have decreased as in the current context, many efficiency investment decisions that would be bypassed, based on fuel price savings, remain intact because of stronger standards. The elasticity with respect to fuel price could be 30% to 40% higher without policy measures (Boonekamp, 2007).

Up-front subsidy payments, which reduce uncertainty about the monetary benefits of an investment that would otherwise depend on high energy prices, are likely to continue to be effective in generating energy efficiency investments. In a conjoint survey of residential energy efficiency projects, respondents were found to be 14% more likely to make a building efficiency upgrade when an up-front rebate was offered than if greater savings on fuel costs, with a discounted value greater than the rebate, were offered (Alberini et al., 2013). As energy prices decrease, the impact of an up-front subsidy in encouraging efficiency investments increases. Tax has also been shown to have a disproportionate

Box 4.2 The interaction of policy and falling household prices for natural gas and electricity (continued)

impact on consumer behaviour relative to equivalent price increases, owing to its greater salience and perceived persistence (Li, Linn and Muehlegger, 2014). Meanwhile, market-based instruments, such as supplier obligations and white certificate programmes, should continue to deliver efficiency investments, albeit potentially at greater cost if consumers at the margin require higher subsidies to take action.

While there have been only small downward movements in household energy prices during 2015 and early 2016, if reductions in natural gas commodity prices remain at current levels, further falls in household prices are likely in 2016-17. This is particularly true for natural gas, as households with fixed-term contracts that are often of over one year in duration return to the market to sign new deals.[2] In percentage terms, household prices could fall most in the United Kingdom, where the commodity price constituted the biggest proportion of the overall price (around 70% in Q3 2015). Elsewhere in Europe, this proportion averaged around 50%.

Policy must continue to support efficiency gains

Over the last decade, policy makers have driven efficiency gains through a range of measures aimed at delivering energy savings while supporting economic growth and mitigating social and environmental concerns. Standards on new vehicles, buildings, appliances and equipment have strengthened and spread to new markets. Market-based instruments, such as white certificate schemes, utility obligations and auctions have increased in number and are commoditising energy efficiency (Chapter 6). Retrofit policies, alongside standards, have continued to drive investment in buildings (Chapter 5). Many policies have been introduced and strengthened during a prolonged period of concern regarding the effects of rising energy prices.

Now that end-user natural gas and oil product prices have fallen, albeit buttressed by energy taxation in many jurisdictions, there is a danger that the short-term political pressure to strengthen existing policies and introduce new ones will diminish. In addition, the continued high level of electricity prices relative to natural gas and oil products presents a possible concern for policy makers. While co-generation will become relatively more cost-effective, lower gasoline and natural gas prices will affect the relative cost-effectiveness of switching to more efficient, electrically powered technologies such as electric vehicles and heat pumps, which are central to most decarbonisation strategies.

The medium-term prospects for efficiency policy remain bright, however. The commitments made through the Nationally Determined Contributions, as part of the Paris Agreement in 2015, can be met cost-effectively only through a ramp-up in energy efficiency action. Lower fossil fuel prices affect the cost-effectiveness of all decarbonisation measures, and efficiency remains at the heart of all credible scenarios to tackle climate change. Recognising the need for strong, predictable policies aimed at meeting medium- to long-term goals, policy makers would do well to continue on four fronts: i) introduce and strengthen performance standards; ii) expand the use of market-based instruments; iii) support an increase in the rate of building retrofits; and iv) use taxation to better reflect the full economic, social and environmental costs of energy production.

[2] In Q4 2014, over half of the gas offers available to households in Europe were on a fixed-term basis, most commonly for between 12 and 24 months (Agency for the Cooperation of Energy Regulators and the Council of European Energy Regulators, 2015).

5. ENERGY EFFICIENCY INVESTMENTS AND TRENDS

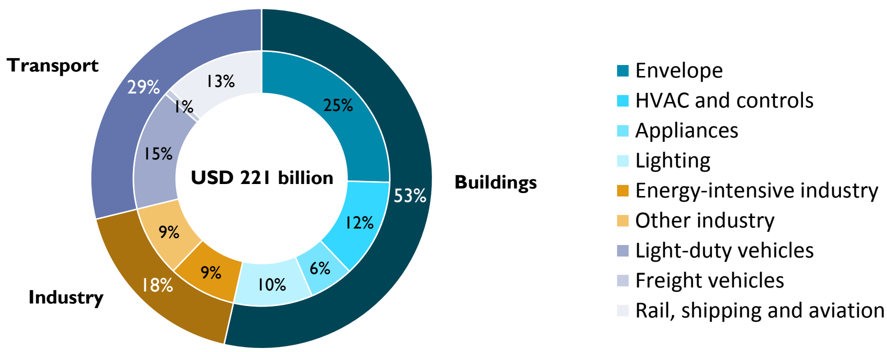
Highlights

- **Global investment in energy efficiency, i.e. the additional investment required for efficient products, grew 6% in 2015 to 221 billion United States dollars (USD).** Investment in buildings was over half of the total investment in efficiency and experienced the strongest growth at 9%. Investment in industry grew by 6% and transport grew by 3%.
- **Investment in energy efficiency is less than 14% of total spending in the energy system (USD 1.6 trillion) in 2015.** However, energy efficiency investment is more than two-thirds larger than investment in conventional electric power generation, excluding renewable energy.
- **Global energy efficiency investment was USD 118 billion in buildings (including appliances and lighting), USD 64 billion in transport, and USD 39 billion in industry.** The United States, the People's Republic of China (hereafter "China"), Germany and France accounted for more than USD 86 billion or 73% of efficiency investment in buildings. In transport, over 75% of global investment in efficient light-duty vehicles (LDVs) was in the United States, the European Union (EU) and China. Energy management systems and efficient motors made up over half of total efficiency investment in industry.
- **Investment in efficient appliances was USD 12 billion with standards and labels improving the average efficiency level for major appliance categories by more than 16% between 2005 and 2015.** Energy efficiency improvements, driven by standards, for refrigerators, washing equipment and lighting saved a cumulative 1 250 terawatt-hours (TWh) of electricity over the past ten years.
- **2015 saw USD 15 billion of investment in zero energy buildings (ZEB) even though relevant policies are in their infancy globally, with USD 12.5 billion of this investment in energy efficiency and USD 2.5 billion in renewable energy.** The European Union, which has already established a nearly zero energy building policy framework, currently dominates the ZEB construction market with investment of more than USD 14 billion.
- **LDVs purchased in 2015 saved 160 000 barrels per day (b/d) in oil consumption, equivalent to 0.4% of oil consumption for global road transport.** Over their life, efficient vehicles adopted in 2015 will avoid up to one billion barrels of oil consumption, approximately the size of the combined publicly held oil stocks of the United States and Europe.
- **Globally, 2015 saw the highest sales of electric vehicles (EVs), up 70% from 2014.** EV sales in 2015 are estimated to save over 33 million barrels of oil consumption over their lifetime. However the impact of EVs on oil consumption is currently very small. Annual oil savings from EV sales in 2015 represent only 0.01% of oil consumption in the transport sector.
- **In industry, direct spending by firms and energy service company (ESCO) contracts continue to drive energy efficiency investment.** Investment in industry energy efficiency in China through energy performance contracts (EPCs) with ESCOs was more than USD 8 billion in 2015.

Introduction

This chapter evaluates, where possible, the total spending and incremental investment on energy efficiency in three sectors: i) buildings; ii) industry; and iii) transport. Total spending is the total expenditure on energy-efficient goods based on their purchase price. The incremental investment in energy efficiency is the additional cost of energy-efficient goods compared with an average efficiency good. The incremental energy efficiency investment provides a closer comparable with other energy supply investments because it reflects the additional spending required to upgrade efficiency and to save energy. Analysis of the buildings sector includes a special focus on appliances, equipment and lighting.[1] Buildings accounts for more than half (53%) of incremental investment, followed by transport (29%) and industry (18%) (Figure 5.1).

Figure 5.1 Global incremental investment in energy efficiency by sector, 2015



Note: HVAC = HVAC = heating, ventilation and air conditioning.

Sources: Analysis and data based on Navigant Research, Consortium for Energy Efficiency, IHS Polk, IEA 4E Technology Collaboration Programme.

Accounting of energy efficiency investment is more complex than accounting for other energy market investment due to factors that include significantly more investors, variable baseline investment and variable incremental investments. This report estimates energy efficiency investment using bottom-up sales data, where available, combining these with top-down global or national data to provide economy-wide coverage. While this approach provides more detail on efficiency investment, the annual investment estimates in this report are not comparable with the energy efficiency investment estimates that used top-down data in previous *Energy Efficiency Market Reports* (2013 and 2014). While the reports are not comparable, the analysis using the bottom-up approach shows year-on-year increases in overall investment.

[1] The section on appliances, equipment and lighting was developed with the support of the International Energy Agency (IEA) Energy Efficient End-Use Equipment Technology Collaboration Programme (4E TCP).

Global market size

Global incremental investment in energy efficiency in the three sectors assessed in this chapter was USD 221 billion in 2015 (Figure 5.1),[2] yet it is less than 14% of the USD 1.6 trillion spent globally on energy supply investments (IEA, 2016a).

Increased total spending on energy efficient products and services is a good indicator that the economy as a whole is becoming more energy efficient. Changes in incremental investment are less straightforward. In some cases, spending is an unambiguous sign of energy efficiency improvement, such as energy retrofits of existing buildings or investment in industrial processes that would otherwise not have been funded. In other cases, such as with appliances or vehicles, a gradual decline in incremental spending may be a sign that more efficient products are becoming cheaper to produce (as the market share of efficient products increases, their prices may decline). This analysis therefore examines total spending and incremental investment by sector to better understand the trends that are making the world more energy efficient.

Energy efficiency investment has risen in each sector (Table 5.1). Incremental investment in buildings is dominated by spending on existing buildings. In industry the focus is on processes that would not have attracted investment without the energy efficiency intervention. Transport sector incremental investment is highly influenced by the annual volume of new vehicle purchases, changes in the annual cost differential of an energy efficient vehicle and government subsidies for energy efficient and electric vehicles (EVs).

Table 5.1 Global market for energy efficiency by sector, 2015

	Total spending	Incremental investment	
	USD billion	USD billion	Change compared with 2014
Buildings	388	118	9%
Envelope	*237*	*56*	
HVAC and controls	*76*	*27*	
Appliances	*34*	*12*	
Lighting	*41*	*22*	
Industry		*39*	4%
Energy-intensive industry		*19*	
Other industry		*20*	
Transport	--	*64*	3%
Light-duty vehicles	*330*	*34*	
Freight vehicles		*2*	
Other transport		*28*	

Note: HVAC = heating, cooling and ventilation.
Sources: Analysis based on Navigant Research, Consortium for Energy Efficiency, IHS Polk, IEA 4E Technology Collaboration Programme.

Methodologies for estimating the incremental investment in energy efficiency are specific to each sector and subsector. The basic principle is that incremental investment reflects money spent for

[2] For projections of investment needs, see also the IEA *World Energy Outlook* and *Energy Technology Perspectives* series.

additional energy efficiency over a baseline case for a product or service within the sector (Table 5.2). For the buildings sector, the incremental investment is calculated by intervention – that is, action on the building envelope (insulation and windows) or systems (HVAC and controls) – and whether the building is existing or new (only a small portion of the spending on energy efficiency for new buildings is considered investment). For the industry sector, the incremental investment is calculated based on the average technology efficiency in the prior year plus the spending on energy management systems that improves system-wide efficiencies. In the transport sector, the vehicle incremental investment is calculated for new LDVs based on the price difference consumers pay between the top 25% of efficient vehicles and average efficiency vehicles.

Table 5.2 Methodology for estimating incremental energy efficiency investment by sector

Sector	Sub-sector	Baseline
Buildings	Building envelope	Minimum 2005 standard in new construction and no spending in existing building retrofit.
	HVAC and controls	Minimum standard in new construction and existing building retrofit
	Appliances and lightbulbs	Minimum standard
	Obligated energy service spending	No spending
Industry	Energy-intensive industry	Sector average technology efficiency in prior year and no energy management system spending
	Other industry	Sector average technology efficiency in prior year and no energy management system spending
Transport	LDVs	Average efficiency of new vehicle sales
	Freight vehicles and other transport	Average intensity of different modes in 2014

The following sections examine energy efficiency in each of the three sectors and also include the special focus on appliances, equipment and lighting.

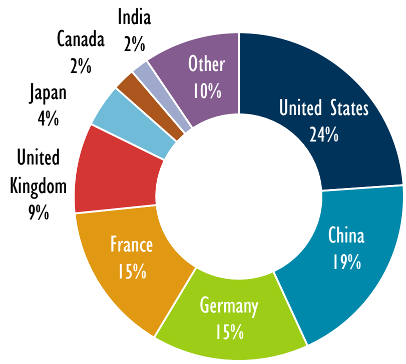
Buildings

- **Global incremental energy efficiency investment in buildings, including appliances and lighting, has been increasing and was USD 118 billion in 2015.** Total spending on energy efficient products and services in buildings worldwide was USD 388 billion in 2015. This is 8% of total building construction spending, a share that has been rising.

Global market size of energy efficiency in buildings

Incremental energy efficiency investment in buildings, including appliances and lighting, was USD 118 billion in 2015. The United States (US), China, Germany and France accounted for more than USD 86 billion or 73% of this investment (Figure 5.2). Total spending on energy-efficient products and services in buildings was USD 388 billion. This is less than 8.5% of the USD 4.6 trillion spent on construction and renovations of new and existing buildings globally.

Figure 5.2 Incremental energy efficiency investment in buildings by country, 2015



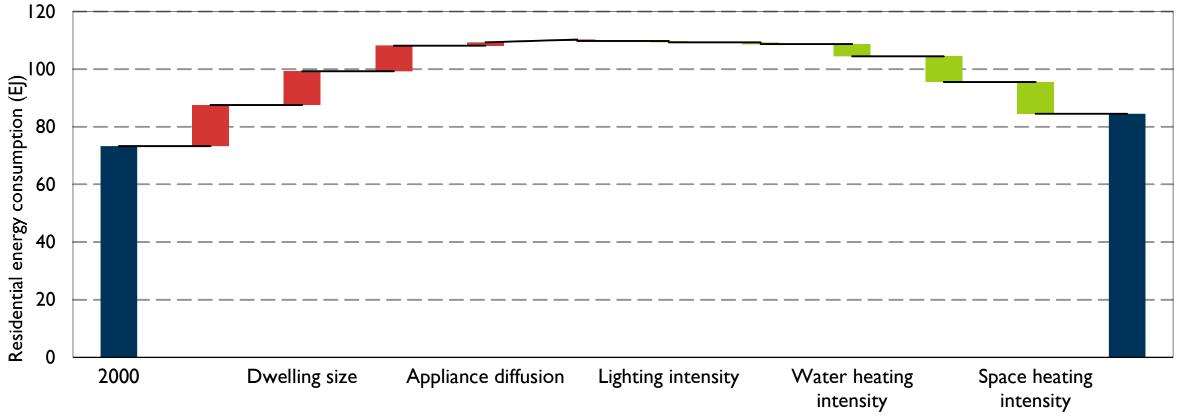
Source: IEA analysis and Navigant Research (2015).

