Energy Efficiency Outlook for India – Sizing up the opportunity

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Table of contents

Acknowledgements

This report was produced as part of the Energy Efficiency in Emerging Economies (E4) Programme which is managed by the Energy Efficiency Division of the International Energy Agency (IEA). The E4 Programme was established in January 2014 to support the scale-up of energy efficiency activities that generate economy-wide benefits in major emerging economies. Thanks go to the Government of Denmark and the European Commission for their funding of this work.

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Our thanks go also to several national and international experts including Anil Kumar Jain from Niti Aayog, Satish Kumar from the Alliance for an Energy Efficient Economy (AEEE), Jyoti P. Painuly from Copenhagen Centre on Energy Efficiency (C2E2), Ashok Kumar from the Central Building Research Institute (CBRI), Lokanadham Krishna from Danfoss India, Ashok Sreenivas and Aditya Chunekar from Prayas (Energy Group), Anup Bandivadekar from The International Council on Clean Transportation (ICCT), Sanjay Dube from the International Institute for Energy Conservation (IIEC), Somnath Bhattarcharjee from the Institute for Industrial Productivity (IIP), Rangan Banerjee from Indian Institute of Technology Bombay (IITB), Rajesh Nair from ITC Infotech and Ashok Sarkar from World Bank.

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

Highlights

- The Indian Government has established several innovative and exemplary energy efficiency policies that are having an impact on energy consumption in the country including the Perform, Achieve and Trade (PAT) scheme for industry, the large-scale national efficient lighting programme for the residential sector, the national street lighting programme and the agriculture demand side management programme. Furthermore, the government has also made significant progress in the removal of energy subsidies and the introduction of new emission standards for passenger vehicles. These, combined with the wider economy transformative initiatives such as Make in India and the Smart Cities Mission, are bound to set India's energy market on a new and improved path towards efficiency.
- India's main challenge is meeting the fast growing energy demand of the country, while also ensuring that the growth is equitably shared among its vast population. Recognising this challenge, India's existing policies focus on energy security and reliability, diversity of supply, energy access and affordability. In line with this goal, India's Intended Nationally Determined Contribution (INDC) commits to increasing the share of non-fossil fuel power generation capacity to 40% and reducing the emissions intensity of the economy by 33-35% by 2030.
- India's primary energy demand has more than doubled since 1990, while gross domestic product (GDP) grew by over four times indicating that economic growth is decoupling from energy consumption. For example, in 2013 it took 40% less energy to create one unit of Indian GDP compared to 1990.
- Primary energy demand is dominated by fossil fuels (73% in 2013) and their share has increased since 2000, fuelled by strong economic growth and an increase in energy demand from the industry and transport sectors. Coal now represents approximately 44% of total primary energy demand largely as a result of the expansion of coal-fired power generation. Coal is followed by biomass and oil with a share of approximately 23% each. Comparatively, natural gas, hydropower, nuclear and modern renewables all play a smaller role in the mix.
- As recognised by the Indian Government, energy efficiency can play a vital role in achieving the country's INDC targets. The importance of energy efficiency and its multiple benefits is illustrated in this report, supported by IEA's World Energy Outlook analysis, under two different scenarios: New Policies Scenario and the India Efficiency Scenario. The New Policies Scenario assumes only those policies and measures that have been formally adopted and announced as of mid-2015. The India Efficiency Scenario shares the same assumptions but includes all economically viable possibilities to increase energy efficiency throughout the energy system. The India Efficiency Scenario identifies additional opportunities available for consideration by policy and decision makers in India.
- Overall the India Efficiency Scenario shows that energy intensity of GDP can be further improved by 19% and primary energy demand reduced by 16% in 2040 compared to the New Policies Scenario. The majority of these energy savings in primary energy demand and electricity demand will come from the industrial sector.
- In the India Efficiency Scenario, energy efficiency in the end-use sectors would enable the power sector to avoid the generation of approximately 875 TWh in 2040 (a 21% drop compared the New Policies Scenario), which in turn would help reduce generation investment worth $18 billion per year and avoid fuel consumption of 175 Mtoe by 2040 – equivalent to approximately the total final energy consumption of Indonesia in 2013 – and of which most is carbon intensive coal consumption. Overall, the value of imports of oil, coal and natural gas would be reduced by 18% to almost $440 billion in 2040 and energy bills of households and industries would be reduced. In terms of CO_2 emissions, the India Efficiency Scenario would

lower emissions by 1 gigatonne (Gt) to 4.2 Gt by 2040, compared to the New Policies Scenario. The additional investment required to achieve the India Efficiency Scenario is on average approximately $60 billion a year - twice the amount in the New Policies Scenario.

- An extensive assessment of the end-use sector potential under the India Efficiency Scenario shows:

  - **Industry:** Energy efficiency can deliver savings of 4.5 EJ by 2040 at an average payback period of just over 3 years. Significant saving potential exists in non-energy-intensive industries as well as the brick and steel industries.
  - **Transport**: Improvements in fuel economy standards for vehicles could save an additional 0.4 EJ in 2040 compared to the New Policies Scenario. Yet the largest potential for improvement is in heavy duty vehicle fuel efficiency, which can be improved by 40% in 2040 compared to current levels. Overall these and other measures could reduce total final energy consumption in the transport sector by 1.7 EJ in 2040.
  - **Buildings:** In the residential and non-residential sectors, energy efficiency could deliver savings of 0.8 and 0.6 EJ respectively by 2040, if policies can successfully overcome economic and behavioural barriers. Minimum energy performance standards (MEPS) for appliances and equipment for both sectors are essential to achieving these savings.
  - **Agriculture**: The New Policies Scenario already includes a range of effective energy efficiency policies set by the Indian Government and therefore the projected energy savings for this sector, under the India Efficiency Scenario, is only 0.1 EJ in 2040, of which more than two-thirds are from electric irrigation pumps. Nevertheless, under both scenarios, these policies will need to be closely monitored to ensure that these savings are achieved.

Introduction

India is moving to the centre stage of the world of energy. The energy sector in India has grown rapidly in recent years, and expectations of future economic and population growth amplified by urbanisation and planned industrialisation support a trend of rapid increase in energy demand. While this presents great opportunities for India, it also presents a range of challenges which need to be addressed. To ensure that energy transformation will be cost-effective, inclusive and sustainable, policy makers will need to focus on energy efficiency to ease pressure on investments in energy supply and infrastructure as well as on the social and environmental impacts derived from these investments. This report is about the potential to increase energy efficiency in the Indian energy sector in the short and long term.

The analysis presented in this report aims to inform Indian policy makers (but also businesses and other stakeholders) about the possible role of energy efficiency in the Indian energy sector looking at a long term projection to 2040. This is done by identifying economically viable potentials to increase energy efficiency on a sector-by-sector basis, estimating the benefits of the resulting energy savings and by identifying effective policies to realise such savings. Thereby, the methodology is the same as in the report *Energy Efficiency Outlook for South Africa – Sizing up the opportunity* (IEA, 2015a). Further, this report draws heavily on the IEA's previous work on the Indian energy sector, in particular the *World Energy Outlook 2015* (IEA, 2015b) special focus on India, and on energy efficiency especially *Capturing the Multiple Benefits of Energy Efficiency* (IEA, 2014) and the *World Energy Outlook 2012* (IEA, 2012) special focus on energy efficiency.

The report is organised as follows. The following section will briefly provide an overview of the scope and methodology and will explicitly define the two scenarios that are analysed; the New Policies Scenario and the India Efficiency Scenario. Subsequently the current landscape of the Indian energy sector is outlined and current and planned energy policies in India are presented. This will be followed by a section showing the implications on the Indian energy sector of the New Policies Scenario and the India Efficiency Scenario. After, the multiple benefits of the increased level of energy efficiency in the India Efficiency Scenario are presented followed by cross-cutting policy recommendations. Finally, results for each energy sector are presented each with a specific focus area and policy recommendations.

Key energy efficiency stakeholders in India

The Ministry of Power (MOP) is responsible for energy policies in the electric power sector in particular covering thermal, hydropower distribution, and the transmission and distribution grid including rural electrification. The National Institution for Transforming India (Niti Aayog) supports the government in assessing and formulating the national plans for the energy sector. The Bureau for Energy Efficiency (BEE), under MOP, implements and regulates energy efficiency policies and programmes as set under the 2001 Energy Conservation Act. The Central Electricity Authority's main task is to advise the central government on national electricity and tariff policy. The Central Electricity Regulatory Commission regulates all electricity activities at both central and interstate level. Energy Efficiency Services Limited (EESL), a joint venture set by four government-owned companies, is responsible for promoting and implementing energy efficiency projects in a wide range of sectors across the country.

Energy Efficiency in Cities

This report does not directly cover energy efficiency in cities in India such as street lighting and water pumping for water and waste water. However, there is a substantial opportunity for energy efficiency in these areas in India. For example, the Street Light National Programme (SLNP) aims to replace 35 million street lights in 100 cities across the country (PIB, 2015). By October 2016, EESL had replaced 1.3 million street lights with estimated annual energy savings of 174 GWh and peak load reduction of 43.5 MW (EESL, 2016a). For more information on opportunities for energy efficiency in cities, refer to the IEA's Energy Technology Perspectives 2016, which includes a focus on urban energy systems.

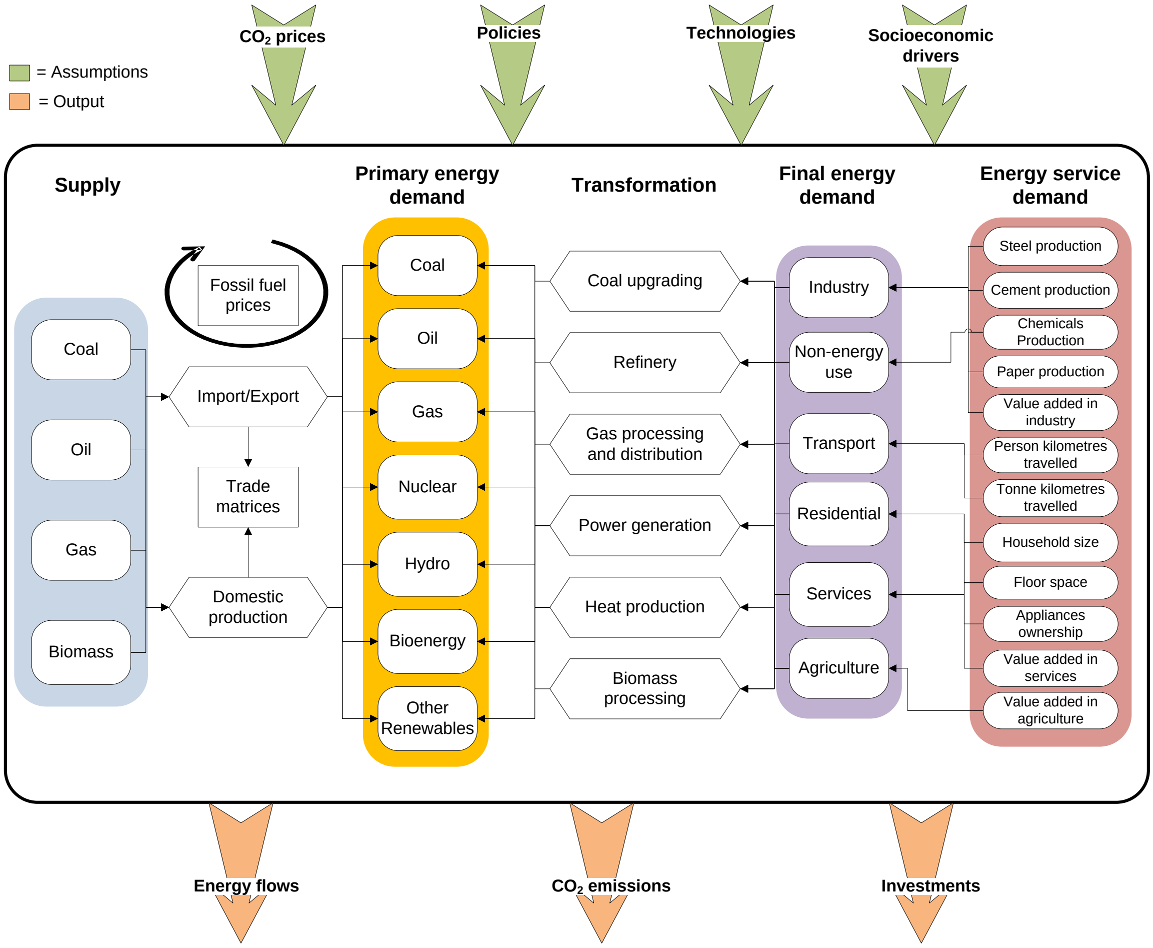
Method

The assessment of energy efficiency potential in India for this report was conducted using the IEA's proprietary World Energy Model (WEM), a large-scale simulation model designed to replicate the functioning of energy markets and the impact of energy policies. The WEM brings together a suite of 25 country or regional models. Similar to other country models including the United States, Japan and China, the India model is based on IEA datasets (see Box 1 for information about energy data for India), and represents its entire energy system and factors in interactions with international energy markets. For the purpose of this study, the time horizon is the year 2040. Figure 1 illustrates key components of the WEM. A brief description of the WEM modelling framework and macroeconomic and demographic assumptions are in Annex A. More details on the investment costs for energy efficiency in end-uses are available on the World Energy Outlook website[1].

Two scenarios are used to highlight the potential for energy savings in each energy-consuming sector of the economy. The ***New Policies Scenario*** assumes only those policies and implementing measures that have been formally adopted and announced as of mid-2015. It therefore provides a baseline of how domestic energy use would evolve if business-as-usual trends in energy demand and supply continue and a reference against which the impact of new efficiency policies can be assessed. Note that this scenario already factors in some degree of improvement in energy efficiency due to existing policies and the natural replacement or upgrade of vehicles or equipment with more efficient ones. The ***India Efficiency Scenario*** – in the spirit of the *Efficient World Scenario* presented in the *World Energy Outlook 2012* (IEA, 2012) – investigates the potential for India to go beyond the New Policies Scenario and tap into the vast technical potential to increase energy efficiency. The scenario assumes that realistic policies and measures are implemented in order to achieve a credible pathway for India. These measures are assumed to be readily available today, meaning they do not require the identification and implementation of innovative sets of energy policies or the deployment of technologies that have yet to be proven in the market.

[1] *http://www.worldenergyoutlook.org/weomodel/investmentcosts/*

Figure 1 • Key components of IEA's World Energy Model (WEM)



Source: (IEA, 2015c)

Box 1 • India's energy sector data

Energy data in India is available from a variety of sources, with the main ministries all collecting data within their areas of responsibility: for example, the Central Electricity Authority, under the Ministry of Power, takes the lead in providing statistical information on the electricity sector. Selected data from these sources are compiled by the Central Statistics Office into an annual "Energy Statistics" publication. The latest statistics used for this report covers the period until 31 March 2014, meaning that the latest calendar year for which there is full coverage is 2013 (most Indian data are available for fiscal years, which run from April to March) (CSO, 2015).

Data from these official energy institutions and from the Central Statistics Office are the bedrock of the statistical information used in the World Energy Outlook 2015 focus on India and in this report. In some cases, however, the way that the data are collected and reported does not exactly match the IEA's reporting requirements, so certain additional numbers in the IEA databases are taken from secondary sources or estimated by analysing related indicators. This applies, for example, to the use of solid biomass as an energy source, the use of back-up or off-grid generation and the split of oil product demand across end-use sectors. Differences in the definitions used and in fiscal years versus calendar year reporting, are also possible causes for adjustment. In some areas, the World Energy Outlook uses a single global source in order to ensure a consistent underlying methodology: this is the case for installed thermal power generation capacity, which is drawn for all countries from a dataset maintained by Platts, which sources its data from the Ministry of Power and others.

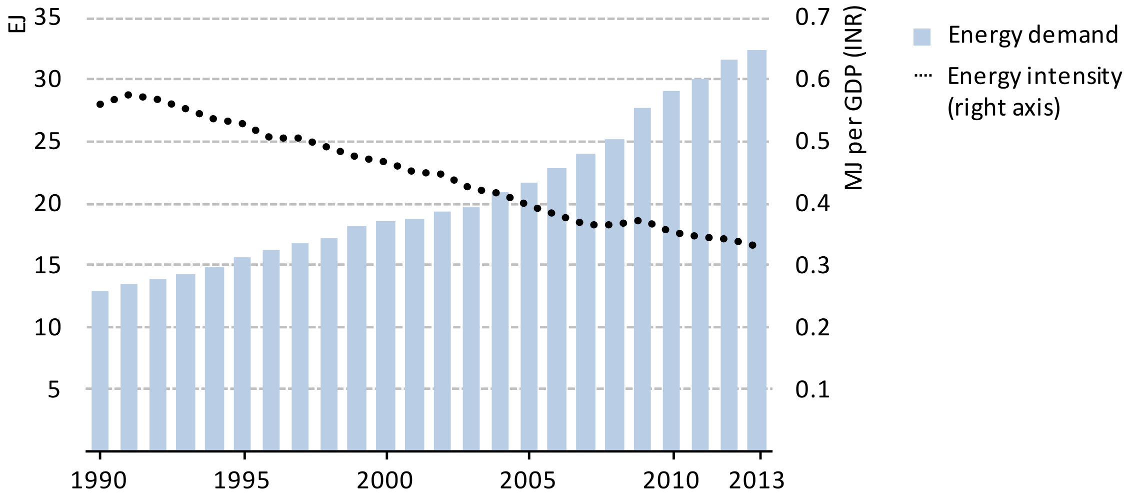
Source: (IEA, 2015b).

Current Energy Landscape and Energy Policies

Economic growth in India has been on average 6.5% since 1990, second only to China among the large emerging economies, and is currently the third largest economy in the world (measured on a PPP basis). Despite this fact, income per capita in India is still low even compared to other emerging economies (income per capita in China is twice that of India). India’s economy has been driven by its commercial and public service sector, which has accounted for around 60% of economic growth since 1990, enabled by high-value sectors such as financial intermediation and information and communications technology. Currently, the commercial and public service sector accounts for half of the GDP in India, but only employs a quarter of the labour force. Agriculture which currently accounts for 17% of GDP, on the other hand, employs around half of the labour force highlighting the social importance of the agriculture sector. The commercial and public service sector-driven nature of the growth in India is different from what one could call a traditional growth path, with an initial strong push from the manufacturing sector. In light of this, the Indian government has announced the “Make in India” initiative, with the aim of boosting the industry’s contribution to GDP and creating 100 million jobs by 2022. The “Make in India” initiative will potentially allow for the growth of lower skilled job opportunities in the manufacturing industry enabling the migration of labour from the agriculture sector as typically the growth in the commercial and public services sector is constrained by the level of education.

Since 1990, India’s primary energy demand has increased 2.5 times, whereas economic growth measured by GDP has increased fourfold over the same period, signalling that a decoupling of energy consumption and economic growth is underway in India. In 2013, it took 40% less energy to create one unit of Indian GDP compared to 1990 (Figure 2). This can partly be explained by the rising importance of the commercial and public service sector in the Indian economy, but also by households shifting away from using solid bioenergy for traditional cooking methods to more efficient technologies and cleaner fuels. Energy demand per capita has grown more modestly (as it has only increased 1.7 times since 1990), and is still only around one-third of the world average, which is explained by the large share of people in India living without access to modern and reliable energy (around 240 million people in India currently do not have access to electricity). To secure the decoupling process it is important to take advantage of the large, untapped, economically viable potential to improve energy efficiency which exists throughout the Indian energy system. Currently, much energy is wasted as efficiency levels of used equipment are relatively low.

Figure 2 • Total primary energy demand and intensity of GDP in India



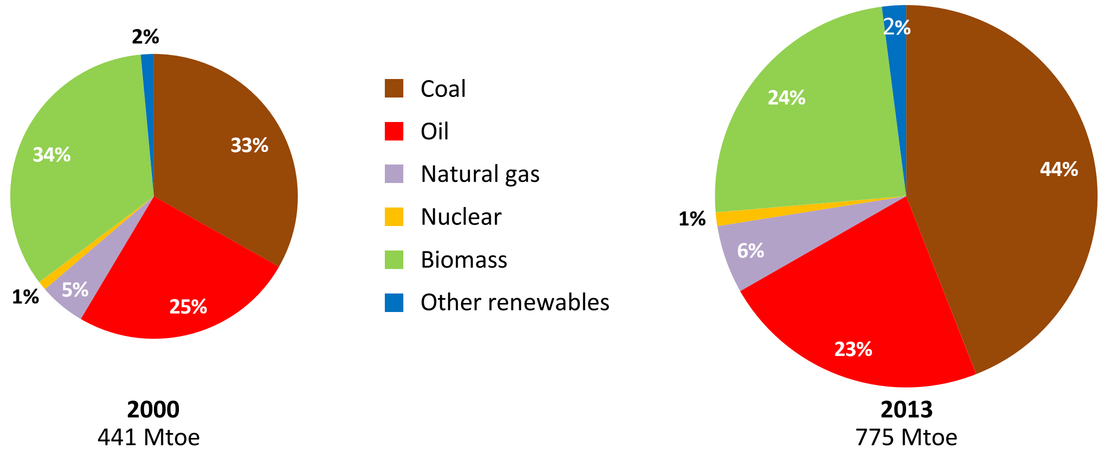
INR values based on figures from the International Monetary Fund

India shares the overarching aim of energy policy throughout the world: to provide secure, affordable and universally available energy as a means to underpin development, while addressing environmental concerns. The submission of India's INDC on 1 October 2015 was a milestone in both India's energy and environmental policy, which includes the twin energy-related commitments to increase the share of non-fossil fuel power generation capacity to 40% by 2030 (with the help of transfer of technology and low cost international finance) and to reduce the emissions intensity of the economy by 33-35% by the same date, measured against a baseline of 2005.

Fuels

The Indian energy mix is dominated by fossil fuels, as almost three-quarters of Indian energy demand is met by these fuel sources (Figure 3). This share has been increasing since 2000, as economic growth has increased demand in the industry and transport sectors while at the same time growth in energy demand in the building sector (which is dominated by **bioenergy**) has been subdued. Further, as households are gradually moving away from the traditional use of solid biomass in cooking and space heating to other fuels (notably liquefied petroleum gas [LPG]) and more modern technologies, the role of bioenergy in the overall Indian energy mix, on a percentage basis, was reduced even further. **Coal** now accounts for almost 45% of the primary energy mix (compared with under a third globally) – mainly because of the expansion of the coal-fired power generation fleet driven by the availability and affordability of coal relative to other fossil fuels. India has the third-largest hard coal reserves in the world, although deposits are generally of low quality (low to medium calorific value and high ash content). The production of coal in India was almost 340 million tonnes of coal equivalent (Mtce) in 2013 and India has a target of reaching a production of 1.5 billion tonnes by 2020.

Figure 3 • Primary energy demand in India by fuel type



In 2014 the consumption of **oil** was 3.8 million barrels per day (mb/d), 40% of which was used in the transport sector. The most widely consumed oil products are diesel, LPG and gasoline. Consumption is (or has been) subsidised to different degrees by the government. Diesel accounts for around 40% of total oil product consumption and for around 70% of road transport fuel use. The large consumption of diesel is explained by a high share of road freight traffic in the transport sector, but also by diesel subsidies, which were removed at the end of 2014. LPG consumption has increased rapidly since 2000 reaching over 0.5 mb/d in 2013, due to urbanisation and subsidies. The government is currently restructuring LPG subsidies from a price control mechanism to a direct benefit transfer scheme by linking the identification system “Aadhaar” to bank accounts.[2] Further, the government launched a “Give it up” campaign encouraging the wealthiest consumers to abandon their LPG subsidies. As of August 2016, over ten million Indians had voluntarily given up the subsidy.[3] Gasoline prices were deregulated in 2010. The domestic crude oil production of only 0.9 mb/d is far from enough to satisfy the demand for oil products of around 3.8 mb/d. This creates substantial import demand and in value terms, crude oil imports account for one-third of total imports to India averaging around $135 billion a year since 2011.

Natural gas plays a minor role in the Indian energy mix (6% in 2013 compared with 21% globally), and it is mostly used for power generation and as a feedstock, and fuel for the production of fertilisers. It also has a small, but growing role in the residential sector and as a transport fuel. **Hydropower, nuclear and modern renewables** (solar, wind and geothermal) are used predominately in the power sector but play a relatively small role in the total energy mix. As part of India’s Intended Nationally Determined Contribution (INDC) the government has set a target for renewables power generation capacity to reach 175 GW by 2022 (including the expansion of solar generation capacity to 100 GW).

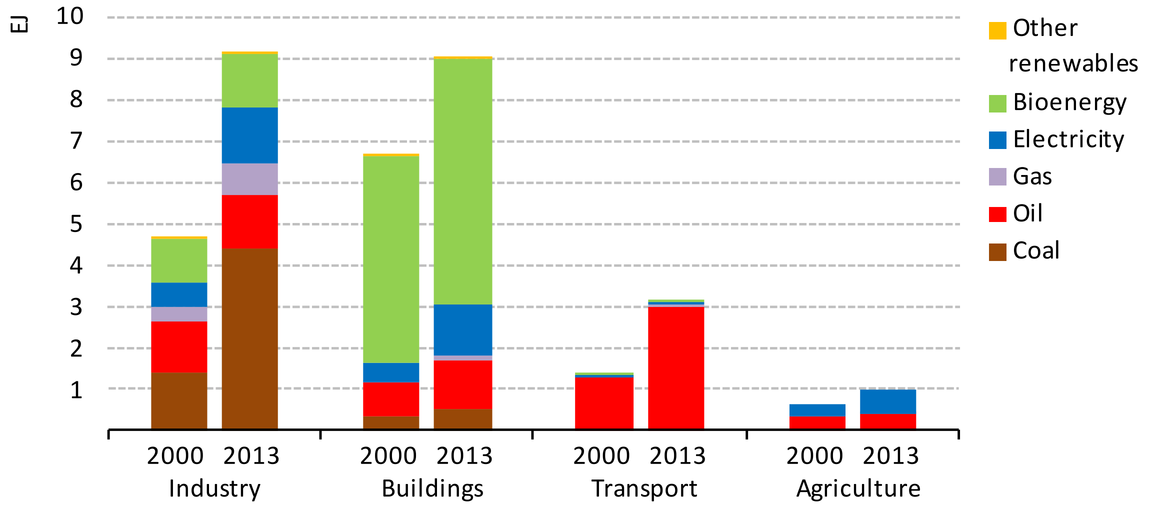
[2] Aadhaar is the intended 12-digit identification number for all Indian residents currently being setup by the Unique Identification Authority of India (UIDAI).

[3] See http://mylpg.in/index.aspx.

End-use sectors

Energy demand in the **buildings** sector[4] over the latter part of the 2000s has been driven in both rural and urban areas by increases in building floor area, rising levels of appliance ownership, especially of fans and televisions, and an increase in refrigerators and air conditioners in urban areas. As a result, electricity demand in the buildings sector grew at an average rate of 8% per year over the 2000-2013 period (Figure 4). In order to ease the growth in electricity consumption in the buildings sector (but also in industry and agriculture), the BEE set up a programme of minimum energy performance standards and energy efficiency labelling for appliances in 2006 (with 10 out of the 21 standards currently mandatory). Further, in June 2015 India officially launched the Smart Cities Mission, the centrepiece of which is the aim to develop 100 smart cities across India. Another objective of the mission is to reduce energy demand of existing buildings, via retrofits, and to enhance the efficiency of new construction more generally.