Energy efficiency investment in buildings is driven by policy more than by end users (owners or landlords). In other words, government policy and utility programmes directly induce most of the incremental investment in those countries with the largest investment. Direct spending by governments, though less than 6% of the total incremental investment, induces much more spending by end users, typically through energy efficiency policies and leveraged investment. The building envelope accounts for the largest share of investment in buildings energy efficiency, at USD 237 billion of spending on products and services and incremental investment of USD 56 billion (Table 5.1). This is primarily accounted for by insulation and windows.

Market trends for energy efficient buildings

In non-residential buildings, a 37% improvement was achieved globally in energy consumption per square metre during the period 2000-15. In residential buildings, energy efficiency improvements of 26% were made, primarily in space heating, cooking and water heating (Figure 5.3). Still, several factors put upward pressure on energy use, including population growth, increase in the size of dwellings and a reduction in the number of occupants per home, often associated with rising income. The following subsections evaluate the trends that prompt increases and decreases in energy consumption by end use.

Figure 5.3 Factors affecting change in global residential energy consumption from 2000 to 2015



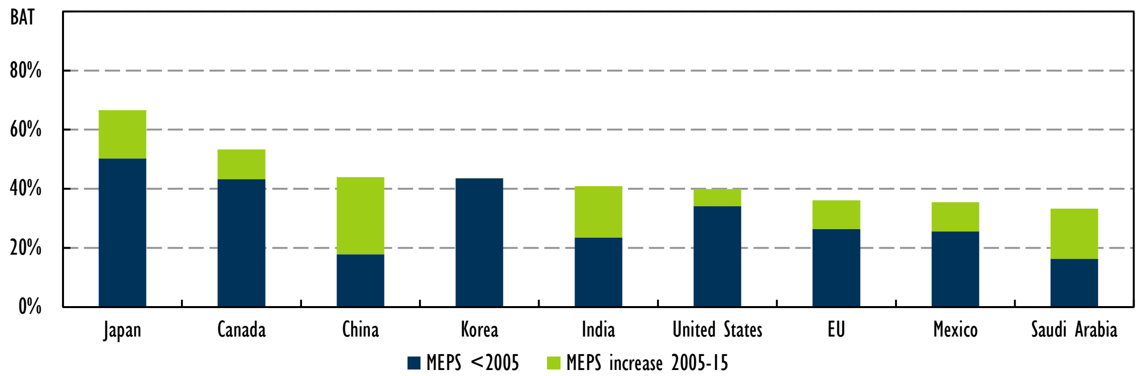
Note: EJ = exajoules.

Space cooling

Growing use of appliances, space cooling and lighting have all pushed up demand for energy service, although the effect has been moderated by improved technology efficiency. With growing populations and rising incomes, developing and emerging economies are expected to dominate global construction of new buildings, accounting for 85% of total floor area growth through 2050. As many of these countries have hot and humid climates, they will also dominate future growth in space cooling demand.

China and India have seen the largest efficiency increases in space cooling equipment over the past decade. Japan has the smallest spread between the minimum available technology and the best available technology (BAT), with minimum energy performance standards (MEPS) at 67% of global BAT (Figure 5.4). Many countries have made only incremental improvements to MEPS for space cooling equipment over the past ten years, and remain far from global BAT given recent technological advances. A large gap remains between the lowest (32%) and highest (69%) proximities,[3] indicating that international harmonisation of space cooling equipment standards is limited and has not been a priority for many countries. It also suggests significant potential energy savings, particularly in hot countries.

Figure 5.4 Space cooling equipment MEPS for selected countries



Space heating and water heating

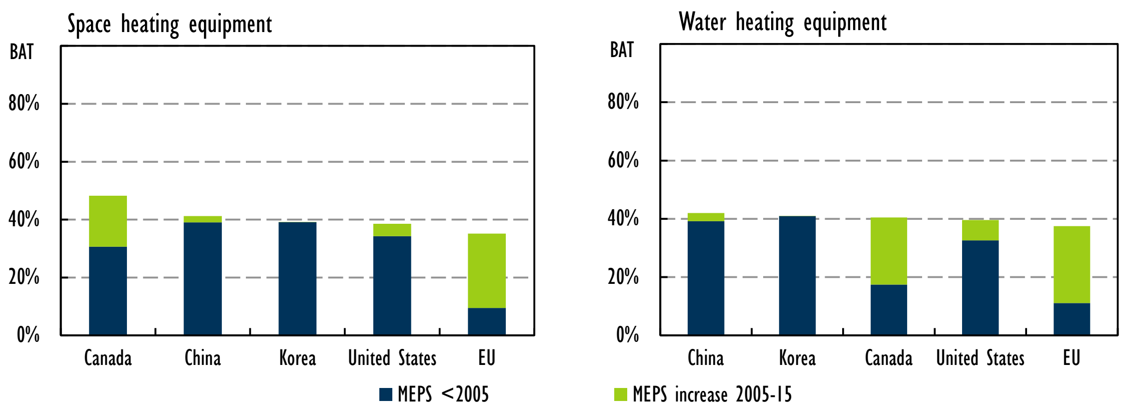
Heating energy use (for both space and water heating) accounted for 50% of total buildings energy consumption in 2015, a decrease from 60% in 1990. This downward trend is a result of improved efficiency standards for buildings and heating equipment.

In terms of standards for space heating equipment, policy makers have made significant performance improvements over the past decade. However, as 50% of the market remains unregulated, significant potential exists to increase efficiency towards BAT performance levels and to cut energy use in half (see Chapter 3). Canada has the highest-performing MEPS for regulated space heating equipment, at 48% of global BAT. In many countries, however, not all heating equipment is regulated by MEPS. When considering regulation coverage across all heating equipment and fuel types, the proximity of existing MEPS to global BAT is significantly lower for countries that allow the purchase of unregulated

[3] The proximity to the BAT is an indicator of the stringency of existing MEPS. The performance level of a specific MEPS is compared with the performance level of the BAT. The percentage difference between the MEPS performance level and the BAT is the proximity.

equipment. This difference in performance levels by regulated equipment is most stark in China (declining from 41% proximity to global BAT to 31% when all fuel types are considered) and Korea (39% to 26%).

Figure 5.5 Heating equipment MEPS for selected countries



Note: Proximity to global BAT for each country is weighted based on the country-specific share of space heating or water heating fuel types over the 2005-15 period. For fuel-based heating, the most efficient boiler or water heater is assumed. For electric space heating or water heating, the most efficient heat pump is chosen. In all cases, only regulated fuel types are included.

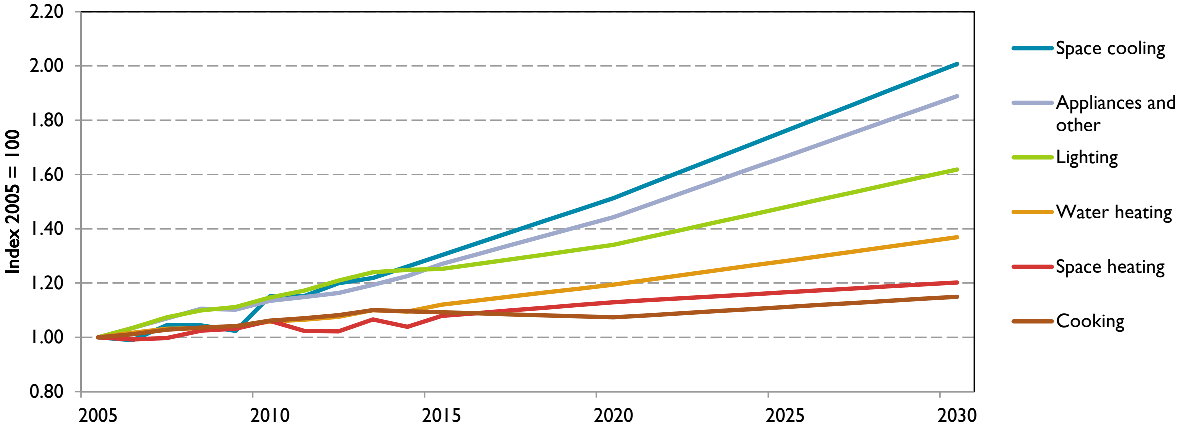
For water heating equipment, the European Union achieved the largest performance increase between 2005 and 2015; its plan to implement new standards in 2017 will continue this trend. By contrast, Korea has not strengthened its MEPS though the performance level is among the highest of countries reviewed. In China and Korea, regulated equipment is relatively close to global BAT, but a significant proportion of unregulated equipment remains in circulation. For China, factoring in non-regulated equipment, the minimum performance of water heating equipment is only 27% of global BAT.

Emerging issues for energy efficient buildings

Global commitments to reduce GHG emissions create major challenges and new opportunities for the building construction and renovation sector. Existing buildings, usually built to much less energy-efficient building codes, will account for 45% of buildings heating and cooling energy demand to 2050. Over the same period, demand for space cooling will rise rapidly as populations and incomes increase in relatively hot regions of the world. These two trends affect member and non-member countries of the Organisation for Economic Co-operation and Development (OECD) very differently. For example, OECD countries are primarily located in climates that have limited space cooling needs and have a high share of buildings that will still exist in 2050. Many non-OECD countries are in climates that are likely to see significant increases in space cooling demand, but new construction dominates through 2050 (Figure 5.6). Thus, there is opportunity to take on the new challenge with more assertive new building energy codes and equipment standards in non-OECD countries.

Another emerging trend in building energy efficiency is the move towards 'zero energy buildings' (ZEBs). Such ZEB policies are in their infancy in most countries and yet USD 15 billion of investment occurred in 2015, including USD 12.5 billion for energy efficiency and 2.5 billion for renewable energy (Navigant, 2015). To achieve global climate targets, policies are needed to integrate energy efficiency and renewable energy investment to achieve ZEBs in new construction although under current market and policy conditions this is not cost-optimal for investors. The European Union currently dominates the market for ZEB construction at more than USD 14 billion (Navigant, 2015); this reflects the enactment of a nearly zero energy building policy framework that prompted recent growth and is expected to stimulate further growth through to 2020.

Figure 5.6 Global buildings sector end-use energy consumption, 2005-30



Sub-sector focus: appliances, equipment and lighting

- **Incremental energy efficiency investment in major appliances, equipment and lighting (products and associated services)[4] was USD 62 billion in 2015.** Total spending on energy efficient appliances, equipment and lighting was USD 150 billion in 2015. Long-term evidence shows product prices falling over the course of successive MEPS.

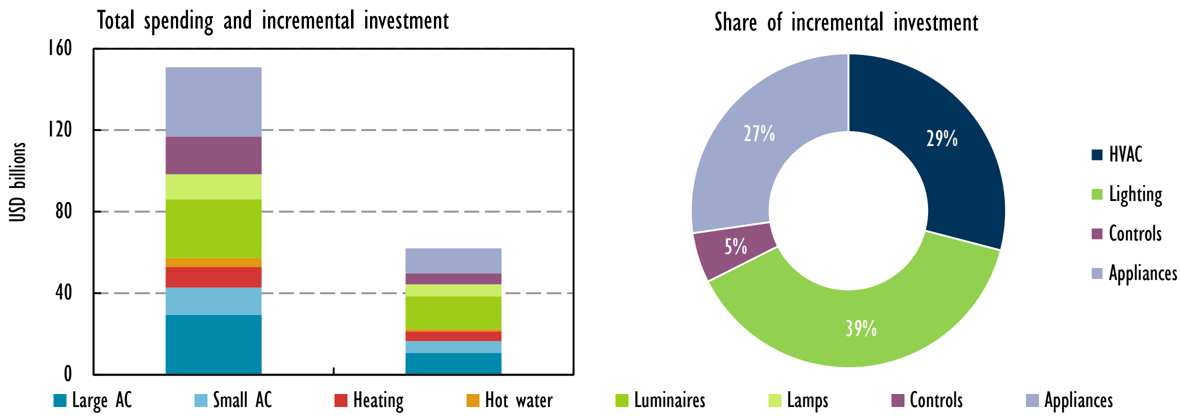
Global market size of energy efficient appliances, equipment and lighting

As with most energy efficiency markets, policy continues to be the main driver of availability, price and sales of energy-efficient appliances, equipment and lighting. Investment in such energy-efficient products continues to grow, ultimately resulting in increased energy savings in both new and existing buildings. Global incremental investment in energy-efficient appliances, equipment and lighting was USD 62 billion in 2015, with total spending of USD 151 billion (Figure 5.7).

Investment in energy-efficient products is evenly spread across three major categories: appliances, HVAC and lighting. Lighting has the largest share (39%) of incremental investment, with the incremental cost of purchasing compact fluorescent lamps, light-emitting diode (LED) light bulbs and luminaires being the main driver. Energy-efficient space cooling, both large and small AC equipment, accounts for the largest share of investment in the HVAC category.

[4] Refrigerators, freezers, washing machines, dishwashers, heating equipment, cooling equipment, water heating equipment and lighting (luminaires and lamps) and controls.

Figure 5.7 Total spending and incremental investment in energy efficient appliances, equipment and lighting, 2015



Note: HVAC includes small air conditioning (AC), large AC, heating and hot water. Lighting includes lamps and luminaires (light fixtures).
Sources: IEA analysis, Navigant Research (2014), IEA 4E Technology Collaboration Programme (Box 5.1).

This special focus on appliances, equipment and lighting was written and analysed in collaboration with the IEA 4E TCP (Box 5.1).

Box 5.1 4E TCP

The 4E TCP has been supporting governments to co-ordinate effective energy efficiency policies since 2008. Twelve countries have joined together under the 4E platform to exchange technical and policy information focused on increasing the production and trade in efficient end-use equipment. The 4E TCP also pools resources and expertise on a wide a range of projects designed to meet the policy needs of participating governments. Participants find that is not only an efficient use of available funds, but results in outcomes that are more comprehensive and authoritative than can be achieved by individual jurisdictions.

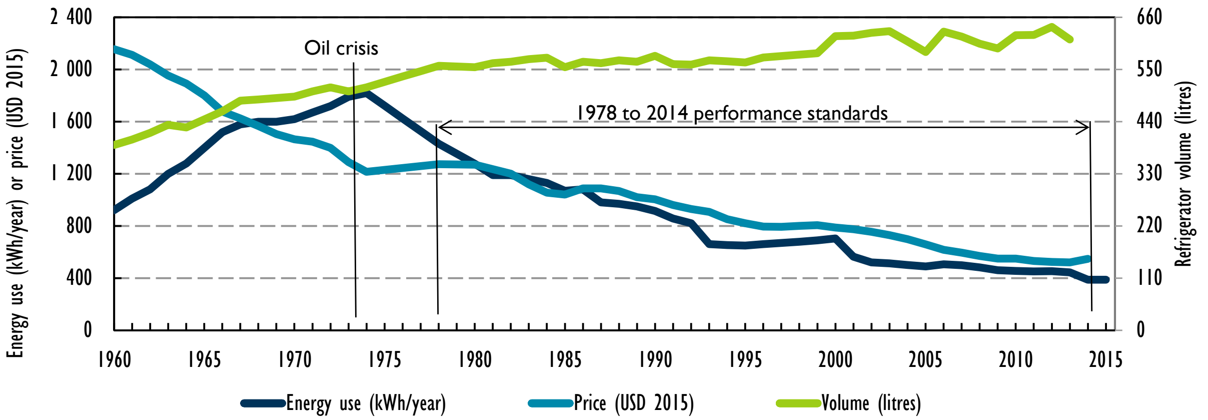
4E TCP is open to membership from all governments. Current members of 4E are: Australia, Austria, Canada, Denmark, France, Japan, Korea, Netherlands, Switzerland, Sweden, the United Kingdom and the United States. Further information on the 4E TCP is available from: www.iea-4e.org

Market trends for energy-efficient appliances, equipment and lighting

Policy is driving the market for increased energy efficiency in appliances, equipment and lighting. The improvement of energy performance standards globally on appliances, equipment and lighting has enabled energy efficiency improvements in the buildings sector that otherwise would have stalled. With the buildings sector energy use dominated by existing buildings, this puts an increasing focus on seeking energy efficiency improvements from the technologies with short lifespans, which have a frequent turnover. These include many of the appliances, equipment and lighting now regulated by MEPS.

Contrary to common perceptions, average appliance prices do not necessarily rise with the introduction of MEPS: other economic and competitive factors have a far greater influence on price trends. When MEPS are in place and the appliance market is stable and fully competitive, long-term evidence shows appliance prices falling substantially and consistently while energy efficiency levels increase. In Mexico for example, refrigerator and air-conditioner prices have stayed flat or decreased since the implementation of MEPS in the 1990s (SEAD, 2015). In the United States, refrigerator prices were falling prior to the introduction in 1978 of appliance efficiency standards and continued to decline through the span of each successive standard (Figure 5.8) (LBNL, 2016).

Figure 5.8 Refrigerator standards, energy use, volume and price in the United States, 1960-2015



Sources: LBNL (2016), LBNL Analysis of AHAM (Association of Home Appliance Manufacturers) Fact Books, Rosenfeld (1999) and Bureau of Labor Statistics, Lawrence Berkeley National Laboratory, Berkeley.

The average efficiency improvement achieved over the past ten years varies by appliance type and across economies, but significant improvements are evident in almost every country that has put in place effective and enforced standards and labelling programmes. Development and implementation of standards seems to have a particularly large impact on the energy efficiency of major appliances. China, the United States and the European Union have achieved increases of more than three times the underlying rate of technology improvement. Where few energy efficiency programmes exist, one-off improvements of more than 30% have been observed when new standards and labelling programmes are first introduced to a market.

Significant scope still exists to strengthen most standards. In the countries participating in the Super-Efficient Equipment and Appliance Deployment Initiative (SEAD),[5] less than one-third of the technical potential savings have been realised so far: just under 20% of the potential in lighting; approximately 50% of the potential in appliances; and 60% of the potential for electric motors and distribution transformers.

The number of countries setting up voluntary and mandatory standards for appliances continues to increase, with refrigerators the best covered, at 75 countries (Table 5.3). Televisions coverage has increased from 21 countries and 41 voluntary measures (standards and labels) in 2004 to 47 countries in 2015 with 135 measures (standards and labels), most of which are mandatory.

The increasing number of standards is reflected in the IEA Efficiency Policy Progress Index (see Chapter 3). China, which has been regulating the efficiency of large appliances since 1989, has the

[5] The members of the Super-Efficient Equipment and Appliance Deployment Initiative (SEAD) are Australia, Brazil, Canada, Chile, the European Commission, Germany, India, Indonesia, Japan, Korea, Mexico, the Russian Federation, South Africa, Sweden, the United Arab Emirates, the United Kingdom and the United States. Japan left SEAD in 2016 but is included for the purposes of this analysis.

highest share (80%) of appliance energy use covered by standards. With much of the coverage already in place in China by 2000, the post-2000 additional policy coverage was limited as use of personal electronics and small appliances grew but the uptake of standards for these devices lagged. The European Union shows the largest growth in the share of appliance energy use covered by standards, from 4% in 2000 to 73% in 2015, due to regulatory efforts made under the Ecodesign Directive.

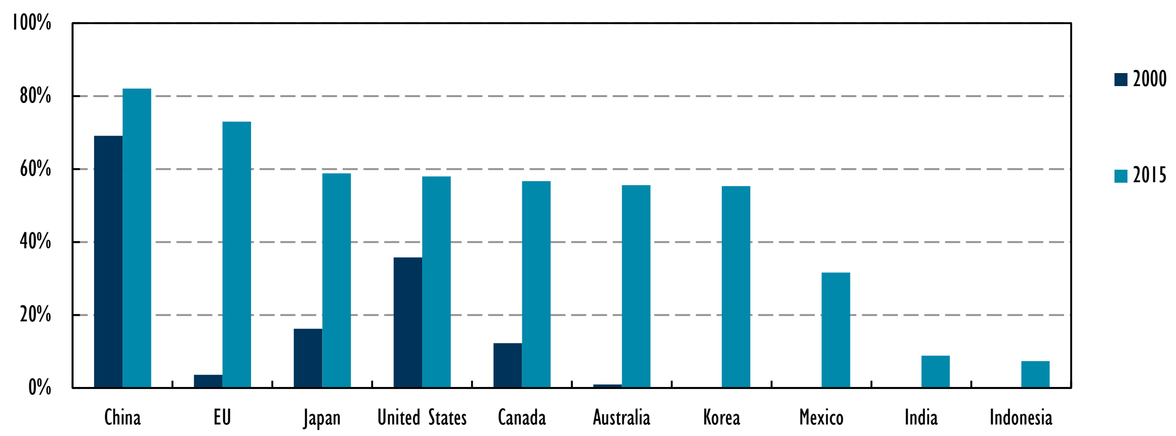
Table 5.3 Most commonly regulated products

Product type	No. of countries regulating	No. of separate standards
Refrigerators	75	185
Room air conditioners	73	152
Lighting lamps or ballasts	67	358
Televisions	47	135

Source: IEA 4E Technology Collaboration Programme.

Average efficiency improvement over the last ten years for new appliances in the major economies includes 16% for refrigerator-freezer energy performance, 21% for washing machines, 23% for room air conditioners and 26% for light bulbs. Energy efficiency improvements to refrigerators, washing equipment and lighting have cumulatively saved 1 250 TWh of electricity demand over the past ten years. Existing standards put in place during the period 2010-14 are projected to avoid energy consumption of 700 TWh of electricity and 560 petajoules (PJ) of oil and gas annually by 2030 for the countries participating in the SEAD initiative. This means that approximately 230 fewer 500 megawatt power plants will be needed in the next 15 years and cumulatively more than 4 gigatonnes of CO_2 will be saved – more than the current annual emissions of the European Union (SEAD, 2016).

Figure 5.9 Appliance energy use covered by standards, 2000 and 2015

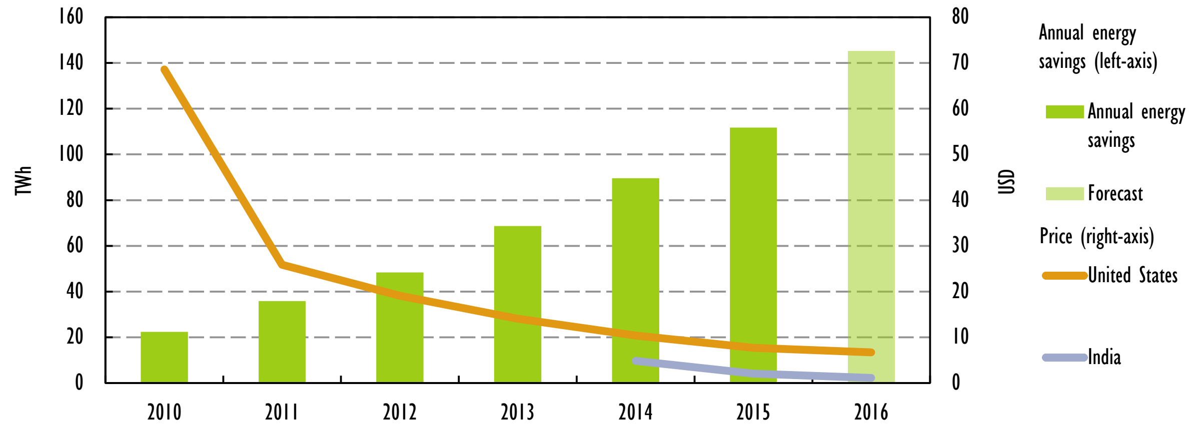


Note: Includes standards for refrigerators, freezers, clothes washing machines, dishwashers, clothes dryers, televisions and computers. Small appliances and electronics are not included. Coverage is weighted by total appliance energy consumption and stock turnover for each product type.

Emerging issues for energy efficient appliances, equipment and lighting

Over the past decade, LED lighting has caused the lighting market to leapfrog regulations with a rapid product adoption rate and increasing energy savings. The cost of LED lightbulbs has dropped steadily over the past five years, increasing their uptake and resulting in annual global energy savings of more than 145 TWh in 2016 (Figure 5.10). While these savings are significant, they represent less than 1% of an additional 1 600 TWh of energy savings in buildings that could be achieved from lighting energy consumption in buildings with full adoption of LED lightbulbs.

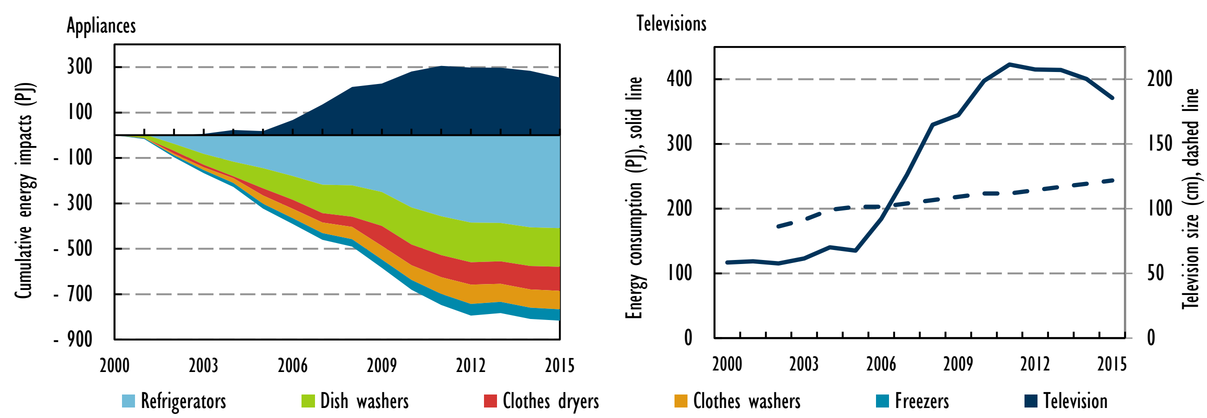
Figure 5.10 LED lightbulb price trend and annual global energy savings, 2010-16



Note: The US price reflects retail cost to the consumer; the LED bulb price in India reflects a bulk procurement price for the Energy Efficiency Services Limited domestic lighting programme. Chart shows savings associated with all LEDs installed since 2009.
Sources: Analysis based on US DOE (2015), communication with EESL India and IEA 4E Technology Collaboration Programme.

Improved energy efficiency of four of the five major appliances has resulted in a net decrease in their energy consumption. Televisions are the exception to this trend (Figure 5.11). A technology shift and resulting lower TV prices enabled higher TV ownership and a growth in screen size such that energy consumption trends outpaced the energy savings from efficiency gains from 1990 to 2011. An encouraging flattening and decreasing energy consumption trend since 2011 is seen with the emergence of LED-lit televisions, another benefit of LED lighting technology improvements.

Figure 5.11 Global energy consumption trends by appliance type, 2000-15



Sources: Television size data from CNET and Statista.

Industry

- **Incremental energy efficiency investment in the industry sector was USD 39 billion in 2015.** Spending on industrial energy management, which enables energy savings beyond efficient equipment improvements is estimated at USD 14 billion.

Global market size of energy efficiency in industry

Using technology cost curves for energy efficiency measures and bottom-up investment data, global incremental energy efficiency investment in industry is estimated to have been USD 39 billion in 2015. This comprises USD 20 billion of investment in non-energy-intensive industry and USD 19 billion of investment in energy-intensive industry. International climate change goals imply that USD 35 billion of annual energy efficiency investment in energy-intensive industry is needed by 2020, an 84% increase from current levels (IEA, 2015).

Energy efficiency spending in industrial energy management is estimated at USD 14 billion in 2015 (Navigant, 2016). Investment in industry energy efficiency in China, largely through EPCs with ESCOs, was more than USD 8 billion in 2015.[6] The Clean Development Mechanism (CDM) has enabled USD 10 billion of investment in energy efficiency in industry over the last ten years (UNEP DTU Partnership, 2016).

The largest share of industrial electricity energy use is for the operation of electric motor systems. Nearly 90% of motors sold globally are covered by MEPS, which continue to be reviewed for improved energy efficiency (IEA, *forthcoming*). While MEPS have good global coverage, significant energy savings potential still exists from investment in energy-efficient motor technologies. In 2015, investment in industrial motor technology is estimated to have been USD 8.5 billion. Further investigations of electric motor-drive systems is included in a special focus on motors in the IEA *World Energy Outlook 2016*.

Market trends for energy efficient industry

Thanks to energy efficiency investment in the industry sector during the first four years of China's 12th Five Year Plan (FYP) (2010-14), energy consumption per unit of industrial output has decreased across a number of key sectors (Table 5.4). Energy consumption has been reduced by 26% per unit of cement and 3.4% per unit of crude steel. Significant energy savings were also achieved for plate glass (21%), caustic soda (18.4%) and other industries. Compared to industrial energy intensities in 2010, activities through 2014 have saved around 4 815 PJ of industrial energy consumption across 11 key industrial products. The reduction of industrial energy intensity generated savings in energy expenditures of USD 18 billion in 2014,[7] split between avoided costs in thermal power generation (USD 6.9 billion) and savings in the manufacturing sector (USD 10.9 billion). These savings represent a significant return on investment: one year of energy savings in industry equalled 48% of the government funding for energy conservation in all sectors during the first four years of the 12th FYP.

[6] For more information on EPCs and ESCOs see Chapter 6.

[7] Assuming an average energy price of USD 4 550 per GJ; based on a price of RMB 525 (USD 84) per 5.5 kilocalories of coal at the end of 2014.

Industrial excess heat, a common by-product of many heavy industries, is still a relatively untapped energy source that, through heat recovery, could be used for other processes. Excess heat should be reduced or captured and reused as much as possible within an efficient industrial process. Both the European Union and China are giving more attention to industrial excess heat that is currently wasted, particularly as feedstock for district heating systems. In China, 55% of national excess heat potential, mostly high- and medium-grade heat, is already being recycled for energy generation or on-site industrial processes. Projects are now under way to recover industrial low-grade excess heat to district heating networks that supply much of the heating in northern China. The use of excess heat depends on the temperature and quantity of heat. High-grade heat can be used for industrial or power generation processes; lower-grade heat may only be useful for heating or pre-heating other processes (such as space heating or water heating). This creates the possibility of a flow of reuse, with high-grade excess heat recovered and reused more economically within an industrial process and the resulting low-grade excess heat used in a district heating network. In China alone, 3 EJ per year of industrial excess heat is currently untapped, ranging from low-grade to high-grade temperatures; if captured and used in district heating systems, it could meet half of China's building heating demand (Tsinghua University, 2015).