Figure 4 • Energy demand by fuel in selected end-use sectors in India



Notes: Other renewables includes solar photovoltaic (PV) and wind. Industry includes energy demand from blast furnaces, coke ovens and petrochemical feedstocks.

Industrial energy demand has almost doubled over the 2000-2013 period, with strong growth from coal and electricity (Figure 4). Large expansion in the energy-intensive sectors, including a tripling in steel production, is one component. Nonetheless, consumption levels of cement and steel are still relatively low for a country of India's size and income levels: consumption of cement is around 220 kilograms (kg) per capita, well behind the levels seen in other fast-growing economies and a long way behind the elevated levels seen in China in recent years (up to 1 770 kg per capita). The energy efficiency policies of the Indian government focus on the large consumers, for whom participation in an innovative market-based trading scheme for energy efficiency certificates (e.g. Perform, Achieve and Trade scheme) is mandatory for over 400 industries.

Over 90% of energy demand in the **transport** sector in India is from road transport. The country's passenger light-duty vehicle (PLDVs) stock has increased by an average of 19% per year since 2000, rising to an estimated 22.5 million in 2013, with an additional 95 million motorbikes and scooters (two and three-wheelers). Yet vehicle ownership levels per capita are still very low (i.e.

[4] The building sector includes the residential and non-residential sector, with the latter including, amongst others, public buildings, offices, shops, hotels and restaurants.

just below 100 vehicles per 1 000 people in 2013 of which most are two/three-wheelers) compared with other emerging economies and well below ownership levels of developed countries (i.e. above 200 vehicles per 1 000 people). Efforts to increase fuel economy of vehicles have been established through mandated fuel economy standards for passenger light-duty vehicles, to come into force in 2017-2018 (financial year), which require an average fuel consumption per new passenger light-duty vehicle of 4.8 litres per 100 kilometres (l/100 km) in 2022/23 (from around 6.0 l/100 km today) (BEE, 2015). Further, fuel economy standards for trucks in India are currently being considered and are likely to be in place by 2020.

The **agricultural** sector, though a small part of energy demand, is a key source of employment and since 2000 has accounted for roughly 15% of the increase in total final electricity demand as more farmers obtained electric pumps for irrigation purposes. Electricity use in agriculture is heavily subsidised, which has led to largely inefficient use of electricity.

Projecting Energy Trends and Energy Efficiency

The New Policies Scenario

The New Policies Scenario for India in this report is identical to that in the *World Energy Outlook 2015* (IEA, 2015b), and thereby draws on the same assumptions for economic and demographic aspects of the Indian society (Table 1).[5] Economic growth is expected to continue at a very fast pace with an annual average growth rate in GDP of 6.5% per year throughout the projection period (2013-2040). This is only slightly lower than growth in the period 2000-2013, where annual average growth was 7.2%. By 2040, India's economy is expected to be over five-times its current size and account for 14% of the world's GDP (up from 4% in 2013). The economic structure is also set to change significantly, as the role of the agriculture sector reduces and the commercial and public service sector continues to dominate the economy. The importance of the industry sector will also increase, supported by the "Make in India" initiative. Niti Aayog have also developed energy scenarios for India upto 2047 as described in Box 2.

Table 1 • Economic and demographic assumptions for India and other emerging countries in the New Policies Scenario

							Average annual growth rates	
		2000	2013	2020	2030	2040	2000-2013	2013-2040
India	GDP ($2014 billion, PPP)	2,778	6,883	11,446	22,517	37,915	7.2%	6.5%
	- Industry sector share	*31%*	*32%*	*33%*	*34%*	*34%*		
	- Services sector share	*41%*	*51%*	*54%*	*56%*	*58%*		
	- Agriculture sector share	*28%*	*17%*	*13%*	*10%*	*8%*		
	Population (millions)	1,042	1,252	1,359	1,495	1,599	1.4%	0.9%
	GDP per capita ($2014, PPP)	2,665	5,497	8,421	15,061	23,715	5.7%	5.6%
GDP per capita ($2014, PPP)	Brazil	12,013	16,266	16,971	23,398	31,569	2.4%	2.5%
	China	3,946	12,310	18,357	30,429	41,781	9.1%	4.6%
	Indonesia	6,066	10,198	13,891	21,526	29,809	4.1%	4.1%
	Russia	13,807	24,687	25,456	36,134	49,360	4.6%	2.6%
	South Africa	10,403	13,054	14,686	18,591	23,216	1.8%	2.2%

Population growth is expected to slow in the coming decades as income levels increase. In the New Policies Scenario we assume the population of India to reach almost 1.6 billion people in 2040. With lower population growth, GDP per capita is expected to continue at a rate of 5.6% on average per year, which is almost the same as the average annual rate of growth from 2000 to 2013. This is higher than many other comparable emerging economies and India, in terms of income levels per capita, is expected to catch up to some extent with these economies and indeed with the world. In 2013, India's GDP per capita was only a quarter of the world average (and 8% of the average GDP per capita in the OECD countries), but this ratio is expected to grow to 80% in 2040 (and just over 40% compared with the OECD countries).

Indian policy makers face the twin challenges of meeting the growing energy requirements, while also ensuring that the growth is equitably shared among its vast population. Therefore, many of

[5] See the *World Energy Outlook 2015* (IEA, 2015b) for a comprehensive overview of assumptions and results of the New Policies Scenario both for India and other world regions. Details on the assumptions regarding energy efficiency investment costs are included in http://www.worldenergyoutlook.org/weomodel/investmentcosts/

India's energy policies focus on energy security and reliability, diversity of supply, energy access and affordability. Table 2 shows a selection of the most important energy policies included in the New Policies Scenario, which consists of both existing and announced policies.[6] The New Policies Scenario does not cover all existing energy policies but focuses on those that have or will have significant potential energy savings. Subsidies are assumed to be completely phased-out by 2025 as part of a policy to gradually phase-out of subsidies to fossil fuels and electricity.

Table 2 • Selected policy assumptions for India in the New Policies Scenario

Cross-cutting policies
■ Energy-related National Missions from the 2008 National Action Plan on Climate Change (on solar energy and enhanced energy efficiency), as well as wind power targets set by the government.
■ A continued levy on coal (domestic and imported) to support the National Clean Energy Fund.
Energy supply
■ Measures to increase fossil-fuel supply, notably of coal, in order to limit import dependence.
■ Greater encouragement of private investment in energy supply, through easing of existing restrictions and simplification of licensing procedures.
■ Efforts to expedite environmental clearances and land allocation for large energy projects.
Power sector
■ A strong push in favour of renewable energy, notably solar and wind power, motivated by the target to reach 175 GW of installed renewable capacity (excluding large hydro) by 2022.
■ Enhanced efforts on village electrification and connection of households lacking electricity supply, with the aim of reaching universal electricity access.
■ Move towards mandatory use of supercritical technology in new coal-fired power generation.
■ Expanded efforts to strengthen the national grid and reduce losses towards the targeted 15%.
Transport
■ Fuel-efficiency standards for new cars and light trucks starting in 2016.
■ Policy support for biofuels (via blending mandates) and natural gas, hybrid and electric vehicles.
■ Dedicated rail corridors to encourage a shift away from road duty.
Industry
■ Efforts to increase the share of manufacturing in GDP, via the "Make in India" programme.
■ Enhanced efficiency measures in line with the Perform, Achieve and Trade (PAT) scheme; support for energy audits, as well as new financing mechanisms for energy efficiency improvements.
Buildings
■ Efforts to plan and rationalise urbanisation in line with the "100 smart cities" concept.
■ Moving from voluntary to mandatory appliance standards for a wider range of appliances.
■ Extension of the building code and efforts to incorporate it effectively into local and municipal by-laws.
■ Subsidies for LPG as an alternative to solid biomass as a cooking fuel.
Agriculture
■ Shift towards metered electricity consumption.
■ Continued gradual reforms to energy pricing, promotion of micro-irrigation, groundwater management and crop diversification.

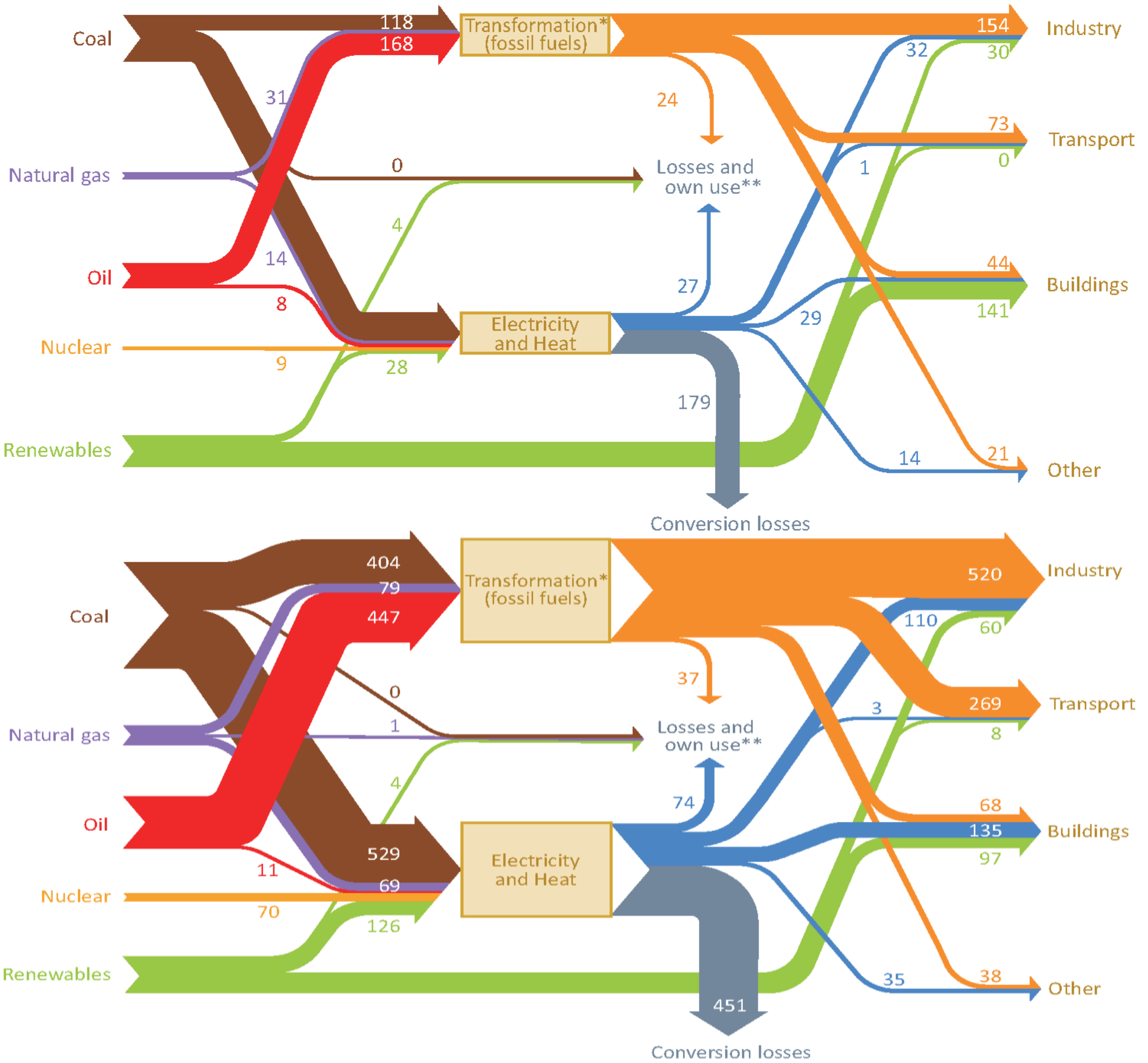
Note: Does not cover all existing energy policies but rather focuses on those that have or will have significant potential energy savings

The results of the New Policies Scenario show that India is moving to the centre stage of the world of energy. For instance, India overtakes China as the largest single source of rising demand both for coal and oil in the period to 2040, although China's consumption of the two fuels is still projected to be almost twice as high as that of India in 2040. Consumption patterns in India will not change dramatically, but will be amplified (Figure 5). Energy use in India more than doubles

[6] The energy-related pledges in India's INDC have not been explicitly included in the assumptions for the New Policies Scenario, as they were announced in October 2015, shortly before the publication of the *World Energy Outlook 2015*, but the key underlying policy measures that support the attainment of INDC objectives are taken into consideration.

to reach 79.5 EJ by 2040 (see Table 3 where the results are compared to the India Efficiency Scenario). Coal retains a central position in the mix, increasing its overall share in primary energy from 44% in 2013 to 49% in 2040, and the decline in the traditional use of solid biomass in household decreases the share of bioenergy in primary energy demand from 24% in 2013 to 11% in 2040. Total final energy consumption across India's end-use sectors – buildings, industry, transport and agriculture – increases by around 3.3% per year on average to 2040, more than doubling to reach 53.4 EJ, by which time it overtakes the level of final energy consumption in the European Union today. Strong growth in the transport sector and in industry, underpinned by the growing economy, increases their shares in overall consumption and consolidates the position of industry as the largest end-user of energy in the Indian economy.

Figure 5 • India's domestic energy balance in the New Policies Scenario, 2013 (top) and 2040 (bottom) in Mtoe



Note: * Transformation of fossil fuels (e.g. oil refining) into a form that can be used in the final consuming sectors (excludes blast furnaces and coke ovens). ** Includes fuel consumed in oil and gas production, transformation losses and own use, generation lost or consumed in the process of electricity production and transmission and distribution losses. *** Includes energy demand from blast furnaces and coke ovens, as well as petrochemical feedstock. Source: (IEA, 2015b).