Table 5.4 Energy intensity improvements and energy expenditure savings for industry in China

Sector output	Energy intensity improvement (2010-14)	Annual energy cost savings (USD millions)
Cement	7.5%	7 547
Thermal power	4.5%	6 905
Raw steel	3.4%	1 815
Aluminium oxide	10.6%	358
Plate glass	21.0%	322
Crude oil refining	11.0%	265
Caustic soda	18.4%	249
Ethylene	9.0%	150
Synthetic ammonia	1.7%	143
Sodium carbonate	4.5%	41
Calcium carbide	0.8%	21
Total		**17 825**

Sources: China ERI (2016) analysis of Ministry of Industry and Information; Industrial associations; State Statistics Bureau, *China Statistical Yearbook 2015*; emerging issues for energy efficient industry.

Transport

- **Incremental energy efficiency investment in transport is estimated to total USD 64 billion in 2015.** Passenger vehicle energy efficiency investment was USD 35 billion, freight transport was USD 2 billion and other transport received USD 28 billion.

Efficiency in the transport sector, in the broadest sense, is about moving people or goods to where they need to go while minimising the amount of energy needed to do so. Under this definition, efficiency can be improved, for example, by investing in infrastructure to move people by a less energy-intensive mode (such as rail rather than road), by investing in fleet management logistics (such as improving load factors in commercial aviation) or by increasing the efficiency of vehicles.

This section focuses on investments in energy-efficient LDVs. More than 88 million road vehicles were sold worldwide in 2015, with the highest share being LDVs used predominantly by passengers and for commercial purposes (e.g. taxi and delivery services). At 75% of transport final energy consumption, road vehicles dominate the sector. The method to quantify investment in energy efficient LDVs is explained in Box 5.2.

Box 5.2 Quantifying investment in the transport sector

To quantify the investment in transport efficiency, the price of energy efficient vehicles (defined as the top 25% of sales ranked by fuel efficiency) is compared with the average price of all vehicles. For improved accuracy, the vehicles market is broken down along two lines: vehicle size and vehicle power. Price comparisons are done only between vehicles having the same size *and* power rating. This ensures that small, low-power cars, which are typically more efficient and generally cheaper, are not compared with trucks, which are often less efficient, more powerful and more expensive.

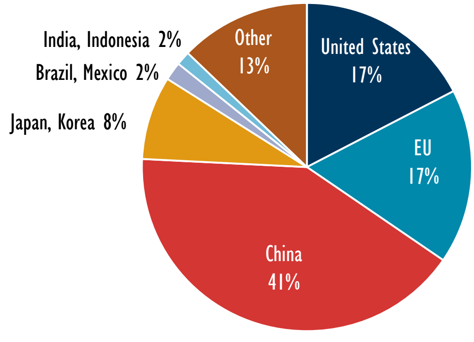
The incremental efficiency investment is quantified by calculating the sales-weighted average price of the top 25% efficient vehicle models in each class-power category and then comparing that price to the average sales-weighted price of all vehicles in each size-power category by country. The average price difference for efficient vehicles is multiplied by the sales numbers of efficient vehicles.

For other vehicle types including freight vehicles, rail, aviation and marine shipping - data on efficiency rating and sales are limited. As a result, it is not possible to carry out the same detailed analysis as conducted for LDVs. For these markets, investment is estimated by calculating the change in the energy intensity of different modes of travel by region and then using a cost-curve of efficient technologies to estimate the investments required to produce the improvements in energy intensity

Investment in energy efficient light-duty vehicles

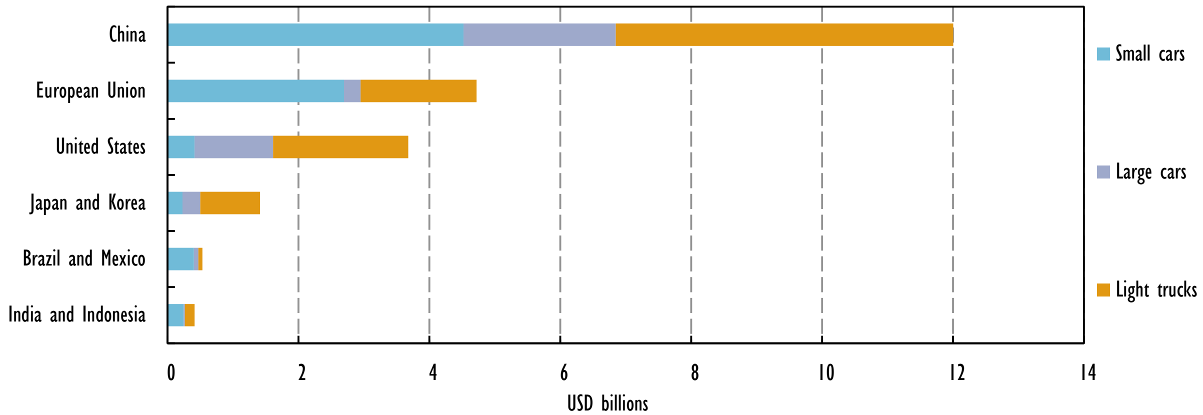
Total spending on energy efficient LDVs was USD 330 billion in 2015, approximately 20% of spending on all LDVs. Incremental investment in efficient LDVs was USD 34 billion, up 3% from 2014. Government investment in energy efficient LDVs includes over USD 4 billion in financial incentives. Over 75% of investment was in three major economies: the United States, the European Union and China (Figure 5.12).

Figure 5.12 Incremental investment in LDV efficiency by region, 2015



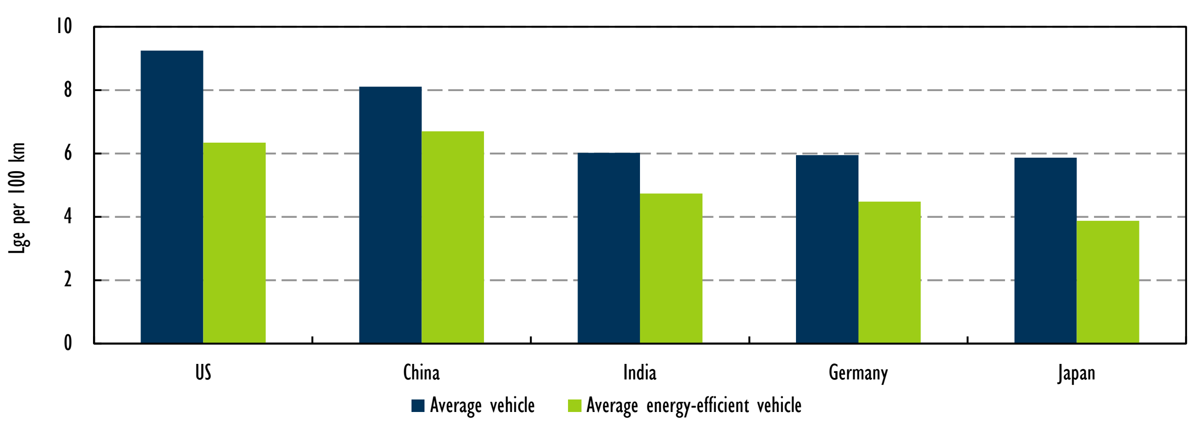
The distribution of investment in efficiency across vehicle classes varies by country. In China, investment is evenly distributed among small cars, large cars, and light trucks (Figure 5.13). In the United States, large cars and light trucks attracted the most investment, whereas in the European Union investment was highest in small cars.

Figure 5.13 Incremental efficiency investment by vehicle type by region, 2015



The degree to which energy-efficient vehicles are, on average, more efficient than average vehicles varies by country: 34% in Japan, 31% in the United States, 25% in Germany, 21% in India and 17% in China (Figure 5.14). Notably, Japan had the most efficient average vehicles and the largest performance gap between average and most efficient vehicles. On average, energy-efficient vehicles sold in the United States had lower efficiency than the average new vehicle in India, Germany and Japan. China had the smallest gap in performance between average and efficient vehicles. From an energy savings perspective, oil consumption in the road transport sector would have been 160 000 bbl/d higher if the energy-efficient vehicles sold in 2015 were hypothetically replaced by average vehicles. This amount represents 0.4% of global road transport oil consumption, which is similar to the oil consumption of New Zealand in 2015. This amount of savings might seem small, but total energy savings over the lifetime of this fleet of efficient vehicles add up to approximately one billion barrels of oil, similar to the combined publicly held oil stocks of the United States and Europe.

Figure 5.14 Fuel economy of new average vehicle and new energy efficient LDVs, 2015

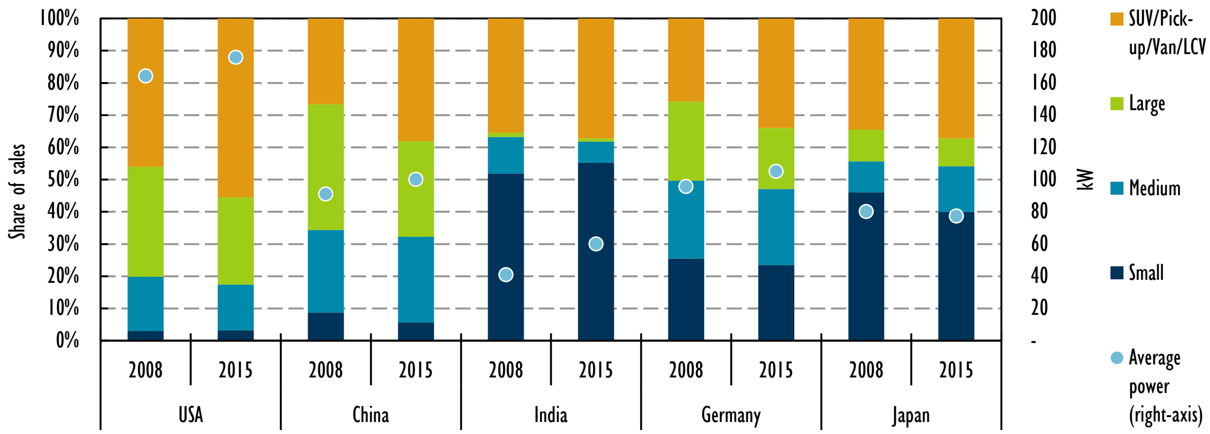


Notes: Lge = litres of gasoline-equivalent; km = kilometre. Energy-efficient vehicles are defined as the top 25% of sales ordered by model energy efficiency rating.

The presence or absence of financial incentives and the state of the economy influence the power and fuel economy of vehicle stocks in a given country. In the United States, where a premium market has few monetary incentives for fuel economy improvements (i.e. fuel taxes or higher registration fees for higher-emitting cars), the market is dominated by large, inefficient, high-powered vehicles (Figure 5.15). In contrast, Japan is an example of a premium market with financial incentives and where the market is dominated by smaller, medium-powered, more efficient vehicles. In emerging markets, where consumers are more sensitive to fuel prices or regulatory measures are in place, small, low-powered vehicles are more common. Over time, developing markets tend towards larger and more powerful vehicles – as has been the trend in China.

Other significant investments in energy efficiency in the transport sector are underway, including rail, public transport, aviation and nautical transport investment. In 2015, investment in energy efficiency in these sectors was USD 30 billion. This does not include other infrastructure investments that improve the efficiency of the transport sector.

Figure 5.15 Market share by vehicle power in selected countries, 2008 and 2015



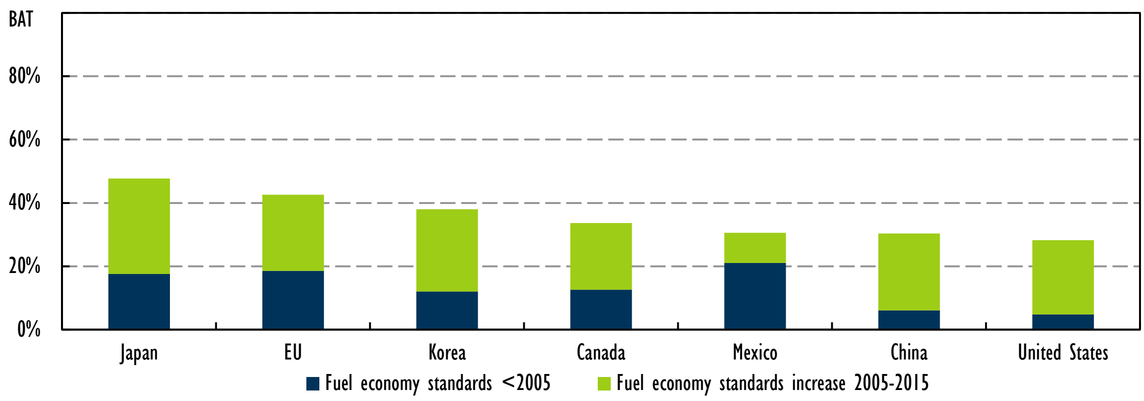
Note: kW = kilowatts; SUV = sport utility vehicle; LCV = light commercial vehicle.

Market trends for energy efficient transport

The average performance level of vehicle standards for passenger and commercial LDVs has increased by 20% to 25% across countries with vehicle fuel economy standards over the past ten years. While standards have effectively removed vehicles with low fuel economies, a fleet of new vehicles adhering to 2015 standards would still be on average only 33% as efficient as a BAT fleet. However, BATs are not necessarily available in every market, and market conditions such as low fuel prices and high vehicle costs still limit the cost-effectiveness of the most efficient vehicles.

Japan has implemented the most aggressive performance improvement. Average new Japanese vehicles are almost 50% as efficient as the most efficient vehicles available. While overall performance in the United States and the European Union has changed by a similar degree, new European vehicle standards are more efficient. In the United States, standards result in the fleet average being less than 30% as efficient as a BAT fleet (Figure 5.16).

Figure 5.16 Performance level increases of vehicle fuel economies by country, 2005-15

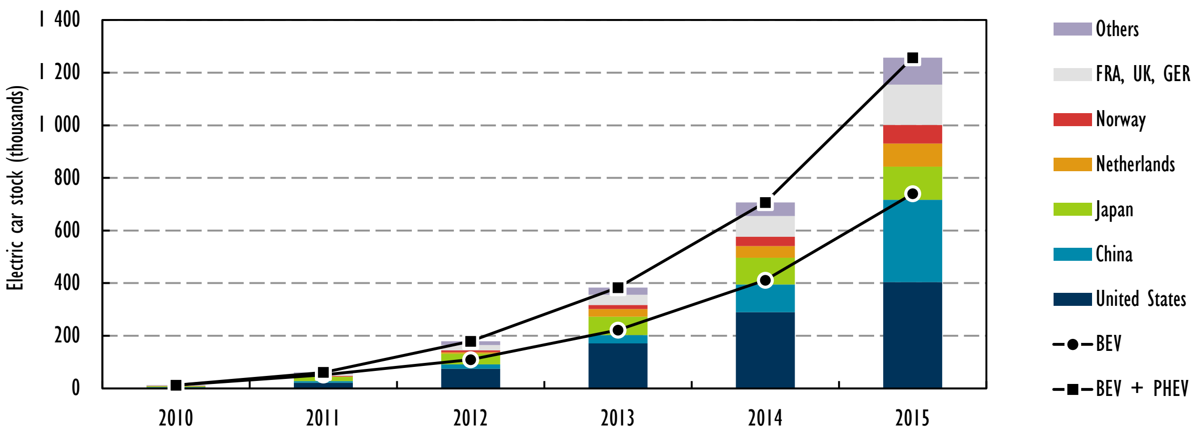


Note: The weighted fuel economy of a 2005, 2015 and BAT fleet is generated by multiplying fuel economy standards or BAT for each vehicle class by the average proportion of that class of vehicles purchased in the country over the period 2005-15. The BAT for passenger cars is the Nissan Leaf, for light-duty trucks the Tesla Model X. For light commercial vehicles, the BAT is the average based on the country-specific vehicle class mix of Ford Fiesta (small van), Ford Transit-Connect (medium van), and Renault Trafic (large van).

Electrification of LDVs driving additional energy savings and investment in transport

A significant portion of future transport energy savings and efficiency investment will be associated with the increasing market share of EVs in passenger LDVs. In 2015, the stock of EVs (including plug-in hybrid EVs [PHEVs] and battery EVs [BEVs]) rose above the 1 million mark to a total of 1.26 million (Figure 5.17). Over 550 000 EVs were sold in 2015. China emerged as the largest EV market, with more sales than the United States for the first time. The largest EV shares in the total vehicle stock are in Norway (23%) and the Netherlands (10%). Globally, 2015 saw the highest sales of EVs, up 70% from new sales in 2014.

Figure 5.17 Stock of electric vehicles in selected countries, 2010-15



Notes: FRA = France; UK = United Kingdom; GER = Germany; BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle.
Source: IEA (2016c), *Global EV Outlook 2016: Beyond One Million Electric Cars.*

The fleet of EV sales in 2015 is estimated to save over 33 million barrels of oil consumption over their lifetime. However, this represents a tiny portion of current oil consumption. Oil savings from EVs sold in 2015 were 0.01% of global oil consumption in the transport sector in 2015. Yet EVs remain a critical technology to reduce GHG emissions. In IEA scenarios that achieve climate change goals, there will need to be 140 million EVs on the road by 2030 (IEA, 2016c).

Policy is a major driver of the growth in EV sales. Broadly, policies include consumer incentives that make EVs more affordable and regulations on manufacturers that make non-EVs less profitable to sell. The Netherlands, for example, offers tax exemptions for owners of EVs. In California, the state's zero-emission vehicle standards will require 25% of all vehicles sold by a particular car company to have zero tailpipe emissions by 2025.

6. THE MARKET FOR ENERGY EFFICIENCY SERVICES

Highlights

- **A burgeoning market exists for energy efficiency services, in which energy efficiency trades almost as a commodity that is bought and sold.** Dedicated energy service companies (ESCOs) alone represented a market of 24 billion United States dollars (USD) in 2015. In the People's Republic of China (hereafter "China"), ESCO revenues were USD 13.3 billion, in the United States (US) USD 6.3 billion, and in the European Union (EU) USD 2.7 billion.
- **Policy contributes to supporting and shaping the energy efficiency services market, with particular progress seen in China, India and the United States.** The size and nature of the market (in terms of, for example, preferred contract structure and sector) are influenced by both framework policies and direct financial support. In the United States, policy has led to a focus on public buildings using the ESCO model. In China, the ESCO market has grown rapidly as a result of policy and subsidies set out over successive Five-Year Plans (FYPs). India has a state-backed ESCO, which is helping to drive efficient lighting solutions.
- **Three broad trends point to further growth of the energy efficiency services market: mergers and acquisitions activity, new technologies, and innovative utility business models.** The number of acquisitions is rising, with more than 50% initiated by companies that were not previously in the energy efficiency services market.
- **Investors are showing strong interest in "green" bonds, which often have a large component of energy efficiency services.** Green bonds grew to USD 42 billion in 2015, with energy efficiency attracting the second-largest investment (20%) after renewable energy (46%). Recent trends in standardisation and climate finance may prompt further growth.

Introduction

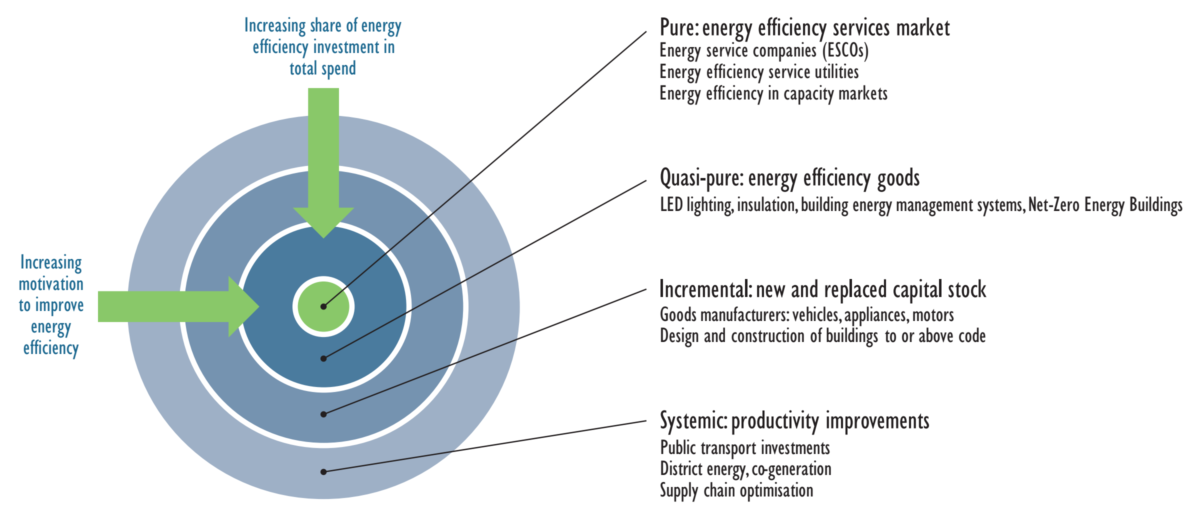
The energy efficiency services market is rapidly developing, with energy efficiency being bought and sold much like a commodity. The markets are more developed in some places, such as China, the United States and the European Union. India's model of an ESCO market that is mainly government-driven has developed as well. Furthermore, growing interest in green financial products represents an important opportunity to channel even more funding toward energy efficiency.

This chapter examines the energy efficiency services market in detail, particularly its potential to unlock large amounts of energy efficiency investment. Policy could play a role in strengthening the nascent market through more expansive and more aggressive targets for climate finance, efforts to standardise green bonds, in general, and boosting energy efficiency investments in particular.

The market for energy efficiency services

In terms of the motivations of the actors involved, the market for energy efficiency services is close to being "pure". It brings together companies that sell comprehensive service packages to improve energy efficiency and customers willing to pay to improve their energy efficiency. The services are often marketed with reference to other benefits of such investment, but as the motivation to improve energy efficiency increases – and the share of spending on actual energy efficiency increases – the market becomes increasingly pure (Figure 6.1). This analysis focuses on this pure market to provide a more reliable assessment of the specific market factors affecting energy efficiency investment.

Figure 6.1 Energy efficiency services in the broader energy efficiency market



Note: LED = light-emitting diode.

Business models in this pure market vary across countries, reflecting differences in national markets and policy contexts. A common denominator is delivering energy services to clients while reducing energy consumption and thus energy bills. This aspect is supported by energy performance contracts (EPCs) in which the service providers are repaid for the work carried out by the energy bill savings such work delivers to clients. Around 70% of ESCO revenue in the United States was generated through EPCs in 2011 (Stuart et al., 2014). Market actors include energy efficiency consulting firms, equipment installers and others.

Energy savings can also be monetised in capacity markets, carbon markets or energy savings markets through energy efficiency obligation (EEO) schemes. Until recently, such schemes have focused mostly on clients with large energy bills and large project sizes in order to achieve economies of scale. Different types of EPC contracts exist, depending on local conditions. For example, either shared savings or guaranteed savings can be agreed between the ESCO and the customer. In France, the dominant form is the heat supply contract (*chauffage*).

A distinct and important group in efficiency markets are ESCOs, which typically provide energy efficiency services paid for by an EPC guaranteeing either energy or monetary savings. While traditional energy savings are at the heart of ESCO activity, they usually try to bundle diverse services (such as technical solutions and financing) for their customers. In some cases, the service package may include measures not related to energy at all. Given their readily identifiable nature and potential to stimulate the pure energy efficiency market, this chapter investigates ESCOs in depth (excluding those lacking a clear energy efficiency orientation).

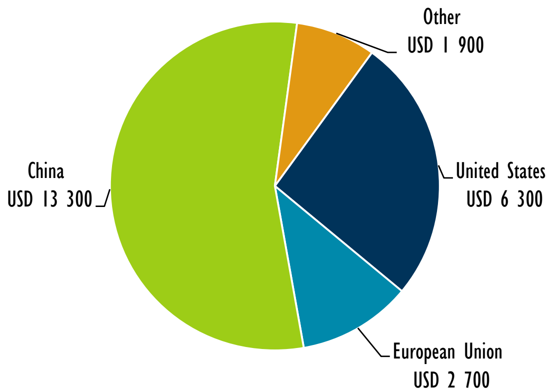
The performance component of the ESCO model is a major advantage as it creates an economic incentive to deliver energy savings; this ensures the investment is made while relieving the customer of the burden of paying up-front costs. Notwithstanding this, EPCs do have transaction costs and further contractual requirements, as savings have to be verified and ESCO services paid for. In some circumstances, ESCOs – as economically motivated actors seeking to run a profitable business – may tackle only simple, low-cost actions and avoid more complicated measures or deeper retrofits. Strong and targeted policy and market maturity may mitigate that risk. Recently, for example, some ESCOs have begun to offer even more comprehensive services encompassing building operations, maintenance and facility management in order to promote behavioural and cultural change at the individual, group and organisational levels to explore new business opportunities in mature markets. The range of expertise that ESCOs bring to a project provides a strong case for contracting them rather than trying to achieve similar energy savings using in-house teams.

Size of the global ESCO market

The global ESCO market was valued at about USD 24 billion in 2015 (Figure 6.2). China has the world's largest market at more than USD 13.3 billion in revenue from EPCs in 2015, followed by the United States at USD 6.3 billion. The ESCO market in the European Union generated USD 2.7 billion in the same year (Navigant Research, 2015).[1]

[1] For China, the value of EPCs signed every single year as reported by EMCA (2015) was spread over four years. The results were added up to create a yearly average to make ESCO revenues comparable to the method used for the United States and the European Union. Note however that Zhao (2016) indicates that cash flow may not be even over the term of an EPC, which can vary between five and 20 years and that 80% of the revenue is usually achieved within the first three years.

Figure 6.2 ESCO revenue by region, 2015, USD billion



Sources: EMCA (2015), "ESCO Development in China – drivers and barriers", presentation, IEA workshop; JRC (2014a), *ESCO Market Report for Non-European Countries 2013*; Navigant Research (2015), *Energy Service Company Market Overview: Expanding ESCO Opportunities in the United States and Europe*.

As China accounts for 55% of worldwide ESCO revenues – and showed 7% growth during in 2015 – it has the strongest impact on future market growth. Future economic growth will also influence the global outlook for energy efficiency services markets. The second-largest energy efficiency services market in the world, the United States, is projected to grow steadily at 7% per year until 2024 (Navigant Research, 2015).

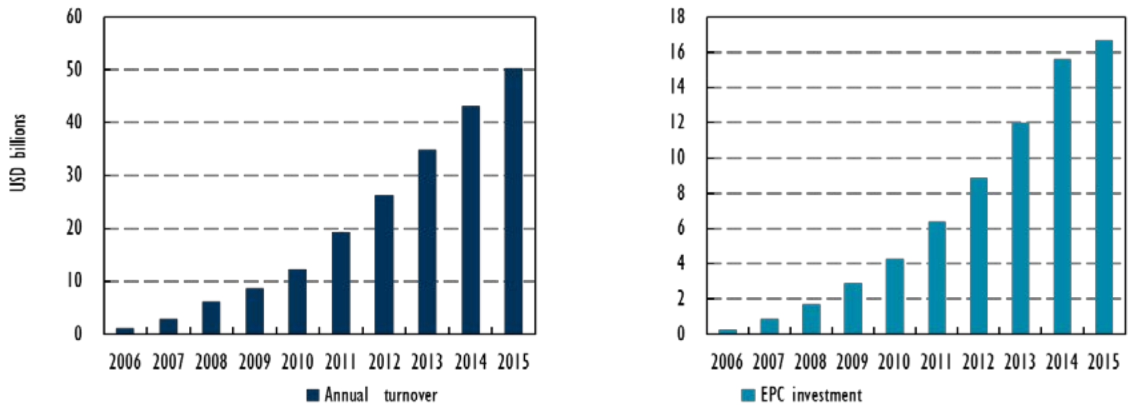
While the market is expected to continue growing, plans in some countries to phase out subsidies and tax breaks (while maintaining regional programmes) may reduce the growth rate. Large markets remain untapped, creating market opportunities for new business entrants. The energy efficiency improvements required to meet international climate change commitments may also contribute to continued expansion of ESCO markets around the world.

Energy efficiency services market in China

In China, ESCOs have been critical not only to achieving energy savings for the economy as a whole but also as a sector of the economy in their own right. In 2015, 5 426 ESCOs exist across the country, some 300 more than in 2014 (Zhao, 2016). These ESCOs employed 607 000 people, an 8% increase compared with 2014. Over the previous five years, the number of ESCOs increased sevenfold (in 2010, only 787 ESCOs were registered). At the same time, EPCs signed grew by 7% in 2015 (Figure 6.3).

Policy is an important driver of this growth as energy intensity improvements are central to China's 11th (2006-10) and 12th (2011-15) FYPs. The ESCO model, which China has been developing over two decades, has a prominent place in this strategy and its success has become more widely noted. In 2013, Chinese ESCOs generated annualised energy savings of 17 million tonnes of oil equivalent (Mtoe) (IEA, 2014). The savings from ESCO activities in that year account for approximately one-third of the targeted average annual savings of the 12th FYP (235 Mtoe between 2011 and 2016, or average annual savings of 46 Mtoe).

Figure 6.3 Turnover and EPC investment in the ESCO market in China



Source: EMCA (2015), "ESCO Development in China – drivers and barriers", presentation, IEA workshop; Zhao, L. (2016), personal communication.

The main business model for ESCOs in China is EPCs. One determining reason for choosing EPCs is policy, as significant national-level subsidies are typically awarded based on performance (municipal governments may add further subsidies). Also, EPCs benefit from preferential tax treatment, with income being exempted for the first three years and taxed at a lower rate for three years following. China plans to phase out the national-level subsidy in the coming years. Local municipal governments, however, continue to provide financial incentives, access and solutions for ESCOs. Various international donors and financial institutions also continue to support development of the Chinese market. As EPCs favour larger-scale projects, most projects are in the industry sector: 50% by number of projects, 70% by total investment (JRC, 2014b). The buildings sector has been second-largest, but a shift is evident with buildings gradually increasing and industry decreasing.

Energy efficiency services market in the United States

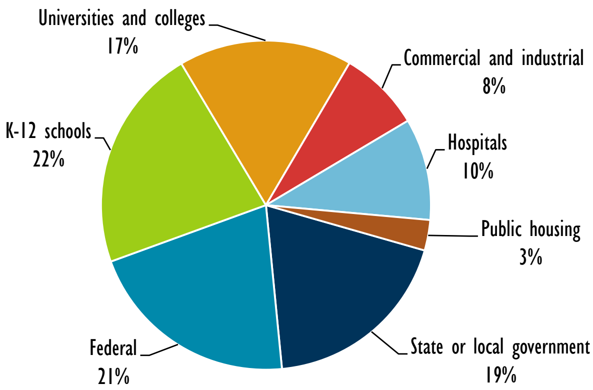
The energy efficiency services market in the United States has grown significantly in the past decade. In 2012, it saved about 34 terawatt-hours of electricity, representing 2.5% of total commercial and institutional electricity consumption (Carvallo, Larsen and Goldman, 2015).[2] ESCO revenues were an estimated USD 6.3 billion in 2015 (Navigant Research, 2015), more than double the USD 2.5 billion in 2004 (Stuart et al., 2014).