Box 2 • India's Energy Security Scenarios 2047

The India Energy Security Scenarios 2047 (IESS), developed by NITI Aayog, is a flexible and interactive energy scenario building tool covering 21 energy demand and supply sectors at five year intervals up to 2047. It is an online open-source excel model with four levels:

- Level 1: Least effort scenario: a worst case scenario with poor domestic energy output, following past trends and with no major polices

- Level 2: Determined effort scenario: achieved through the implementation of current government policies

- Level 3: Aggressive effort scenario: an achievable scenario but will require significant and hard changes

- Level 4: Heroic effort scenario: a best case scenario with the highest efficiency possible

The tool was developed to support policy and decision makers on energy planning and facilitate discussions on possible policy measures in renewable energy and energy efficiency.

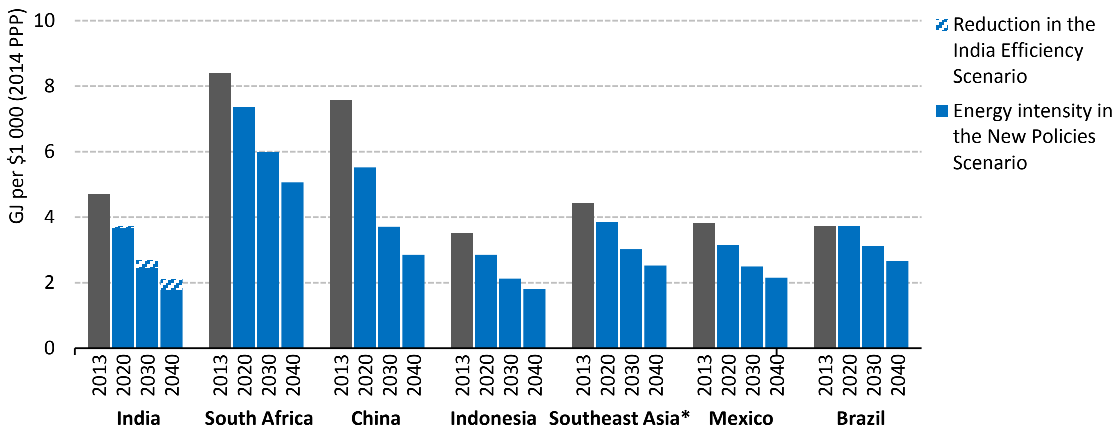
Source: (Niti Aayog, 2016)

The India Efficiency Scenario

The India Efficiency Scenario stands on the shoulders of the New Policies Scenario in the sense that all assumptions are the same, but the India Efficiency Scenario includes all economically viable possibilities to increase energy efficiency throughout the energy system.[7] This is made possible by the extensive technology detail in IEA's *World Energy Model* and by previous quantitative analysis done by the IEA on India, specifically the special focus on India in the *World Energy Outlook 2015* (IEA, 2015b). The *World Energy Outlook 2015* presented a specific scenario for India called the India Vision Case, which examined the implications of an accelerated realisation of key Indian policy targets, most importantly the "Make in India" initiative and expanding electricity access, whereby fundamental assumptions (e.g. the economic structure of India) was different from those of the New Policies Scenario. The India Efficiency Scenario in this report, however, uses the same fundamental assumptions as the New Policies Scenario and focuses exclusively on potential to increase energy efficiency.

There are several economic, market, institutional and behavioural barriers and perceived financial risks that are hindering the take-up of economically viable investments in energy efficiency in India, which could bring multiple benefits to consumers, producers and society as a whole. Overall, the India Efficiency Scenario shows that energy intensity of GDP in India can be improved by an estimated 19% in 2040. India currently has a high energy intensity compared to most emerging economies, excluding China, (17.2 GJ per $1 000 in 2013), and is already expected to experience a fast improvement in the New Policies Scenario where energy intensity drops to 7.5 GJ per $1 000 in 2040. If policies and measures to increase energy efficiency are expanded further, energy intensity could drop to 6.3 GJ per $1 000, which brings India in the same range as China and Indonesia in 2040 (Figure 6).

Figure 6 • Total primary energy intensity of GDP in selected countries in the New Policies Scenario and India Efficiency Scenario



Note: * excluding Indonesia

[7] An economically viable investment in energy efficiency is in this report defined as an investment in more energy efficiency end-use equipment with a shorter (undiscounted) payback period than the lifetime of the equipment.

Table 3 • Energy mix in the New Policies Scenario and energy savings by sector in the India Efficiency Scenario, 2013-2040

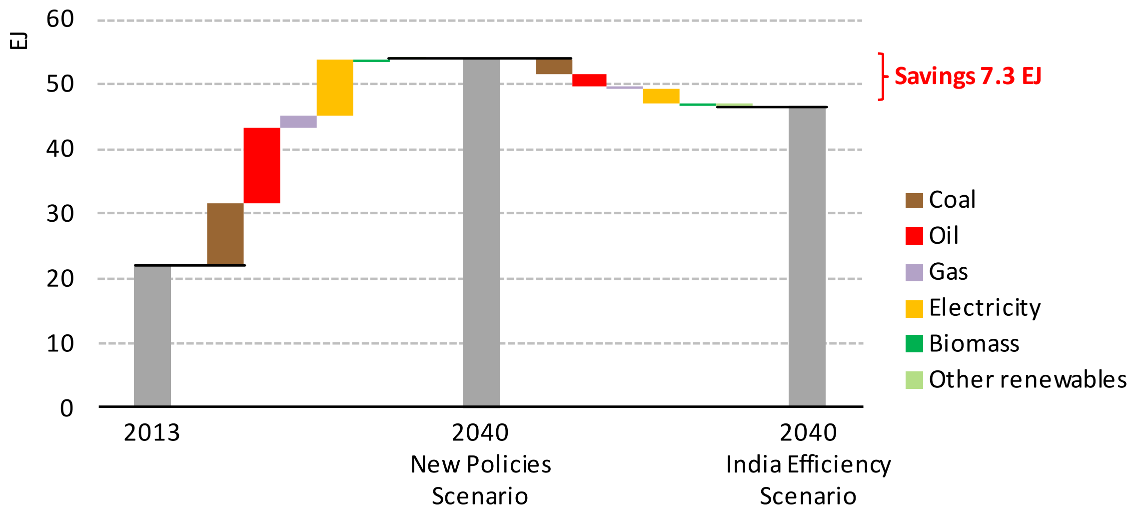
	New Policies Scenario, EJ				Energy savings in India Efficiency Scenario: Energy savings, EJ			Share of savings **		
	2013	2020	2030	2040	2020	2030	2040	2020	2030	2040
Total primary energy demand *	**32.5**	**42.6**	**60.3**	**80.0**	**-0.8**	**-5.4**	**-12.6**			
Power generation	**11.8**	**16.5**	**24.3**	**33.8**	**-0.6**	**-3.5**	**-7.3**	**82%**	**66%**	**58%**
Other energy sector	**2.9**	**3.8**	**5.7**	**7.7**	**-0.1**	**-0.6**	**-1.2**	**4%**	**4%**	**3%**
of which: electricity	*1.1*	*1.5*	*2.3*	*3.1*	*-0.1*	*-0.4*	*-0.8*	-	-	-
Blast furnace and coke ovens	0.6	1.1	2.1	2.8	-0.03	-0.2	-0.4	-	-	-
Total final energy consumption	**22.0**	**28.7**	**40.5**	**53.4**	**-0.3**	**-2.8**	**-7.3**	**14%**	**30%**	**39%**
of which: electricity	*3.2*	*4.8*	*8.0*	*11.8*	*-0.2*	*-1.2*	*-2.4*			
Residential buildings	**7.7**	**8.4**	**9.1**	**9.7**	**-0.1**	**-0.3**	**-0.7**	**18%**	**12%**	**9%**
Space cooling	0.2	0.3	0.8	1.7	-0.03	-0.2	-0.5	8%	8%	7%
Space heating***	0.9	1.0	0.9	0.7	0.00	-0.02	-0.03	1%	1%	0%
Water heating	0.2	0.3	0.5	0.6	0.00	-0.02	-0.03	1%	1%	0%
Lighting	0.5	0.4	0.4	0.4	-0.01	-0.01	-0.02	2%	0%	0%
Cooking	5.5	5.9	5.6	4.7	0.00	-0.01	-0.01	1%	0%	0%
Appliances	0.3	0.5	1.0	1.6	-0.02	-0.1	-0.1	6%	3%	2%
Non-residential buildings	**1.3**	**1.8**	**2.4**	**2.8**	**0.0**	**-0.3**	**-0.6**	**12%**	**10%**	**9%**
Industry ******	**7.7**	**11.0**	**17.5**	**24.0**	**-0.2**	**-1.7**	**-4.1**	**52%**	**60%**	**56%**
Iron and steel	1.3	2.2	4.2	5.6	-0.1	-0.4	-0.9	17%	15%	12%
Chemicals	0.9	1.1	1.5	1.8	0.00	-0.05	-0.1	1%	2%	2%
Cement	0.7	1.0	1.4	1.8	0.00	-0.1	-0.1	1%	3%	1%
Paper	0.1	0.2	0.3	0.3	-0.01	-0.02	-0.03	2%	1%	0%
Aluminium	0.2	0.3	0.5	0.7	-0.01	-0.03	-0.1	2%	1%	1%
Other industry	4.5	6.2	9.5	13.9	-0.1	-1.1	-2.9	28%	40%	40%
Transport	**3.1**	**4.5**	**7.4**	**11.7**	**0.0**	**-0.4**	**-1.7**	**11%**	**15%**	**24%**
Road	2.9	4.2	6.9	11.1	-0.04	-0.4	-1.7	11%	15%	24%
Road passenger	*1.7*	*2.5*	*3.5*	*5.5*	*-0.01*	*-0.1*	*-0.5*	*3%*	*3%*	*7%*
Road freight	*1.4*	*1.6*	*3.4*	*5.5*	*-0.03*	*-0.3*	*-1.2*	*9%*	*12%*	*16%*
Domestic aviation	0.1	0.1	0.2	0.3	0.0	0.0	0.0	0%	0%	0%
Other (rail, pipeline, navigation)	0.2	0.2	0.3	0.4	0.0	0.0	0.0	0%	0%	0%
Agriculture	**1.0**	**1.3**	**1.8**	**2.1**	**0.0**	**-0.1**	**-0.1**	**7%**	**2%**	**2%**
Non-energy use	**1.2**	**1.7**	**2.4**	**3.0**	**0.0**	**0.0**	**0.0**	**0%**	**0%**	**0%**
Petrochemical feedstocks	0.7	1.2	1.7	2.2	0.0	0.0	0.0	0%	0%	0%

Note : * Total primary energy demand is the sum of power generation, other energy sector and total final energy consumption, when electricity consumption have been subtracted from the two latter to avoid double-counting. ** Share of savings for power generation, other energy sector and total final energy consumption is relative to total primary energy demand (where electricity consumption has been subtracted from the two latter). For end-use sectors share of savings are relative to total final energy consumption. *** This includes consumption of non-modern fuels, such as biomass, for space heating **** In this report, when speaking of energy demand in the industry sector energy consumption in blast furnaces and coke ovens and petrochemical feedstocks are added to total final energy consumption in industry.

By 2040, the primary energy demand in the India Efficiency Scenario is 12.6 EJ lower than in the New Policies Scenario, a decrease of 16%. Looking at the savings throughout the energy system in India, the vast majority is due to lower power generation as energy efficiency decreases the demand for electricity (lower power generation accounts for almost 60% of the savings in primary energy demand in 2040). The lower electricity demand in end-use sectors is further amplified by the high degree of losses in the Indian electricity transmission and distribution network. Nearly 40% of savings in primary energy demand in 2040 is due to lower energy demand in end-use sector. Within end-use sectors, energy efficiency in the industry sector accounts for over half of the savings in total final energy consumption. This is not only due to the industry sector's large share of the energy mix, but also because of a disproportionally large share of cost-effective energy efficiency potential in the non-energy-intensive industry (a part of 'Other industry' in Table 3) specifically in small and medium sized enterprises in the unorganised sector[8] of the Indian economy. In the buildings sector (the largest end-use sector in 2013) the potential to increase energy efficiency lies in space cooling in particular, which is expected to grow significantly as income levels rise and access to electricity expands. In the transport sector, energy efficiency in trucks could reduce final energy consumption in transport by 15%.

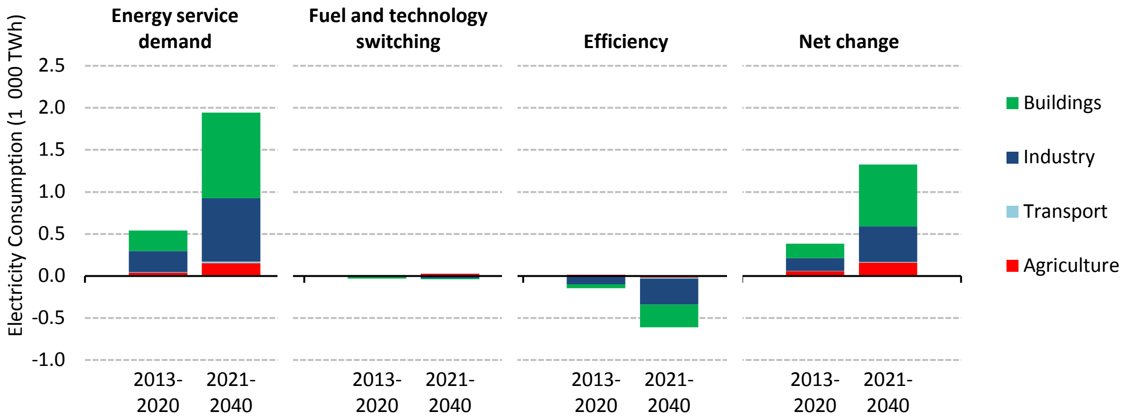
In terms of fuel use in end-use sectors, energy savings are primarily due to lower electricity, coal and oil demand, with shares of savings in total final energy consumption in 2040 of 41%, 31% and 19% respectively (Figure 7). The electricity savings stem not only from more energy efficient electrical equipment in buildings, but also from a significant potential to increase energy efficiency in electricity use in the industrial sector (in 2040 lower electricity demand in the industrial sector accounts for almost half of the total lower electricity demand). Looking at the electricity demand in the India Efficiency Scenario over the entire projection period (2013-2040) the industrial sector accounts for over half the energy efficiency savings, whereas the buildings sector accounts for just over 40% (Figure 8). Lower coal demand in the India Efficiency Scenario compared to the New Policies Scenario is almost exclusively from the industrial sector and lower oil demand in the transport sector accounts for over 80% of the total lower oil demand in 2040.

Figure 7 • Total final energy consumption by fuel in the New Policies Scenario and savings in the India Efficiency Scenario, 2013-2040



[8] The unorganised sector consists of all incorporated private enterprises owned by individuals or households engaged in the sale and production of goods and services operated on a proprietary or partnership basis and with less than ten workers (or twenty if not using electricity) (OECD, 2015)

Figure 8 • Change in electricity consumption by end-use sector and contributing factor in the India Efficiency Scenario, 2013-2040



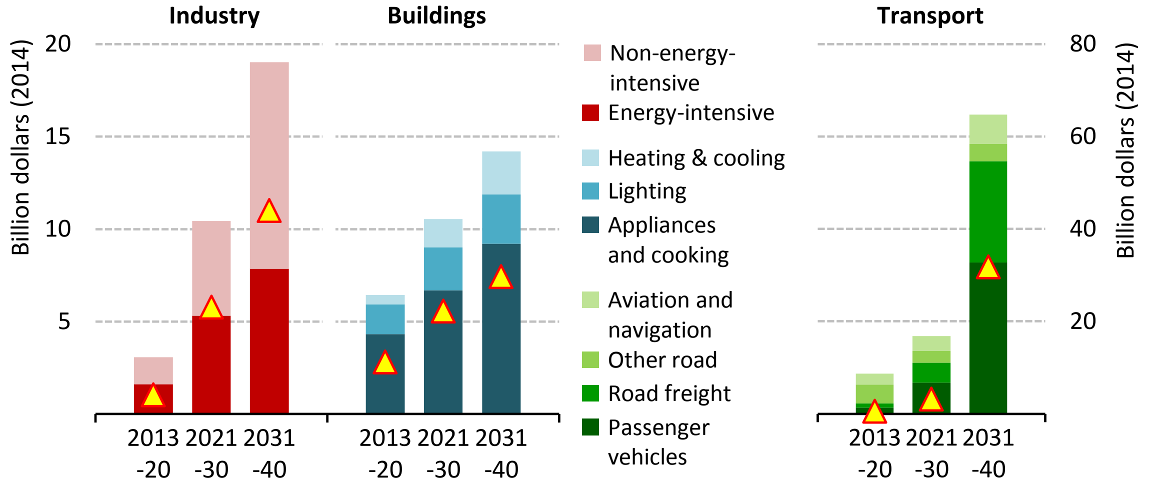
Investments and the cost-effectiveness of energy efficiency potentials

Expanding energy efficiency will require extra investments in order to cover higher up-front costs for more energy efficient equipment, machinery and vehicles. In the India Efficiency Scenario, investments in energy efficiency amount to an average of almost $60 billion a year over the projection period. This is almost twice the amount in the New Policies Scenario. Mobilising almost $60 billion in annual investment in end-use energy efficiency represents a big challenge, with hurdles taking different forms from sector to sector. Any success in realising the multiple benefits of the energy efficiency potential described in this report will depend on the success of efforts to move capital to these energy efficiency investments, robust implementation and effective delivery of energy savings.

Looking at how investments are distributed across sectors, results show that the transport sector accounts for the majority (Figure 9). India's transport system has been traditionally dominated by mass transport (buses, which are part of "other road" in Figure 9, currently account for about half of energy consumption in road transport), but in the future PLDVs are expected to take a more predominant role and account for the bulk of the increase in energy efficiency spending. The energy efficiency investments in the New Policy Scenario are amplified in the India Efficiency Scenario, where fuel economy standards for vehicles are tightened even further than in the New Policies Scenario. It is important to note that the India Efficiency Scenario does not increase its projection on the number of electric vehicles compared to the New Policies Scenario. The electric vehicle sector and its technologies are developing at a fast rate, which will be further reflected in the forthcoming World Energy Outlook projections. In the industry sector, investments will mostly be made in the less energy-intensive industries, including brick-making, textiles, food and machinery, which contrasts to where investments are currently made.

In the buildings sector energy efficiency investments are predominantly in appliances, spending on which rises with increasing income levels and therefore appliance ownership levels rise. In the New Policies Scenario, minimum energy performance standards for appliances are projected to become more stringent and mandatory for a wider range of appliances, including televisions, refrigerators and washing machines, although the higher investments in the India Efficiency Scenario indicate untapped energy efficiency potential. Efficiency spending for lighting plays an important role both in the New Policies Scenario (and therefore in the India Efficiency Scenario), as a consequence of India's current lighting programmes that will provide incentives to switch from incandescent light bulbs and compact fluorescent lamps (CFLs) to light-emitting diodes (LEDs) that are becoming more and more efficient (see Box 3).

Figure 9 • Average annual investments in energy efficiency in the India Efficiency Scenario, 2013-2040



Note: Yellow triangles indicate the extra investment in the India Efficiency Scenario compared to the New Policies Scenario. The volume of efficiency investment in the industry and buildings sectors is on the left axis; the higher volume of investment in transport is indicated on the right axis.

Box 3 • Efficient lighting on a grand scale

Energy Efficiency Services Limited (EESL), a joint venture of various state-owned companies, was established by India's Ministry of Power as part of the National Mission on Enhanced Energy Efficiency of Power. EESL has several projects underway to promote efficiency in households, public buildings, street lighting and agriculture. The major focus so far has been on lighting, in both buildings and street lighting, which together represent approximately 15% of national electricity consumption and can be reduced by at least 50% once old inefficient light bulbs have been replaced by LEDs. The level of ambition and the results have both been impressive, particularly as a result of strong political support.

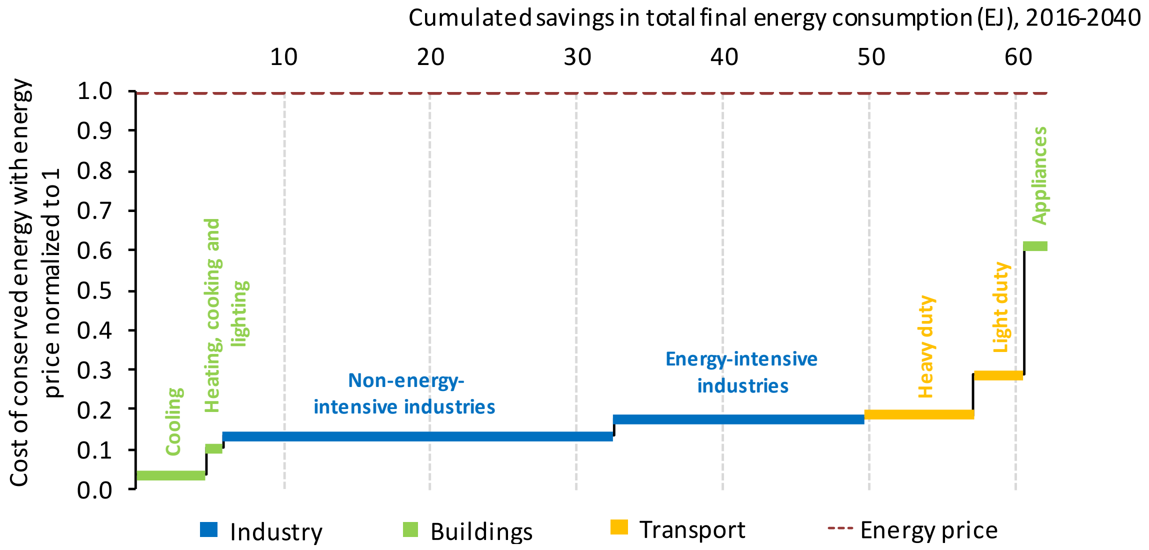
EESL is responsible for implementing the Street Light National Programme, which aims to replace 35 million inefficient light bulbs used for street lighting in 100 Indian cities. No additional investment has to be made by the municipalities because EESL finances the up-front cost and is paid through the financial savings from lower electricity bills under the pay-as-you save approach. In parallel, EESL is promoting efficient lighting in households and has provided more than 150 million LEDs across 14 states by August 2016. The target is to replace 770 million incandescent bulbs with LEDs by 2019. The higher up-front cost related to energy efficiency, which constitutes one of the main barriers to wider adoption, is financed by EESL and is either paid back by consumers via their electricity bills or paid back by distribution companies with an annuity over a period of three to ten years.

The commitment from EESL to efficient lighting has been a game changer for India's lighting market. The assurance of a stable, large-scale demand for LEDs has led to the build-up of domestic production, driving down the bulk procurement price paid by EESL for one high quality 9 watt LED bulb from more than INR 300 ($4.5) at the start of 2014 to around INR 56 ($0.8) in mid-2016. Similarly the retail price of LED bulbs has been cut to about INR 200 ($3.0), significantly lower than European and US retail prices. Next in line for EESL are initiatives to accelerate the deployment of highly efficient ceiling fans, air conditioners and electric pumps used in agriculture.

Source: (IEA, 2015b) (EESL, 2016a).

To measure the cost-effectiveness of the extra investments in the India Efficiency Scenario (compared to the New Policy Scenario) we use the metric cost of conserved energy, which measures how much it costs to save a unit of energy.[9] A measure is considered cost-effective when the cost of conserved energy is less than the price of the energy used. The larger the difference between the cost of conserved energy and the energy price, the more cost-effective the investment is. On average the costs of conserved energy of the extra investments in the India Efficiency Scenario is one-fifth of the energy prices, meaning that every rupee invested in improving energy efficiency would save five rupees (Figure 10). Seen over the projection period, the savings in the industry sector occur at a cost of conserved energy of only 15% of the energy price. Another metric for measuring cost-effectiveness, which could be more familiar especially in the industry sector, is the internal rate of return.[10] In the energy-intensive sector, investment opportunities have an average internal rate of return of about 25% over the period, which is dwarfed by the impressive internal rate of return in the non-energy-intensive sector at nearly 100%. In the transport sector, investments look particularly cost-effective in heavy-duty vehicles, which includes medium-duty and trucks, where the latter accounts for almost three-quarters of the energy savings and show more cost-effective investment opportunities (costs of conserved energy are on average 19% of the energy price in trucks). In the buildings sector, cooling shows both the largest energy savings potential and the most cost-effective investment of all investments in the India Efficiency Scenario. Savings are reached at a cost at only 4% of energy price.

Figure 10 • Estimated average cost of conserved energy of energy efficiency investments in selected end-uses in the India Efficiency Scenario (normalized energy prices), 2016-2040



Note: The energy prices have been normalized to 1 as different sectors and end-uses use different fuels and therefore face different energy prices. Only residential buildings are included in this figure.

Power system effects and lower investments needs

The power system in India has to cope with a number of challenges for the future, all of which will be eased if energy efficiency is improved throughout the system. Power generation capacity needs to be expanded to serve rapidly growing power demand (in the New Policies Scenario, electricity demand more than triples over the period to 2040) in a way that incorporates flexible

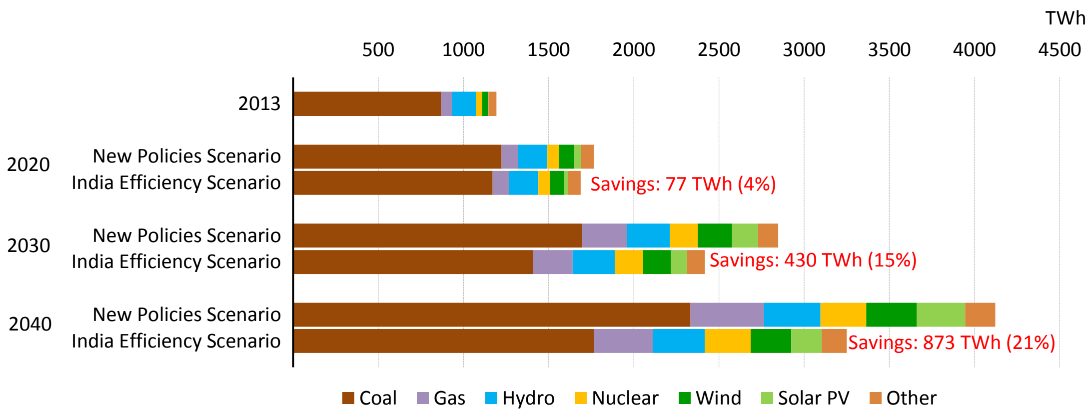
[9] The cost of conserved energy is defined as the additional investment ($) per unit of saved energy (toe or joules).

[10] The internal rate of return is the discount rate which implies a net present value of a cash flow of zero.

power plants to meet demand at any time, and integrates variable renewable energy technologies. Electricity transmission and distribution networks will need massive investments to transport growing amounts of power, and to bring down the notoriously high network losses (average network losses in India are currently 20%, which is amongst the highest in the world). However, the financial situation of Indian distribution utilities can hinder these investments as they have been accumulating large financial losses, because of the way electricity subsidies are organised (IEA, 2015b). How India addresses these challenges is primarily a question of policy, but energy efficiency in end-use sectors will decrease demand for electricity and thereby helping to reduce these challenges.