Evidence suggests that policy and funding are as important in shaping the ESCO market as customer demand in itself. The dominant share of the ESCO market (more than 80% of clients and 90% of revenues for ESCOs) is made up of the public and institutional sector (Stuart et al., 2014) (Figure 6.4). This can partly be explained by strong federal policy and funding. The American Reinvestment and Recovery Act, which entered into force in 2009, provided financial support for energy efficiency measures in public facilities. While this financing did not have to be channelled through ESCOs, the ESCO business model benefited. In 2011, the presidential memorandum "Implementation of Energy Savings Projects and Performance-Based Contracting for Energy Savings" earmarked a minimum of USD 2 billion in EPCs for federal buildings and was focused on the ESCO business model. The initiative

[2] The institutional consumption is understood as municipalities, universities, schools, and hospitals.

called for energy conservation measures with a payback period of ten years or less. In 2015, Executive Order 13693 set out future plans requiring an annual 2.5% improvement in the energy intensity of federal buildings over the period 2015 to 2025. It identified EPCs as the key delivery mechanism. Consequently, the energy efficiency services market for public buildings (municipalities, universities, schools and hospitals) has been growing particularly strongly since 2008. The average term of an EPC is 17 years (Navigant Research, 2015).

Figure 6.4 ESCO revenues in the United States by customer type



Note: K-12 = primary and secondary school.
Source: Navigant Research (2015), *Energy Service Company Market Overview: Expanding ESCO Opportunities in the United States and Europe*.

In addition to federal policy, 43 US states have implemented programmes to promote ESCOs and EPCs. In California, the Energy Commission has led efforts in building efficiency standards and increased energy efficiency in new commercial facilities by 30%. In addition, many utilities continue to support investment in energy efficiency building upgrades. Municipalities can also help improve the market environment. Chicago, for example, has set a goal to retrofit 50% of the city's commercial and industrial buildings by 2020.

In the United States, ESCOs focus primarily on efficiency improvements in public buildings (municipalities, universities, schools and hospitals) (Figure 6.4). In 2015, over 90% of ESCO revenues in the United States stemmed from government contracts; commercial and industrial clients accounted for only 8% (Navigant Research, 2015). The majority of the contract work was to replace building heating and cooling equipment with more efficient technologies.

EEOs, sometimes known as demand-side management or energy efficiency programmes for utilities, also contribute to developing an ESCO market in the United States. In 2012, 38% of public-sector ESCO projects used incentives funded ultimately by the utility customer, mostly through obligations (Carvallo, Larsen and Goldman, 2015).

Energy efficiency services market in the European Union

In the European Union, ESCO revenues were USD 2.7 billion in 2015 (Navigant Research, 2015). In European markets, EPCs are a relatively recent development. More popular are energy supply contracts (ESCs) and heat supply contracts that sell units of heat or steam. This has contextual and historical reasons, partly due to policy decisions, that still influence the market today. Favourable and standardised regulation for public procurement has translated into a concentration of the energy efficiency services market on these kinds of projects.

One of the main policy drivers for market growth in the European Union is the 2012 Energy Efficiency Directive (EED), which sets a target of 20% less energy consumption by 2020 compared with the projected reference level. Article 18 of the EED aims to develop the ESCO market in Europe and sets a standard definition for ESCOs for all EU countries. The EED also stimulates development of the ESCO market through two articles in particular: i) Article 7 requires member states to establish EEOs for certain designated businesses (or propose an alternative); and ii) Article 5 establishes mandatory saving targets per unit of floor area for public buildings.

Energy efficiency services market in India

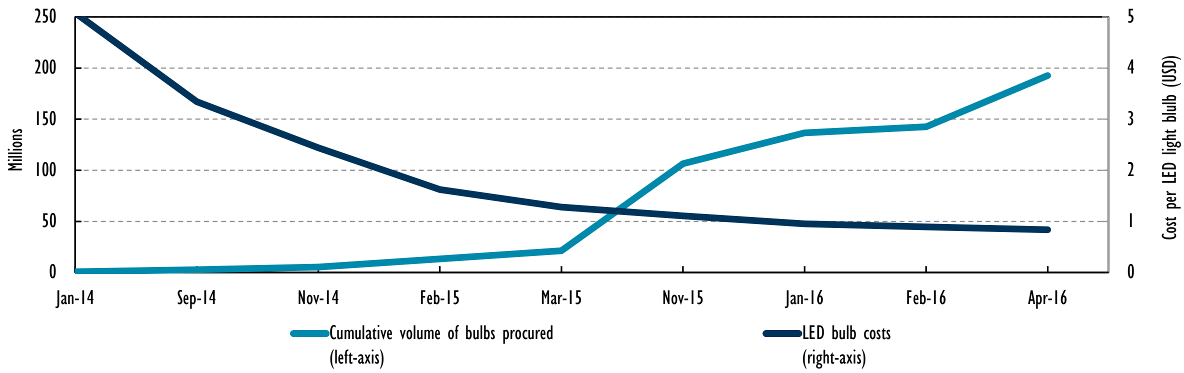
Policy in India has helped create a super-ESCO, known as Energy Efficiency Services Limited (EESL), which is a joint venture of four state-owned companies: Power Grid, National Thermal Power Corporation Ltd., Rural Electrification Corporation Ltd. and the Power Finance Corporation Ltd. Established in 2010 by the Ministry of Power, EESL has an authorised share capital of USD 80 million (EESL, 2016a).

While EESL carries out a wide range of energy efficiency service projects at both national and state levels, its major focus has been lighting, which represents 10% to 15% of India's electricity consumption. Replacing existing inefficient lighting could halve this demand (IEA, 2015). EESL is helping customers to move from incandescent bulbs and compact fluorescent lamps (CFL) to LEDs. By April 2016, a total of 14 states and 120 cities had enrolled in the programme, resulting in the creation of approximately 30 000 direct temporary jobs in order to distribute the LEDs to consumers. By the end of 2015, a total of 100 million LEDs had been distributed to 25 million households, achieving important progress toward the overall target of replacing 770 million incandescent bulbs with LEDs by 2019 (EESL, 2016b).

The policy signal combined with public bulk procurement (through EESL) of growing volumes of LEDs have helped to drive down the cost per LED bulb by 80% in just two years – wholesale prices fell from USD 4.60 in January 2014 to USD 0.80 in April 2016 (supported by a general reduction in LED prices) (Figure 6.5). In January 2014, EESL procured 750 000 LEDs. The peak purchase, in November 2015, was 85.2 million LEDs. In parallel, retail market prices of LEDs have declined to less than USD 3.70, substantially lower than European retail prices (but still above prices achieved in the public procurement process) (EESL, 2015). The aim is to bring the retail market price of LEDs below the current CFL price of approximately USD 1.50. To date, the total cost of procuring all these bulbs is USD 200 million, representing a significant investment.

Another landmark programme aims to replace 35 million street lights in cities across India. By December 2015, EESL had replaced 440 000 street lights in 100 cities with estimated annual energy savings of 112 gigawatt-hours and peak load reduction of 18.6 megawatts (EESL, 2015), representing approximately USD 11.7 million in cost savings for municipalities. Building on the success in its domestic market, EESL is now looking to expand the model to other appliances and other emerging economies.

Figure 6.5 Price per LED bulb and volumes procured for the EESL lighting replacement programme, 2014-16



Source: EESL (2015), "Scaling up Energy Efficiency in India", presentation by Saurubh Kumar; EESL, (2016c), personal communication.

Policies shape the energy efficiency services market

As described in the previous section, different business models and contract types have evolved in different regions and countries, at least partly due to policy and regulatory environments (Table 6.1). In the case of the Chinese ESCO market, subsidies and tax incentives prompted significant growth. The presidential memorandum and executive order in the United States prompted ESCOs to focus on public building retrofits. Likewise, public procurement, with services provided by EESL, strengthened the LED market in India. Clearly, governments can play a key role in expanding the energy efficiency services market. Past policies are in part responsible for the markets seen to date, though socio-economic and cultural factors are also important.

Table 6.1 ESCO market characteristics by country

Country	Policy and programmes	Market concentration	Dominant contract type
China	Initial World Bank funding for EPCs, tax incentives and subsidies, FYPs	Industry and buildings	EPC (shared and guaranteed savings), outsourcing contracts
France	Delegation of water/heat supply in the past, strict standardisation of public procurement for chauffage contracts, Grenelle law targets reduction of energy consumption in buildings, energy transition law, white certificates scheme	Public buildings (heating, ventilation and air conditioning [HVAC])	Heat supply contract
Germany	Federal/state level standardisation of EPCs, consumer education by federal/state agencies, transition to renewable energy, phase-out of nuclear energy	All sectors, focus on the public sector and industry processes (heating/hot water, renewables, co-generation, public lighting, automation, pumps)	ESC, focus is on the delivery of a contracted supply of services
India	Support from various donors for industry ESCO projects, government agency-developed standardised measurement and verification for ESCOs, EPC contracts	Industry and public sector	EPC (guaranteed savings)

Country	Policy and programmes	Market concentration	Dominant contract type
Italy	Decree 115/2008 for EPC contracts, tax deduction for building refurbishment, white certificates scheme	Public sector (buildings), industry (lighting, heating)	Heat supply contract
United States	Update to Executive Order 13693, state and municipal retrofit programmes	Energy conservation (lighting, buildings, etc.), public buildings	EPC

Source: JRC (2014b), *ESCO Market Report 2013*; JRC (2014a), *ESCO Market Report for Non-European Countries 2013*; Navigant Research (2015), *Energy Service Company Market Overview: Expanding ESCO Opportunities in the United States and Europe*.

While some dominant trends can be discerned in the preceding examples (e.g. a preference for public-sector projects, building energy efficiency and EPCs), different business models achieve varying levels of success in different markets and regions. Sometimes, larger-scale policy changes and adaptation are required to facilitate development of the energy efficiency services market. In the United States, for example, some parties perceived potential risk from residential retrofit under property-assessed clean energy (PACE) programmes. This led financial authorities to discourage mortgage providers from providing this type of finance, which allows borrowers to pay back loans through property taxes. Over time, new models have evolved and rules have been changed such that PACE financing has been taken up to a greater extent, including in the residential sector (in California and Florida). The programne can be expected to grow further as the Federal Housing Administration (FHA) issued new guidance in July 2016 that PACE financing is in line with FHA-backed mortgages under certain conditions.

The European Union faces a different challenge. Accounting rules require that capital expenditures incurred in the context of EPCs have to be recorded on the balance sheet as debt, except if they satisfy all conditions for being a public-private partnership (PPP) or are considered as operational leases. These accounting rules often impede municipalities from engaging in retrofit actions as they are often constrained by not being able to further increase their debt levels.

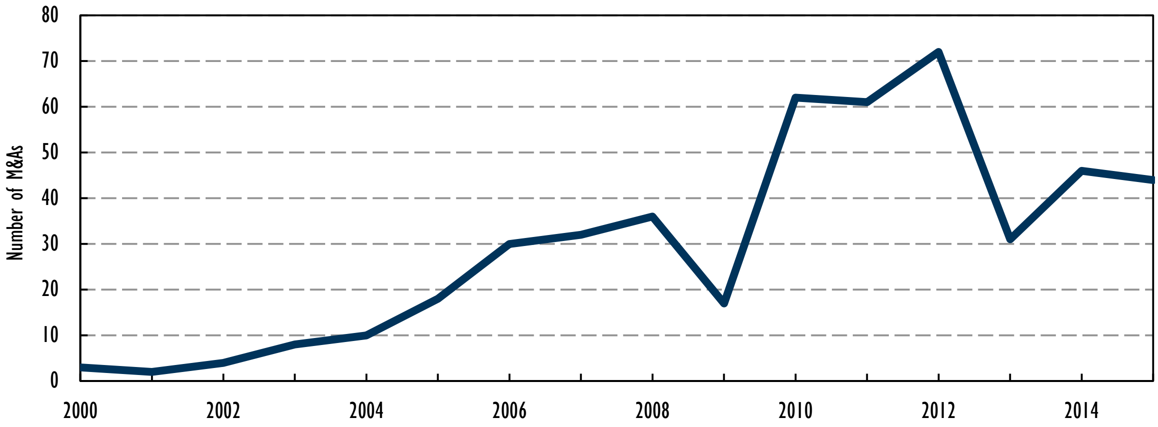
Outlook for the energy efficiency services market

Numerous signals build confidence that the energy efficiency services market has potential for future growth. Understanding these signals is important for policy makers to create an enabling environment.

Energy efficiency services firms increasingly being acquired

In recent years, the energy efficiency services market attracted more attention from companies, including those not historically active in it. This is reflected in an increase of mergers and acquisitions (M&As) of enterprises in the market over the past 15 years (Figure 6.6), and may be an indicator of a strategy to enter a market in which business opportunities are expected.

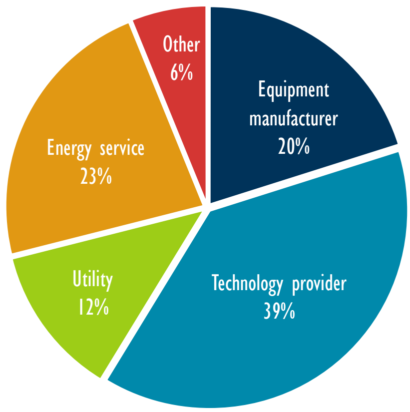
Figure 6.6 Number of companies acquired in the energy efficiency services market, 2000-14



Note: Chart compiled by tracking the number of mergers & acquisitions (M&A) in the energy efficiency services marketplace. Energy efficiency services marketplace for this figure consists of a sample from Bloomberg New Energy Finance (BNEF) including the three energy efficiency categories as well as the digital energy categories. No relevance filter was applied on the BNEF data. Only total number of transactions per year were tracked.
Source: Based on data from BNEF (2016).

The identities of the acquirers are also telling. They include not only actors traditionally active in the energy efficiency services market (such as utilities or ESCOs), but also manufacturers, information and communications technologies (ICT) providers, and others, including the transport sector (Box 6.1). More than 50% of the 487 M&As reviewed in this analysis were initiated by companies not traditionally considered part of the energy services market (Figure 6.7).

Figure 6.7 Share of energy efficiency service enterprises acquired, classified by sector of the acquirer, 2000-15



Note: This chart uses the number of M&As in the energy efficiency services market from 2000-15 classifying the industry of the acquirer into the categories outlined above through International Energy Agency (IEA) analysis. Energy efficiency services marketplace for this figure consists of a sample from BNEF including the three energy efficiency categories as well as the digital energy categories. No relevance filter was applied on the BNEF data. In total 487 transactions were tracked.

Source: Based on data from BNEF (2016).

Box 6.1 Strategies of new market entrants

One strategy for entering the market, particularly for larger companies, is to acquire companies across different sectors of the energy efficiency services market (e.g. technology, electric transport, etc.). ABB is an example of a large company having bought various companies along the energy efficiency services value chain, including ICT companies, technology manufacturers and transport businesses (Table 6.2). In fact, more than 50% of ABB acquisitions since 2010 have been related to the energy efficiency services market.