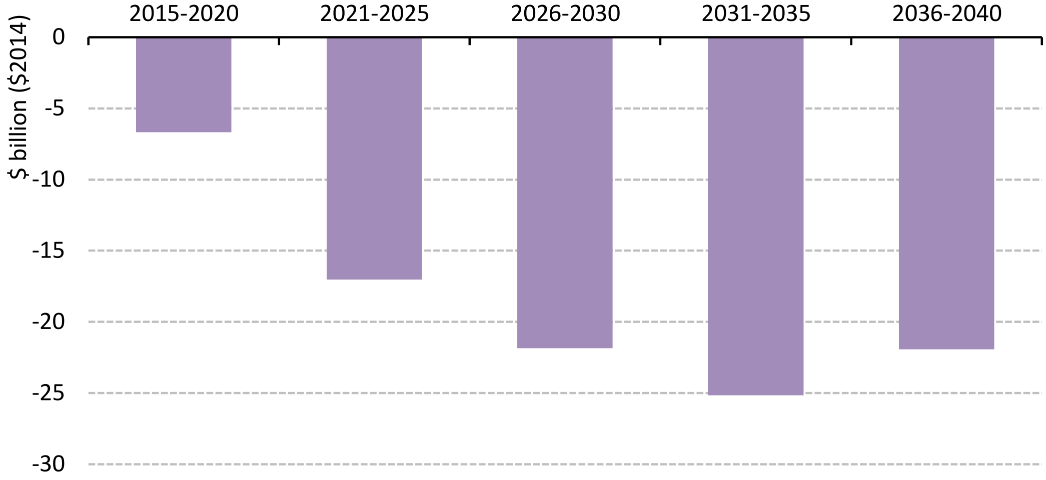
With lower electricity demand, lower electricity production will naturally follow amplified by the high losses in transmission and distribution in India. The growth in electricity generation will thereby be slower in the India Efficiency Scenario compared to the growth in the New Policies Scenario (Figure 11). In the New Policies Scenario, electricity production increases from 1 193 TWh in 2013 to over 4 100 TWh in 2040, meaning that power output in India is larger than power generation in the European Union by 2035. The power generation mix becomes increasingly diverse as the share of coal in the power mix drops to 57% (down from 73% today), with renewables, nuclear and gas all increasing at high rates. In the India Efficiency Scenario, energy savings in the industry, building, transport and agriculture sector enables the power sector to avoid producing about 875 TWh in 2040 (a 21% drop compared the New Policies Scenario).

Figure 11 • Savings in electricity generation in the India Efficiency Scenario, 2013-2040



The significantly lower electricity demand has great implications for the expected growth in capacity and fuel consumption in the power system. Fuel consumption in the power sector is projected to increase by almost three times from 282 Mtoe in 2013 to over 800 Mtoe in 2040 in the New Policies Scenario, which is lowered by 175 Mtoe in 2040 in India Efficiency Scenario (an amount just above the total final energy consumption in Indonesia in 2013). Over three-quarters of these savings occur in coal demand. Installed power generation capacity is expected to increase by three-and-a-half-times, from 290 GW in 2014 to over 1 075 GW in 2040 in the New Policies Scenario. In the India Efficiency Scenario, however, installed capacity grows to “only” 835 GW (a reduction of 22%). With significantly lower capacity needs, the necessary investments to facilitate India’s expected energy demand growth are also substantially reduced (Figure 12). On average, over the projection period power system investments (i.e. investments in power plants and network) are about $18 billion lower in the India Efficiency Scenario compared to the New Policies Scenario.

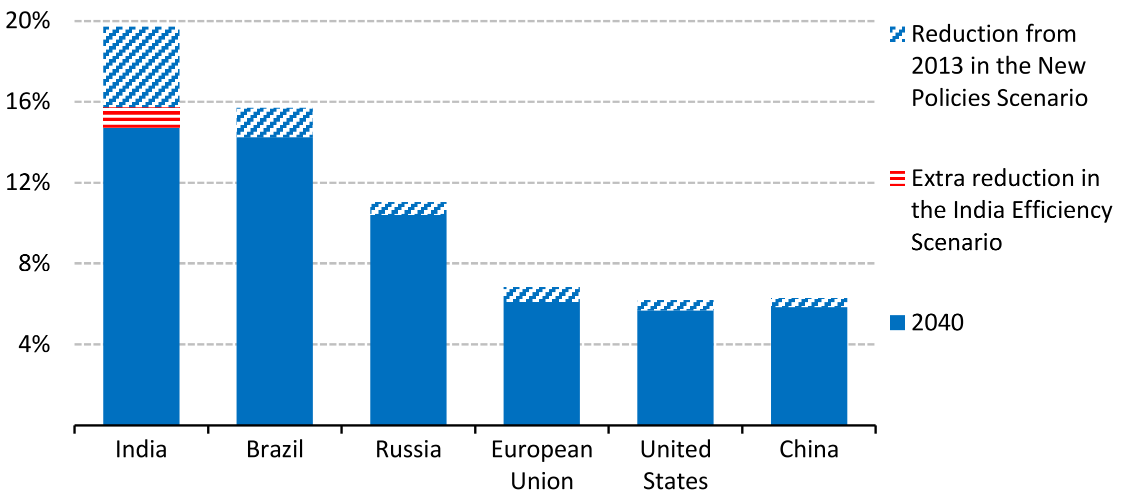
Figure 12 • Reduction in average annual power system investments in the India Efficiency Scenario compared to the New Policies Scenario



Transmission, distribution and commercial losses

India's network suffers from one of the highest shares of loss (of electricity generation) in the world (Figure 13). Network losses are driven by technical and commercial factors. The technical losses typically increase with ambient temperatures and distance between generation sources and demand centres. Ageing and poorly maintained networks are more prone to high technical losses than modern and efficient installations. On the commercial side, theft, unmetered consumption and inadequate revenue collection contribute to network losses. In our projections in the New Policies Scenario, India takes steps to bring down network losses over time, with the share dropping from 20% today to 16% in 2040.

Figure 13 • Transmission and distribution losses in India and selected countries in the New Policies Scenario



The projected drop in transmission and distribution losses in the New Policies Scenario is large compared to other regions and will require many policies to be successful. In the India Efficiency Scenario, we project that a further 1% point drop is possible bringing the total transmission and distribution losses in 2040 to 15%, due to a stronger effort to bring down commercial losses. Although estimates about the degree to which the high network losses are because of commercial losses are scarce, the issue remains high on the agenda for Indian policy makers due to the detrimental financial impacts for distribution utilities. From an energy efficiency perspective, un-billed consumption and theft is a problem as the illegal consumer does not face an incentive to save electricity. With a price of zero, electricity consumption is effectively subsidised, and acts in these cases as a redistribution mechanism, which makes it a sensitive public issue. Therefore efforts to bring down commercial losses should be complemented with efforts to expand electricity access and eliminate poverty, in order to enable the poorest part of the Indian population to be able to benefit from energy services and pay for them.

Policy Recommendations for Energy Efficiency in Power Generation

India offers substantial opportunities for investment in energy efficiency on both the supply side and the transmission and distribution network. The potential measures tend to require high initial investments but will provide significant economic benefits in the medium to long-term as India's power sector expands.

Improvement of metering and billing of consumers

It is essential for state governments and state utilities to improve metering, billing and collection to provide consumers with information on the real value for electricity and incentivise better use of electricity and efficiency measures. Adequate metering will support the reduction of distribution losses and help improve the state utilities balance sheet, potentially allowing them to invest in higher efficient transmission and distribution infrastructure, in renewable and higher efficiency power generation as well as in demand-side management and energy efficiency measures.

Reducing transmission and distribution losses

Reducing the current high transmission and distribution losses is paramount and should be a central and state government priority such as shown by the introduction of the Ujwal Distribution Companies Assurance Yojana. Concerted efforts should be made to bring down the physical losses of electricity through the investment in efficient transmission and distribution systems such as high efficiency transformers, superconducting transformers and high temperature superconductors and potentially, in the future, direct current and ultra-high voltage transmission.

Overall, continued reduction of technical losses will help bring network costs down over time, despite grid expansion and the growing volume of power transmission. This is the key to countering rising power generation cost and keeping power affordable for all.

Moving to higher efficiency power generation

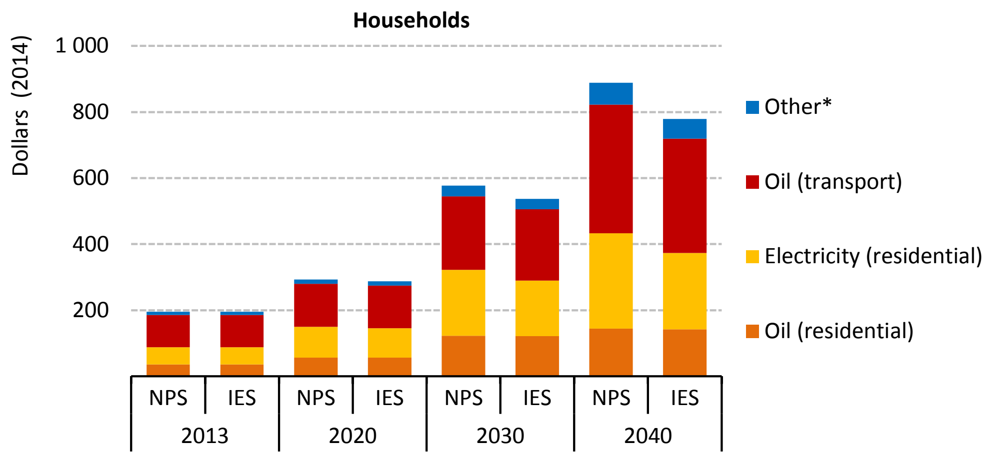
With its fast growing demand for electricity generation, India has a unique opportunity to ensure that all new coal power generation uses the best available technology (e.g. super critical and ultra-supercritical technology), especially as these power plants will likely last more than forty years. The higher capital cost of these technologies is justified by higher efficiency and therefore helps reduce fuel expenditure compared to sub-critical coal power plants. In addition, high efficiency power generation can help generation costs be less exposed to the volatility of coal prices. The central and state governments should assess and consider mandating the use of best available technologies in new coal-fired power generation and, if possible, upgrade existing subcritical coal power plants. Over the last couple of years, the government has recognised and made good progress on this front with approximately 52 supercritical units commissioned with total capacity of 36 GW and with approximately 45 GW under construction (MOP, 2016). Coal thermal power capacity amounted to 186 GW in 2016 (CEA, 2016).

The Multiple Benefits of Energy Efficiency

Energy spending

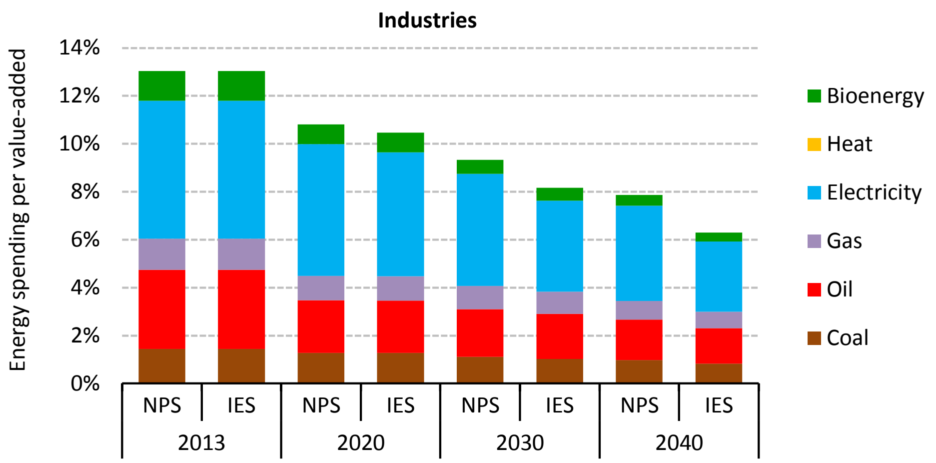
In the two scenarios it is assumed that the average disposable income for Indian households increases from just above $6 000 per year in 2013 to almost $22 000 in 2040 (in 2014 dollars). As living standards rise and energy consumption increases, the average Indian household expenditure on energy is expected to increase from just under $200 in 2013 to almost $900 per year in the New Policies Scenario (Figure 14 and Figure 15). Because of lower energy consumption in the India Efficiency Scenario this could be reduced by 12% in 2040 making energy spending about $780 per year. For Indian industries, the average energy spending as a share of the created value-added is expected to decline from about 13% today to reach 8% in the New Policies Scenario. In the Indian Efficiency Scenario this is lowered to 6% in 2040, as more efficient equipment reduces demand for energy.

Figure 14 • Average fuel expenditure in households, 2013-2040



Note: NPS = New Policies Scenario. IES = India Efficiency Scenario. * Includes coal and natural gas used in the residential sector, and biofuels, electricity and natural gas used in transport.