Table 6.2 Acquisitions related to the energy efficiency services market by ABB since 2010

Company	Sector	Acquisition value	Year
Ventyx	Software/ITC	USD 1 billion	2010
Baldor Electric	Electric motors/Technology	USD 4.2 billion	2011
Ecotality	Charging equipment/Energy equipment	USD 10 million	2011
Epyon B.V.	Fast electric vehicle (EV) charging/Transport	Undisclosed	2011
Newave	Infrastructure/Smart infrastructure	USD 180 million	2011
Powercorp	Renewable energy grid integration/Smart infrastructure	Undisclosed	2011
Validus DC Systems	Power infrastructure/Energy equipment	USD 15 million (est.)	2011
Thomas & Betts	Low-voltage equipment/Energy equipment	USD 3.9 billion	2012
Newron System	Software/ITC	Undisclosed	2013
Power One	Solar inverters/Energy equipment	USD 1 billion	2013
SIVA	Robotics/Technology	Undisclosed	2016
Tropos	Wireless Internet/ITC	USD 35 million	2013
Gomtec	Robotics/Technology	Undisclosed	2015

Sources: Greentech Media (2012), “ABB Acquires Tropos, Resumes Smart Grid M&A Spree”; Greentech Media (2013a), “ABB and Ventyx: The Long March to Smart Grid IT/OT Convergence”; Greentech Media (2013b), “ABB, Tropos Offer AMI Plus Free Wi-Fi in Silicon Valley”; Seeking Alpha (2016), “ABB acquires SVIA automation solutions”.

Data analytics and ICT firms are among those entering the market. One prominent example is the purchase of Opower by Oracle for USD 532 million. The opportunity to link data analytics, smart homes and cloud computing to energy efficiency services seems to be one driver of this interest. Transport companies are also acquiring firms and may be intending to secure a head start on the development of the EV market. Manufacturers (such as GE) or technology firms (such as Philips) are acquiring energy businesses as they look to expand the range of products they offer to clients (e.g. lighting or heating services) in the context of the continuing trend from product-oriented economies to service-oriented economies. Philips Lighting, for example, is shifting from its traditional focus on manufacturing light bulbs to offering diverse lighting services, ranging from lighting large buildings and street lighting to specialist lighting of events. These services can span from feasibility studies to project management, performance contracts and solutions for financing. GE has also moved into the lighting business, again combining it with other technologies. With an upgrade to LEDs, lighting energy consumption drops from factoring around 30% to 40% of commercial building energy consumption to 15% to 20%. Adding sensors and controls in LED lighting systems, for example, reduces lighting energy consumption by an additional 20% to 40%. But the greatest energy reductions are achieved when systems are adapted to the specific context.

Technology advances leading to new opportunities

Correctly predicting, monetising and delivering energy savings is at the heart of the energy efficiency services business. Currently, energy efficiency projects are evaluated (and paid for) by a calculation of potential savings at the beginning, with the investment being paid back from lower energy costs over time. This approach may misalign incentives, as actual performance matters less than predicted performance. With new technologies (such as smart meters) emerging to move to performance-based remuneration, appropriate policy is needed, potentially linked to the appearance of "prosumers" generating themselves some of the energy they use due to distributed generation.

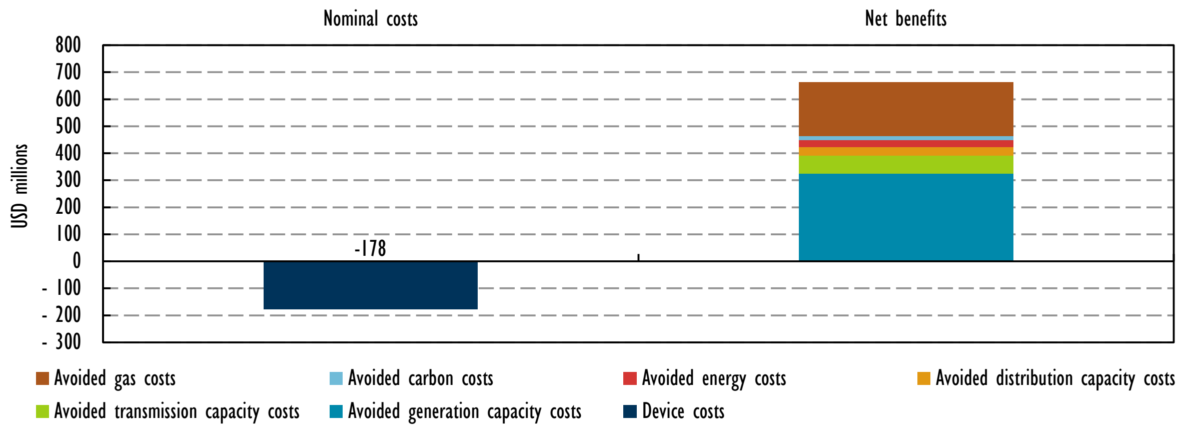
The US states of California and New York are developing and implementing legislation that transforms energy efficiency into a tradeable commodity. Essentially, the legislation defines a unit of energy savings such that it can be compared in the market and priced. This allows the market to set a price (e.g. in comparison with the price of other generation capacity in case the savings are not realised) on which investors can aggregate and invest. In California, building energy efficiency interventions will be evaluated on the comparison between the pre-intervention baseline consumption and the post-intervention outcome. The California Public Utilities Commission will incorporate meter-based performance measurement in its goals and budgets. In New York State, the *Reforming the Energy Vision* proposal calls for a redesign of rate-making and increasing system-wide efficiency. Within this vision, there is large potential to accelerate deployment of smart meters. New York's electricity company, ConEdison, has announced plans to install 4.7 million meters, which will provide the utility with near real-time data. Estimating that the new system will collect 1.5 billion data points daily, the company expects to translate this stream of information into new earning mechanisms.

Smart metering is not the only way to unlock potential for the energy efficiency services market. Smart "connected" appliances and devices may deliver similar benefits. Many companies are already rolling out smart thermostats, for example. Such devices allow businesses to "get closer" to end users and better understand what new services could appeal to them. Analytics help identify which customers value which services. Some companies also provide customers with usage data reports to incentivise behaviour change, for example by comparing their usage to that of similar customers. The increased information for the customer enabled by new technology may, however, prove a double-edged sword for utilities: it could enable consumers to switch more easily to cheaper providers (facilitated almost automatically by software).

Utilities increasingly involved in energy efficiency services market

Most IEA countries have experienced a decade of stagnant electricity demand, partly due to energy efficiency gains since 1990. As a consequence, the traditional business model of utilities is challenged and many utilities are turning to energy efficiency services to recover and even increase revenues. In recent surveys, the top leadership of utilities identified three new future revenue streams: energy management for commercial and industrial consumers; non-traditional grid services; and EV charging services (IDC Energy Insights, 2015). The resulting business model can be described as the energy efficiency service utility. If appropriate incentives and regulations are in place, such demand-side efficiency programmes could turn into new revenues for utilities. For example, calculations show that the benefits of avoided costs outweigh the costs of the programme (Figure 6.8). In addition to these direct economic benefits to the utility, there are several other benefits to society.

Figure 6.8 Potential benefits for an energy efficiency service utility in the United States over 20 years



Note: this chart shows a hypothetical example based on assumptions on customers, load profiles, programmes and technologies, impact on energy use and peak demand, structure of existing rates and marginal costs.
Source: Brattle Group (2014), "The emergence of the energy service utility", presentation to the North Carolina Electric Membership Corporation.

Policy makers can help shape this change in the utility business model through various market-based instruments such as obligation schemes, capacity markets and auctions. In 2006, 12 US states had energy savings targets in place for utilities; by 2016, 25 states required such targets (Baatz, Gilleo and Barigye, 2016). Utilities worldwide spend more than USD 11 billion per year on such schemes, more than half of it in the United States (Table 6.3). Previous analysis found a correlation between obligation schemes and ESCO market activity: the five US states highly ranked in ESCO market activity also rank highly in terms of per capita spending on rate-payer-funded energy efficiency programmes (Larsen, Goldman and Satchwell, 2012).

Creating this kind of energy efficiency services market has significant value for the energy system overall (and is therefore in the interest of policy makers) and contributes to the development of the market itself. The EED in the European Union, for example, has enabled the number of EEO schemes in EU member states to increase from 5 (before the directive came into force) to 13 that are currently operational, and 3 more scheduled to start in the future.

Table 6.3 Spending on energy efficiency programmes by utilities

Country/region	Year	Costs (USD millions/year)
United States	2014	6 038
Ontario (Canada)	2014	364
Australia	2014/15	143*
European Union	Depending on member state	4 339**
Brazil	2015	191

Country/region	Year	Costs (USD millions/year)
China	2015	448
Korea	2015	98
Uruguay	2016	3
South Africa	2008	44
Total		**11 668**

* In the case of Australia, cost data were available only for New South Wales and the Australian Capital Territory. In order to estimate the total expenditure for Australia's four EEOs the expenditure for Victoria has been calculated by applying figures from the scheme in New South Wales, and the estimate for Southern Australia is based on figures for the Australian Capital Territory.

** The expenditure estimate for the whole of the European Union is based on average cost data for Austria, Denmark, France, Italy, and the United Kingdom.

Note: This table includes utilities, distributors, and retail and government entities, all programme types (energy efficiency capacity auctions, energy efficiency auctions, energy efficiency resource standards and obligations), all types of fuels for which efficiency is mandated. For the United States, the figures include only spending through energy efficiency resource standards; they do not include other energy efficiency programmes, even if utilities are involved in delivery or funding.

Box 6.2 Strategies of utilities in the energy efficiency service market

Utilities try to put in place strategies similar to those of other actors such as manufacturers and technology providers. In the United Kingdom, for instance, all six major utilities have launched smart thermostat solutions to provide smart heating services to end users (Table 6.4). In some cases, the utilities partner with technology companies.

Table 6.4 Six major UK utilities offering smart thermostat solutions

Company	Smart thermostat solution
British Gas	Hive
EDF Energy	HeatSmart
E.ON	Touch
Npower	Nest
Scottish Power	Connect
SSE	Tado

Germany is also seeing radical change in the orientation of major utilities. E.ON was first to announce a separation of the traditional generation business from the renewable energy business; others have since followed. In 2016, RWE is launching a new company and ownership structure, focusing on renewable energy, the grid and retail. Vattenfall sold its domestic lignite business in early 2016. These changes were made mainly in response to both policy developments that are transforming the German energy market and the general market outlook. Many other companies are in line with offering new services and trends described above.

Financing energy efficiency services

Diverse financing sources of energy efficiency services exist and include traditional sources of capital. In the simplest form, households invest directly by using cash or savings to buy, for example, a more energy-efficient refrigerator or a smart meter. Other common financial sources such as loans (e.g. to purchase a more efficient vehicle) are also widely used. Additional mechanisms are needed, however, to provide the required scale of financing – at a low and affordable cost – to meet climate goals. Climate finance can meet some of the financing needs, especially in emerging countries. But only growth in bankable and tradable energy efficiency services commodities, e.g. through ESCOs, will attract the engagement of capital markets.

Capital markets have a potentially important role in financing energy efficiency services, particularly through asset-backed security (ABS) and green bonds focused on (or with a large component of) energy efficiency. Emphasis is now being placed on how to scale up these approaches. As investors move towards strategies aligned with low-carbon transformation, energy efficiency assets are seen as an important means to decarbonise their portfolios.

International climate finance for energy efficiency services

By helping to bridge the gap between a project and the market, climate finance has the potential to unlock significant investment in energy efficiency services. Climate funds may be a particular opportunity for emerging economies; energy efficiency services should tap into this resource to a much greater degree. Only 1.7% of bilateral and 3.6% of multilateral development projects dedicated to climate finance include "energy efficiency" in the title or project description (compared with 2.5% of bilateral and 6.9% of multilateral projects that contain "renewable energy" in the title or project description).[3] This amounts to a total of USD 4.6 billion of climate finance directed towards energy efficiency (Table 6.5), compared with USD 7.1 billion for renewable energy. Increasing that amount could make more finance available to fund energy efficiency services in countries where the market is not yet mature.

Table 6.5 Climate finance dedicated to energy efficiency services

	Value		Projects	
	Constant 2013 USD billions	Share of total climate finance	Number of projects	Share of total climate finance
Bilateral energy efficiency projects	1 780 225	3.4%	259	1.7%
Multilateral energy efficiency projects	2 778 949	6.4%	91	3.6%
Total energy efficiency projects	4 559 173	4.8%	350	2.0%

Note: Estimates based on tracking mentions of "energy efficiency" in the subset of climate-relevant Rio Markers in the project title or project description. This provides only a rough estimate in the absence of a dedicated marker and possible aggregation of projects in the creditor reporting database (for instance projects mentioning only "the creation of ESCOs" without using the term "energy efficiency" would not be captured).
Source: Based on OECD (2016), Creditor reporting database, Rio Markers.

[3] The values and percentages presented are based on a set of climate-related development finance projects extracted from the Creditor Reporting System database. They provide only a rough estimate in the absence of a dedicated marker and different reporting practices of splitting or aggregating projects. Also, projects with descriptions in languages other than English and French, or containing different wording, may not be captured in the text search. The total number of projects refers to this subset and may differ from other statistics on donor funding.

Engaging the capital markets

Since the Paris Agreement was adopted at the United Nations Framework Convention on Climate Change, 21st Conference of the Parties (COP21), there has been significant growth in investor interest in climate change. Likewise, commitments have been made for green investments and portfolio decarbonisation to increase the percentage of green portfolios, with investments in energy efficiency, renewables and other low-carbon technologies being central to such goals. In 2015, an initiative by the United Nations Environment Programme Finance Initiative (UNEP FI) and the International Partnership for Energy Efficiency Cooperation (IPEEC) mobilised more than 100 banks and investors (representing more than USD 4 trillion in assets) to increase energy efficiency finance. In addition, public interest in environment-friendly investments seems to be growing. It is important to emphasise that these are not necessarily new financing requirements but may also be a redirection of existing flows towards certain environmental goals (e.g. energy efficiency).

All this leads to a rising demand for relevant sources of finance such as green bonds. This is reflected in oversubscription of green bonds issued (which makes them a relatively liquid asset, and thus interesting to investors). Unibail Rodamco, the third-largest real estate company in the world, for example, has launched various green bonds including three with energy efficiency as an element. The one issued in April 2015 was more than six times oversubscribed. Similarly, the German real estate and mortgage bank BerlinHyp issued its first-ever green *Pfandbrief* (a covered bond governed in accordance with German law). The USD 562 million (500 million euros [EUR]) green bond, which has a seven-year tenor, was more than four times oversubscribed. The proceeds are used to finance green buildings that have an appropriate energy efficiency certificate.

Apple is another example; the company has issued USD 1.5 billion in bonds dedicated to financing clean energy projects across its global business operations. Proceeds from the green bond sales will be used to finance renewable energy, energy storage and energy efficiency projects, as well as green buildings and resource conservation efforts. ABN AMRO Bank issued a USD 562 million (EUR 500 million) green bond in June 2015, which enables investors to (indirectly) invest in mortgages of highly energy-efficient homes, as well as in loans for solar panels on existing homes and sustainable commercial property. The demand has led to numerous related initiatives – further testament to the strengthening interest in low-carbon investments (Table 6.6).