Figure 15 • Average energy spending per value-added for industries, 2013-2040

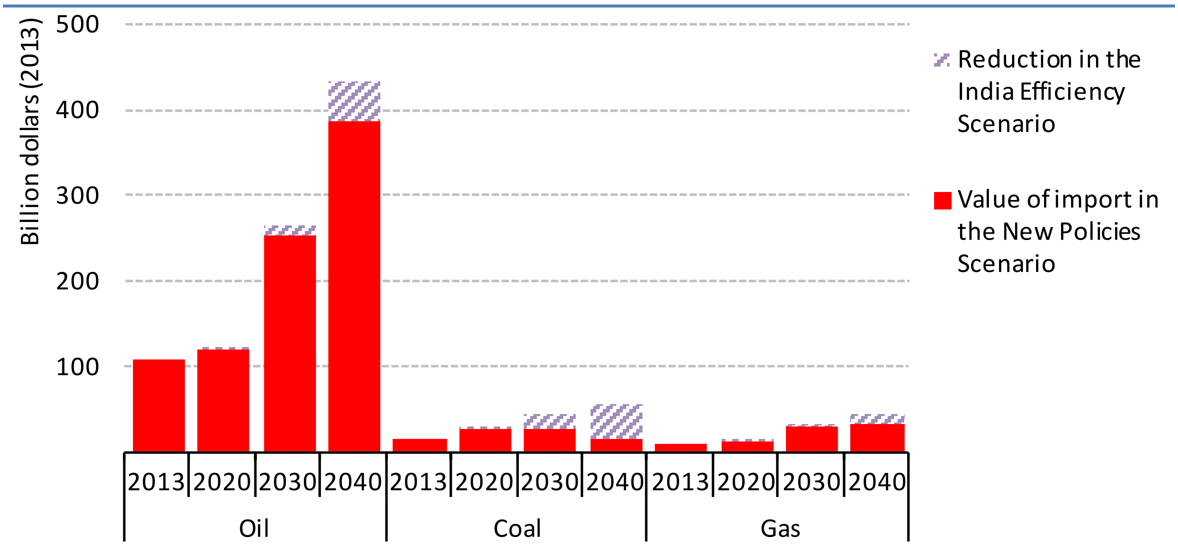


Note: NPS = New Policies Scenario. IES = India Efficiency Scenario.

Fossil fuel import bills

India is the third-largest importer of crude oil in the world. In value terms, crude oil imports account for one-third of total imports in India averaging around $135 billion a year since 2011. Indian policy makers are aware of this challenge, and have an energy security objective of reducing reliance on fossil-fuel imports by 10%. Adding oil, coal and natural gas the value of imports in India in 2013 was close to $140 billion (in 2014 dollars). With the expected growth in energy demand in the New Policies Scenario this number is expected to increase significantly to over $530 billion in 2040 (Figure 16). Most of the increase comes from oil, which reflects both the higher oil prices in the future (see (IEA, 2015b)) for a comprehensive analysis of the current low oil prices), and a more than three-fold increase in volume of oil imports from 2.8 mb/d currently to 9 mb/d in 2040. In the India Efficiency Scenario the value of imports of oil, coal and natural gas is reduced by 18% to almost $440 billion in 2040.

Figure 16 • Oil, coal and natural gas import bills in the New Policies Scenario and potential savings due to energy efficiency in the India Efficiency Scenario, 2013-2040



Implications for air quality

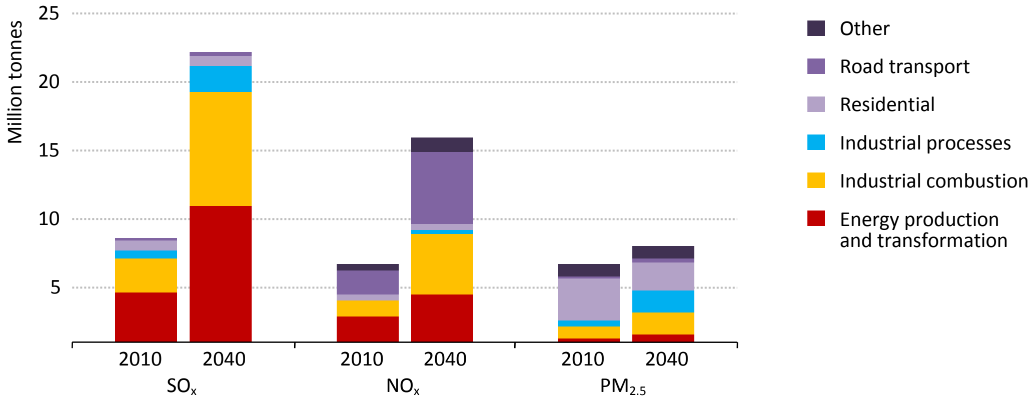
India is currently burning more fossil fuels and biomass than it has at any other time in the past. As it does this, it is releasing more pollutants into the air than ever, including fine particulate matter ($PM_{2.5}$)[11], sulphur oxides (SO_x) and nitrogen oxides (NO_x). India has 13 of the world's 20 most-polluted cities and an estimated 660 million people live in areas in which the government's own national air quality standards are not met. It is estimated that life expectancy, as a result, is reduced by 3.2 years for each person living in these areas. Furthermore, an additional 315 million people – almost the population of the US – is expected to live in urban areas by 2040, exacerbating the problem. The *World Energy Outlook 2015* (IEA, 2015b) special focus on India presented an analysis of the impact of the New Policies Scenario on the amount of emissions of each of the mentioned pollutants, to help identify the improvements that can be made in the energy system to manage these issues.[12] The results showed that over the period to 2040,

[11] $PM_{2.5}$ refers to particulate matter less than 2.5 micrometres in diameter; these fine particles are particularly damaging to health as they can penetrate deep into the lungs when inhaled.

[12] The analysis of the impacts of future local air pollution trends has been developed in collaboration with the International Institute for Applied Systems Analysis.

emissions of SO_x rise to more than twice their current levels, with a similar increase in NO_x emissions and slower growth in $PM_{2.5}$ emissions (Figure 17). The large increases in SO_x and NO_x emissions are primarily due to coal combustion in the power plants and industrial process (and increased oil combustion in the transport sector for NO_x). The emissions of $PM_{2.5}$ are related to incomplete combustion of biomass by households and industry. There are two conflicting trends; households will emit fewer particles as biomass is substituted with modern fuels, but biomass combustion in industry is expected to increase.

Figure 17 • Emissions of NOx, SOx and PM2.5 in the New Policies Scenario by sector, 2010 and 2040



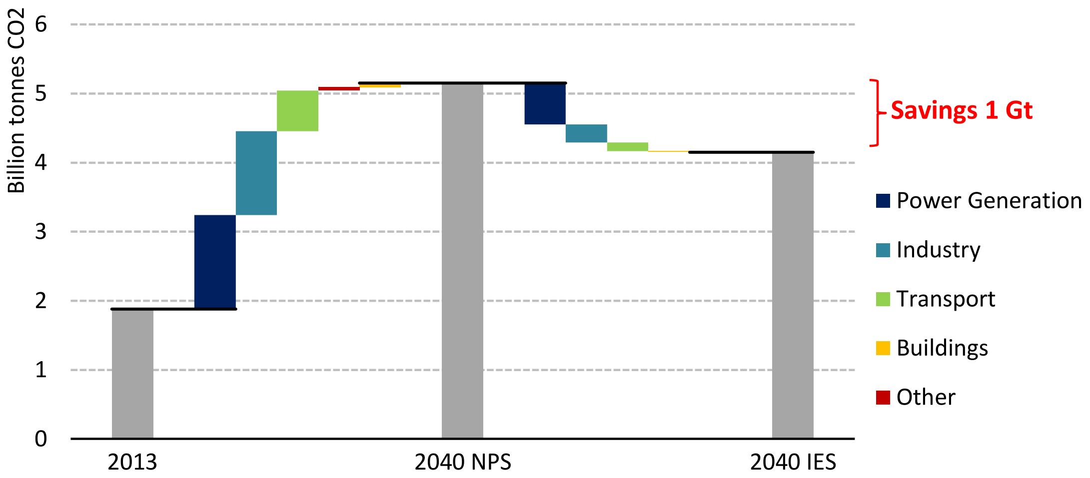
Source: (IEA, 2015b).

Lower energy use in all energy sectors in the India Efficiency Scenario will dampen the emission of local pollutants and thereby improve the air quality in India, especially since a large share of the energy savings will come from lower coal demand in the power sector. Energy efficiency therefore also acts as a tool for Indian policy makers to lower public health impacts of India's rapid economic development, although it is important to complement energy efficiency with specific air pollution policies, for instance tighter controls on emissions from combustion plants, higher standards for exhaust emissions from road vehicles and an accelerated roll-out of more efficient biomass cook stoves.

Effects on CO_2 emissions

In the New Policies Scenario, energy-related CO_2 emissions increase from 1.9 Gt in 2013 to 5.2 Gt in 2040, but if all the economically-viable energy efficiency potential is used (as in the India Efficiency Scenario) this number is lowered by 1Gt (or 19%) to 4.2 Gt (Figure 18). Currently, India's CO_2 emissions per capita are relatively low at just one-quarter of China's and the European Union's and one-tenth the level in the United States. However, India is the third-largest emitter of CO_2 emissions in the world, behind only China and the United States, because of India's large economy and high dependence on coal for power generation and the use of inefficient subcritical plants for combustion.

Figure 18 • Energy-related CO2 emission abatement due to energy efficiency, 2013-2040



Cross-cutting Policy Recommendations

This section reviews cross-sectoral policies that impact all sectors. Reviews of five key topics[13] follow with descriptions of the progress being made in India and recommendations for further action. Overall, governments play a crucial role in setting the environment for energy efficiency by coordinating policies across all sectors to address certain issues like data, prices and market barriers. Coordination across ministries and state governments as well as between government and the private sector is essential. Effective energy efficiency governance comprises of the combination of regulatory frameworks and funding mechanisms, institutional arrangements, and co-ordination mechanisms, which are integrated and support the implementation of energy efficiency policies.

Strategies and Actions Plans

Based on analysis of energy use, markets, technologies and efficiency opportunities, governments should formulate and regularly update strategies and action plans for improving energy efficiency throughout their economies. In India, a major milestone for energy efficiency policy was the establishment of the Energy Conservation Act in 2001 and the creation of the BEE in 2002 by the MOP. The BEE is tasked with the development, implementation and monitoring of energy efficiency policies in India. The Planning Commission, now known as the National Institution for Transforming India (NITI Aayog), is broadly responsible for governing the energy policy landscape in the country. The National Mission for Enhanced Energy Efficiency (NMEEE), established under the National Action Plan on Climate Change in 2008, establishes new programmes and initiatives to contribute to climate change mitigation through energy efficiency. The new Integrated Energy Policy, planned by NITI Aayog, will provide a unique opportunity for strengthening the cross-sector framework for energy efficiency based on past experience and lessons learned.

[13] Based on IEA's 25 Energy Efficiency Policy Recommendations - www.iea.org/publications/freepublications/publication/25-energy-efficiency-policy-recommendations---2011-update.html

Data Collection and Indicators

Reliable and timely data on energy end uses, markets, technologies and efficiency opportunities in all sectors contribute to the development of effective energy efficiency strategies and policies. Data collection during the design, implementation and evaluation phases is an essential part of any energy efficiency policy, and the development of indicators can help in monitoring their progress over time. Official energy data in India is available from a wide variety of sources and compiled by the Central Statistics Office, while the MOP and the BEE take the lead on collecting and compiling energy efficiency data and developing indicators. It is important to enhance coordination amongst all these organisations to maximise resources and data quality. EESL and state utilities also collect relevant data as part of the implementation and evaluation of their demand-side management projects.

There has been an improvement in energy data compilation to support effective energy efficiency strategies and policies in India in the past ten years. For example, the PAT scheme has helped gather better data on the industrial sector as well as enabled the monitoring of their performance and benchmarking it against other industries and good practices. Nevertheless, the Central Statistics Office's Energy Statistics 2015 highlights the need to improve disaggregation of energy data to enable adequate monitoring of energy efficiency (CSO, 2015)[14]. The MOP and BEE should continue to augment this effort to gather quality and reliable data and seek alignment with international best practices. It will be essential to ensure there are adequate data collection and a monitoring framework in place for energy efficiency policies supported by regular training and capacity building.

Competitive Energy Markets with appropriate Regulation

Governments should periodically review regulations and subsidies to ensure that retail energy prices reflect the full costs of energy supply and delivery, including environmental costs. India is undergoing a major subsidy reform to cut fossil fuel subsidies. In 2014, fossil fuel consumption subsidies amounted to $38.2 billion in India (4th highest in the world and 1.9% of India's GDP) of which approximately 78% were for oil, 12% for gas and 10% for electricity. This represented a decrease from $47.2 billion in 2013 as a result of the government's reform of diesel subsidies in 2014, following similar reforms to gasoline in 2010. This is a major step for the Indian government to reduce the financial burden of fossil fuel subsidies on the public purse. However, the government should continue to review regulations to ensure that retail energy prices reflect the full costs of energy and enable a greater investment in energy efficiency from the private sector.

Private Investment in Energy Efficiency

Energy efficiency investment in India is still very dependent on government regulation and funding. The private sector, including local banks and energy service companies (ESCOs), has yet to explore the potential for energy efficiency services and financing in India. Energy efficiency is a potentially multi-billion dollar market in India (USAID, 2013) (EESL, 2016b) (Sustainability-Outlook, 2016). Governments should facilitate private investment in energy efficiency by

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[14] As stated in the Central Statistics Office's Energy Statistics 2015, "*(…) total final consumption is disaggregated into sectors, like industry, transport, residential, services and others. However, the level of disaggregation of such energy data is not enough to monitor energy efficiency, as no information is given for example on the residential or services end uses, nor on the transport vehicle types or segments.*" *Source: http://mospi.nic.in/Mospi_New/upload/Energy_stats_2015_26mar15.pdf*

supporting energy efficiency capacity building, standardised measurement and verification protocols, including for energy performance contracting, private lending and energy efficiency technology research, development demonstration and deployment (RDD&D). The Indian government has introduced several energy efficiency programmes that are contributing to a rise in private investment in energy efficiency. For example, the NMEEE seeks to unlock more than $10.8 billion of investment across different sectors including lighting. In the industrial sector, NMEEE introduced the PAT scheme that targets large industrial energy consumers to generate energy savings. EESL is making substantial investments and expects to invest $27 billion from 2015 to 2019 leading to annual energy savings of 140 billion kWh. The Indian government should continue to raise its ambition triggering further private investment in energy efficiency. The government should continue to implement targeted education and capacity building programmes, such as the BEE's Energy Savers Programme[15], to enable effective decision-making and investment in energy efficiency in all sectors.