Table 6.6 Examples of initiatives promoting low-carbon investments

Initiative	Key details
Montreal Carbon Pledge	Led by the United Nations Principles for Responsible Investment, this initiative brings together more than 120 investors with USD 10 trillion of assets under management. It calls for a commitment to measure and disclose the carbon footprint, and to take action to decarbonise investment portfolios. Energy efficiency and alternative sources of energy are considered important elements.
Institutional Investors Group	This network-style forum for investor collaboration on climate change has 120 members representing USD 15 trillion (EUR 13 trillion) in assets. It pursues change in market signals by encouraging the adoption of public policy solutions that ensure a low-carbon economy, as well as measures for adaptation. It aims to inform investment practices to preserve and enhance long-term investment values.
France Article 173 of the Energy Transition Bill	France is the first country in the world to introduce a carbon-reporting obligation on financial institutions, requiring institutional investors to disclose consideration of environmental and social issues in decision making and target setting. Listed companies are required to report on the risks of climate change to their business and

	on mitigation measures taken.
Climate Bonds Initiative	This investor-focused, not-for-profit organisation seeks to mobilise debt capital markets for climate change, tracking the green labelled market since 2009. It gives broad areas of inclusion for green bonds (such as green residential mortgages for energy efficiency, low-emission vehicles, etc.) with the aim of establishing common definitions and a cohesive thematic bond market across global markets.
2 Degrees Investing Initiative	This grouping of large insurance companies, banks and others aims to align investment scenarios with 2°C climate scenarios, and to develop relevant metrics. Regulation and policies to incentivise capital for energy transition financing are to be mobilised.
Energy Efficiency Finance Task Group	Established as a work stream by the G20, it recognises the importance of, and tries to increase finance for, energy efficiency by reviewing policies and best practices that channel more funds towards energy-efficient activities.

Sources: Montreal Carbon Pledge (2016), website; UNEP FI (2016), website; IIGCC (2016), website; Legifrance (2016), website; Climate Bonds Initiative (2016a), website; 2° Investing Initiative (2016), website.

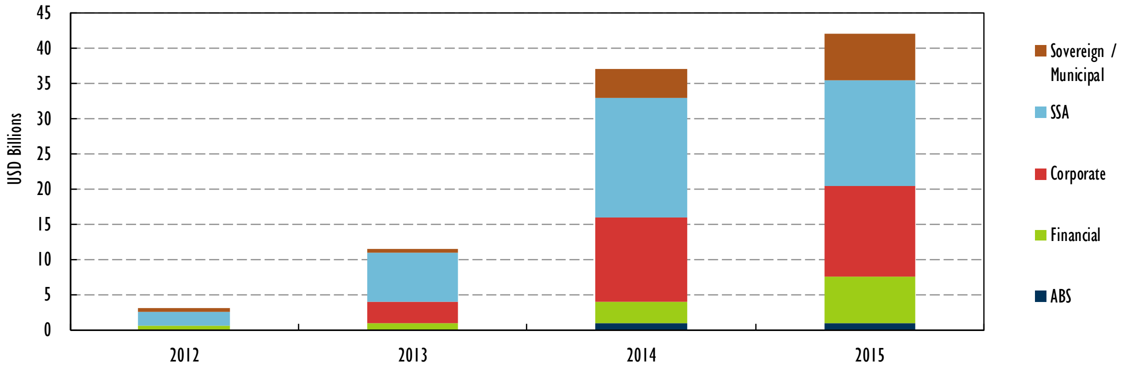
Like any other bond, a green bond is a fixed income instrument for raising capital from institutional investors in debt capital markets. The issuer differentiates green bonds through a series of commitments to use the proceeds for low-carbon investments in a transparent manner.

Overview of the green bond market

The market for green bonds has grown since they were introduced in 2007-08 by multilateral development banks. A number of corporations, municipalities and banks have now significantly expanded the universe of green bond issuers and boosted their issuance. In 2015, the value of the green bond market reached USD 42 billion (Figure 6.9).

In 2015, USD 8.2 billion of green bond proceeds was allocated to energy efficiency (19.6% of the total). Most (45.8%) green bond proceeds go to renewable energy (Climate Bonds Initiative, 2016b). In 2016, green bond issuance reached USD 28 billion by May and the Climate Bonds Initiative (2016c) predicted that it could reach up to USD 100 billion by year-end. A key component of this growth was an announcement by Chinese issuers of their intention to issue more than USD 45 billion in green bonds in 2016.

Figure 6.9 Annual green bond issuance, 2012-15



Notes: SSA = supranational, sub-sovereign and agency. Project bonds are not included. Other statistics on green bonds may differ due to other datasets.
Source: Climate Bonds Initiative (2016b), *2015 Green Bond Market Roundup*.

The term “green bond” has been applied to a number of different capital market instruments used to finance or refinance renewables and other low-carbon investments (Table 6.7). They are becoming more and more associated with energy efficiency.

Table 6.7 Overview of capital market instruments in the green bonds class

Instrument	Description
Corporate green bond	Classic bond with risk on the corporate issuer. There is normally an obligation to demonstrate the use of proceeds for green business activities with subsequent monitoring. This type of green bond lends itself well to the energy efficiency business that the corporate entity is involved in.
Project bond	A bond backed by one or several green projects. Investors are usually exposed to the underlying project risk. The projects tend to be large infrastructure. This type of bond would apply to energy efficiency only to the extent that the underlying project has an energy efficiency element.
ABS	A bond collateralised by a pool of loans or similar assets. Covered bonds are a type of ABS particularly relevant for energy efficiency in that portfolios of energy efficiency building loans can be used as collateral. ABS are considered to have significant potential as they are less likely to be constrained by government, fiscal and corporate balance sheet rules. As a result, much attention and effort are being placed on developing energy efficiency ABS.
SSA	Bonds issued by international financial institutions (IFIs) such as the World Bank and the European Investment Bank. These bonds can apply to energy efficiency where the IFI uses its proceeds under an energy efficiency programme.
Sovereign or municipal bond	A bond issued by a government, region or city. Normally the proceeds of these bonds are applied to an infrastructure programme; they are a good match for energy efficiency investments in public buildings and infrastructure.
Financial sector bond	A corporate type bond issued by a financial institution that uses proceeds to finance or refinance green projects. These bonds tend to be closely linked to large renewable projects, but certain financial institutions have used them to finance energy efficiency activities.

Sovereign and municipal bonds have had a particularly catalysing role in supporting energy efficiency. Initiatives such as PACE in the United States have led to the securitisation of energy efficiency loans on the basis of ABS. This type of approach is considered to have potential to tap significant amounts of low-cost finance, which in turn has the virtuous circle effect of promoting energy efficiency. The PACE market is starting to show clear signs of maturity. Many areas have introduced local legislation allowing energy efficiency loans on both commercial and residential properties to be repaid as part of the property tax bill. These loans can be pooled together by the local tax authority and sold to securitisation in special purpose vehicles, which can then sell ABS (in this case the pool of PACE loans) green bonds to the capital markets. This may also contribute to developing ESCOs.

Variants and indeed a whole ecosystem of energy efficiency providers are forming. One example is the Warehouse for Energy Efficiency Loans (WHEEL), a PPP established by a number of financial institutions and state entities. Its aim is to create a secondary market for energy efficiency residential loans within the capital markets. WHEEL buys loans from existing state or local government residential programmes; it issued its first USD 12.58 million ABS green energy bond, backed by residential energy efficiency loans, in 2015. A similar model has been developed by the Inter-American Development Bank and the Clean Technology Fund, providing financing of USD 125 million for energy efficiency projects developed by Mexican ESCOs.

Standardisation of green bonds and energy efficiency investment

Increasing demand for green bonds as well as the inclusion of energy efficiency services in the bond offerings has prompted demand for standardisation of these bonds and investments. Such standardisation facilitates investment and drives even more demand. Consequently, attention is turning to appropriate metrics and sources of data for standardisation. These standardisation trends are necessary at both project and aggregated levels to define green bonds in general and energy efficiency bonds in particular. On a project level, standardising measurement and verification helps evaluate associated risks and improves investor confidence. This then enables later aggregation into portfolios that investors can evaluate for risks. Various initiatives have begun this task (Table 6.8).

Table 6.8 Initiatives for standardisation of green bonds and energy efficiency bonds

	Green bond standardisation
Initiative	***Key details***
Green Bond Principles	Voluntary process providing guidelines on transparency and disclosure to promote integrity of the green bond market clarifying the approach for issuance for use by all market actors. It comprises guidance for issuers on key components in launching a credible green bond.
Green Bond Standards	A screening tool for investors and governments allowing prioritisation of climate and green bonds with the confidence that the funds are used to deliver climate change solutions. Provides a set of criteria for low-carbon residential and commercial buildings and retrofits.
	Green bond standardisation with an angle on energy efficiency
Initiative	***Key details***
Climate Strategies and Metric Exploring Options for Institutional Investors, Investing Initiative Portfolio Carbon Initiative Report	This is a study by the 2 Degrees Investment Initiative, the World Resources Initiative and the UNEP FI. It reviews the strategies available to investors seeking to measure and improve the climate friendliness of their portfolios by asset class and achieve emissions reductions in the real economy through positioning and signalling. It looks at different climate-related investments and recognises the role of energy efficiency as a key driver of decarbonisation with an emphasis on developing better metrics such as improving the data quality around energy savings.
Climate Bonds Standard	Backed by the Climate Bond Standards Board of pre-eminent investor entities (USD 34 trillion of assets under management) this is a multisector standard certified by a third-party verifier as an easy-to-use tool. It allows investors and intermediaries to assess the environmental integrity of bonds claiming to address climate change mitigation and adaptation.
	Energy efficiency bond standardisation
Initiative	***Key details***
Energy Efficiency Financial Institutions Group (EEFIG)	The group established action points aimed at standardisation, improving data and metrics such as buildings certification methodologies, energy performance certificate standards, and procedures for energy efficiency and building renovation underwriting for both debt and equity investments. The development of common loan documentation associated with energy efficiency building renovation will enable the aggregation of residential retrofit loans into portfolios with a size sufficiently large for capital markets instruments. Monitoring the loan performance data will provide an understanding of the risks associated with the portfolios required by an institutional investor to decide his willingness to invest. In 2016, EEFIG expects to also launch a database of energy efficiency investments in Europe as well as procedural standards for financial institutions making energy efficiency investments.

Environmental Defense Fund's Investor Confidence Project (ICP)	New pilot programme with the New Jersey Board of Utilities to scale up private investment in energy efficiency in buildings. The pilot brings ICP's market-based approach to energy efficiency into an existing state efficiency incentive programme. One of the goals is to assemble data over three years that will provide project developers and authorities with new information regarding performance. It brings measurement and verification metrics to energy efficiency retrofit projects providing information about projects that conform to the ICP Energy Performance Protocols originated by credentialed developers and verified by a quality assurance provider. The appropriate protocol for baselining energy usage and predicting savings must be applied and specific plans for commissioning, operations and maintenance, and measurement and verification included.

Sources: EEFIG (2015), Final report; 2 Degrees investment Initiative, WRI and UNEP-FI (2015), *Climate Strategies and Metrics: Exploring Options for Institutional Investors*; EDF (2016), website; ICP (2016), website; Climate Bonds Initiative (2016a), website; Ceres (2014), *Green Bond Principles 2014: Voluntary Process Guidelines for Issuing Green Bonds*.

ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronyms and abbreviations

4E TCP	Energy Efficient End-Use Equipment Technology Collaboration Programme
ABS	asset-backed security
AC	air conditioning
BAT	best available technology
BEC	building energy code
BEE	building energy efficiency
BEV	battery electric vehicles
BNEF	Bloomberg New Energy Finance
CAFC	corporate average fuel consumption
CAFE	corporate average fuel economy
CAGR	compound annual growth rate
CBD	Commercial Building Disclosure
CDM	Clean Development Mechanism
CFL	compact fluorescent lamps
CO_2	carbon dioxide
COP21	21st Conference of the Parties
CPS	Current Policies Scenario
EED	Energy Efficiency Directive
EEFIG	Energy Efficiency Financial Institutions Group
EEMR	*Energy Efficiency Market Report*
EEO	energy efficiency obligation
EESL	Energy Efficiency Services Limited
EPC	energy performance contracts
EPPI	Efficiency Policy Progress Index
ERI	Energy Research Institute
ESC	energy supply contract
ESCO	energy service companies
EU	European Union
EUR	euro
EV	electric vehicles
FHA	Federal Housing Administration
FYP	Five-Year Plan
GDP	gross domestic product
GHG	greenhouse gas
GVA	gross value added
HDV	heavy-duty vehicles
HVAC	heating, ventilation and air conditioning
ICP	Investor Confidence Project
ICT	information and communications technologies
IEA	International Energy Agency

IFI	international financial institutions
IPEEC	International Partnership for Energy Efficiency Cooperation
LDV	light-duty vehicles
LED	light-emitting diode
LNG	liquefied natural gas
M&A	mergers & acquisitions
MEPS	minimum energy performance standards
MoMo	IEA Mobility Model
NBP	National Balancing Point
NBS	National Bureau of Statistics China
NDC	Nationally Determined Contributions
NDRC	National Development and Reform Commission
OECD	Organisation for Economic Co-operation and Development
PACE	property-assessed clean energy
PAT	Perform, Achieve, Trade
PHEV	plug-in hybrid electric vehicles
PPP	public-private partnerships
PPP	purchasing power parity
SEAD	Super-Efficient Equipment and Appliance Deployment
SSA	supranational, sub-sovereign and agency
SUV	sport utility vehicle
TFC	total final consumption
TPES	total primary energy supply
TTF	Title Transfer Facility
UNEP FI	United Nations Environment Programme Finance Initiative
US	United States
USD	United States dollar
WEO	*World Energy Outlook*
WHEEL	Warehouse for Energy Efficiency Loans
WLTP	Worldwide Harmonised Light Vehicles Test Procedure
WTI	West Texas intermediate
ZEB	zero energy buildings

Units of measurement

bbl/d	barrels per day
cm	centimetre
EJ	exajoules
$GtCO_2$	gigatonnes carbon dioxide
km	kilometres
kW	kilowatts
kWh	kilowatt-hour
L/100 km	litres per 100 kilometres
Lge	litres of gasoline equivalent
m^2	square metres
mb/d	million barrels per day
mpg	miles per gallon

Mtce	million tonnes of coal equivalent
$MtCO_2$	million tonnes carbon dioxide
Mtoe	million tonnes of oil equivalent
MW	megawatt
PJ	petajoule
t	tonne
toe	tonnes of oil equivalent
TWh	terawatt-hour

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ENERGY EFFICIENCY

Market Report 2016

Often called the "first fuel" of the global energy system, energy efficiency is one of the most important steps that any government can take to move towards a sustainable energy system.

To check on the progress made on this front, the IEA *Energy Efficiency Market Report* tracks the core indicators of energy efficiency. This year, the report takes a new approach and expands the scope of analysis by examining the drivers of energy efficiency programmes in emerging economies, as well as the impact of those policies.

Some of the questions that are addressed in this year's report include:

- Which countries and policies are having the greatest impact, and what is the recipe for their success?
- Are we improving energy efficiency fast enough to achieve our climate goals?
- What is the size of energy efficiency investments around the world and in key energy-consuming sectors?
- What has been the impact of low energy prices on these efficiency investments?
- What are the benefits of efficiency programmes on climate policy, energy security and public budgets?
- What are the market trends for energy efficiency services and financing?

The *Energy Efficiency Market Report* is the global tracker for energy efficiency programmes, providing policy makers and the private sector with insights on the latest trends and market prospects.