Monitoring, Enforcement and Evaluation of Policies

There is a need to improve energy efficiency monitoring, enforcement and evaluation in India as there are several examples of data gaps and limited funding to undertake adequate monitoring and evaluation activities at both national and state level (RAP, 2014). The government should make a greater effort to monitor, enforce, evaluate, and periodically update, energy efficiency policies and measures in all sectors. Policy and programme effectiveness should be evaluated during and after implementation, with the results used as an input to subsequent decision making and planning. Monitoring and evaluation, with baseline assessments and periodic review and reporting, should be established when new policies and measures are implemented. Non-compliance should be identified with a fair and transparent process, and should be reported and made public. Associated penalties should be clear and serve as constructive deterrents to non-compliance. In India, continued data collection and evaluation of programme and policy effectiveness should be a priority to enable improvement in future energy efficiency policies.

Energy Efficiency Potential by Sector

Industry

Energy needs in industry have almost doubled since 2000 from 4.6 EJ to 9.1 EJ in 2013, which is an average annual increase of 5.3% per year. Currently, industrial energy demand accounts for around 40% of total final energy consumption in India. Almost half of the current energy demand in industry is met by coal, with the rest supplied almost evenly by oil, gas, electricity and bioenergy (Figure 19). The majority of the bioenergy is used mainly in the small cottage industry and agro-industries. However, from 2000 to 2013, energy intensity in the industrial sector actually dropped by 74%, which could be related to several factors such as changes in industrial fuel type, efficient technologies, changes to less intensive industry and national GDP growth (IEA, 2016a). The largest industry in India in terms of energy use is the steel industry (21% of total demand), which reflects the development stage India is (and has been) in as industrialisation, rising incomes and urbanisation increases demand for building materials. Further, India has become an important global manufacturing hub for energy-intensive building materials. Steel production has increased by 9% per year since 2000. The increased demand for building materials

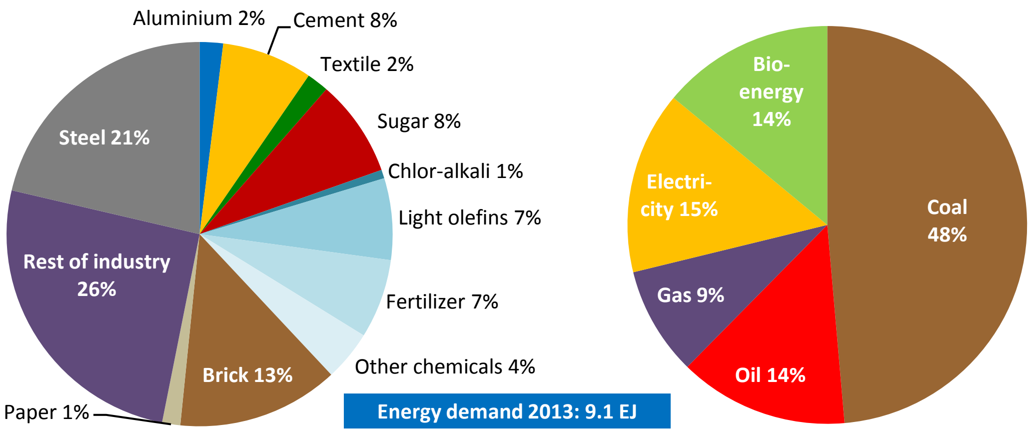
[15] http://energysavers.co.in/

is also visible in the cement industry, which has experienced similar growth rates in production. Further, the brick industry is the second largest energy consumer in the industry sector as a large part of demand for building materials is still supplied by traditional clay bricks.

The rapid increase in energy demand in the industry sector is projected to continue, although at a slightly slower pace. We project industrial energy demand to increase by 4.4% annually to 2040, representing more than 50% of final consumption by 2040. With continued economic growth India's demand for infrastructure in the future will be substantial and will drive the demand for energy-intensive materials. In addition, industries ranging from chemicals, textiles and food to transport equipment are increasing their production quickly to satisfy the needs of a larger and more prosperous society.

The structure and patterns of energy consumption in the various industrial branches in India are very different: some energy-intensive industries, including chemicals, cement, aluminium and, to some extent, steel, are dominated by large enterprises; others, particularly the brick industry, consist of thousands of small and medium enterprises (SMEs). The latter, with generally poor energy performance, account in total for about 45% of manufacturing output (SME Chamber of India, 2015). The energy efficiency policies of the Indian government focus on the large consumers, for whom participation in an innovative market-based trading scheme for energy efficiency certificates is mandatory (Box 4).

Figure 19 • Estimated energy demand in the industry sector, 2013



Note: Includes energy use in blast furnaces and coke ovens and chemical feedstock.

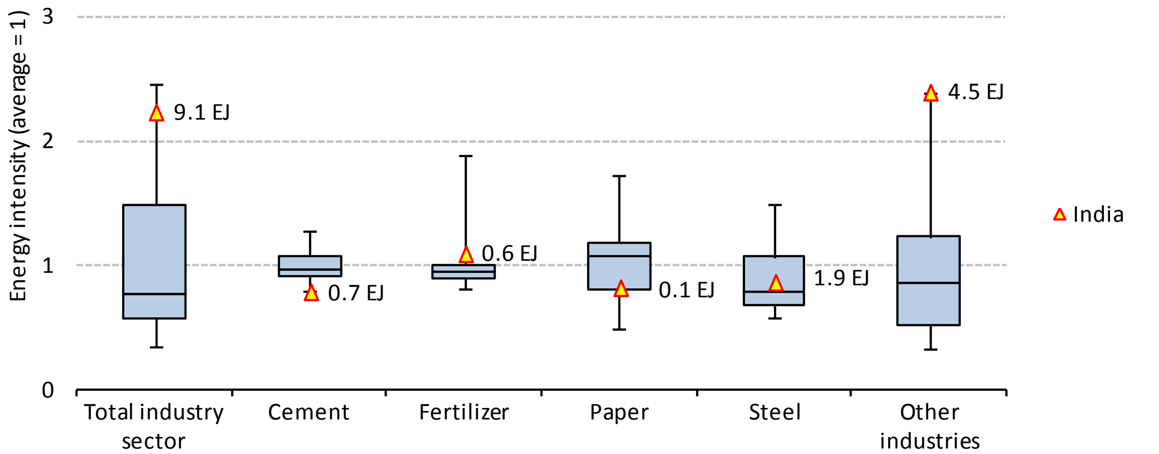
Box 4 • India's policies on energy efficiency in industry

The Perform, Achieve and Trade (PAT) scheme, a mandatory market-based trading programme with a target system based on industry-specific audits and benchmarking, was introduced in 2012 under the Energy Conservation Act. It specifies energy saving targets for 478 of the most energy-intensive facilities with an energy consumption of more than 1.3 PJ (lower for some industries) in the aluminium, cement, chlor-alkali, fertiliser, steel, paper and textiles industries. The first cycle of the PAT scheme (2012-2015) aimed to reduce energy consumption on average by 4.1% making up 36% of total industrial energy consumption (2009-10 levels). Industries can comply with the targets by achieving their own energy savings and generating energy savings certificates and trading these certificates in the market. Based on the latest assessment of 427 industrial enterprises under the first cycle, the original target was surpassed with a reduction in energy consumption of 5.3%. For the second cycle of the PAT programme (2016-2019), the plan is to expand it to 900 to 950 industrial enterprises, representing a share of 50% of industrial energy consumption (2009-10 levels), covering both existing sectors and new sectors such as refineries, railways and state distribution companies (BEE, 2016b) (BEE, 2016c).

In addition, the Partial Risk Sharing Facility (PRSF), established by the Small Industries Development Bank of India, provides partial credit guarantees for energy efficiency projects financed by local banks that are implemented by ESCOs. It covers a range of sector projects such as large industries (including those in the PAT scheme above) and SMEs (SIDBI, 2016). However, implementing energy efficiency policies for industrial SMEs is relatively difficult due to their diverse nature, lower awareness, the perceived risk of some efficiency technologies, lack of capital, limited technical capacity and relatively higher transaction costs[16]. The BEE has targeted industrial clusters, where SMEs have based themselves around locally available resources. In these clusters, energy use assessments, efficiency manuals and capacity building are provided to particularly energy-intensive SMEs, such as the food, brick or textile companies, with the objective of saving 73 PJ in 2016/2017. Financial assistance and low-interest loans are available for selected energy efficiency measures and management systems in SMEs (partially funded by development banks). However, the overall uptake of these loans has been slow when compared to the extensive opportunities for energy efficiency in industry in India today.

Source: (IEA, 2015b).

Figure 20 • Energy intensities in selected Indian industrial sub-sectors compared to other regions, 2013

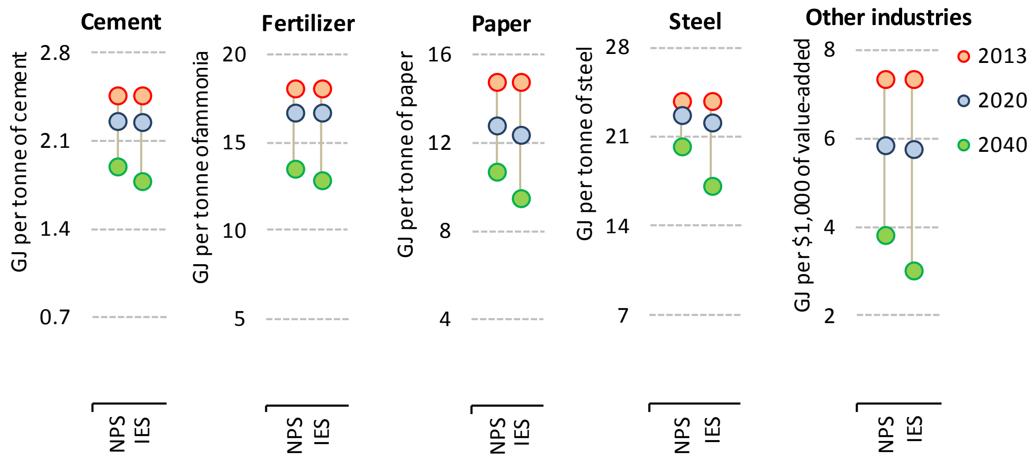


Note: Boxplots indicates minimum, maximum and 1st-3rd quartile. For each sub-sector energy intensities have been scaled such that the average (across regions) is 1. In order to insure a meaningful comparison across regions for the subsectors, energy intensities have been adjusted for structural differences, i.e. differences in clinker-to-cement ratios, pulp-to-paper ratios and different technologies in steel production. The category 'Other industries' contains the bricks, sugar, textile industry and the category 'Rest of industries' showed in Figure 19.

[16] The IEA's "Accelerating Energy Efficiency in SMEs" describes how well-designed energy efficiency programmes can address these barriers, unlocking a wide range of benefits.

Due to the rapid development of the Indian economy, the technologies (and hence energy intensities) in the industrial sub-sectors are sometimes based on global best-practices and sometimes more old-fashioned (Figure 20). Some energy-intensive industries (for instance cement) are already the most energy-efficient in the world, with relatively large production units and the use of modern technologies. India achieves this world-class performance by using a relatively high share of fly ash and blast furnace slag as a substitute for energy-intensive clinker production. The fertilizer industry is another good example as the energy efficiency of urea production in gas-based production plants in India is now one of the best in the world and has improved from 0.84 toe/tonne urea in 1990 (Nand & Goswami, 2008) to around 0.64 toe/tonne urea in 2013. A key to understanding the success of these industries in improving energy efficiency is the long-lasting collaboration and knowledge sharing happening in industry organisations. For the cement industry, knowledge sharing of the benefits of new technology was a way to improve competitiveness when most cement companies in the late 1990's faced bankruptcy. In recent years, the PAT scheme has further heightened energy consumption awareness. As a result of these early efforts, the potential to improve energy efficiency beyond what is already anticipated in the New Policies Scenario is more limited compared to the other industries in India (Figure 21).

Figure 21 • Energy intensities of selected industrial sub-sectors in the New Policies Scenario and the India Efficiency Scenario



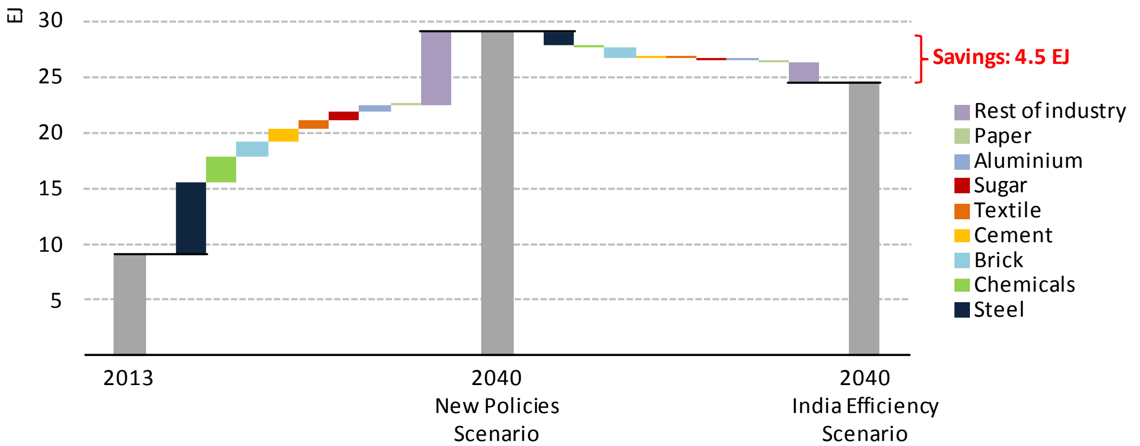
Note: The category 'Other industries' contains the bricks, sugar, textile industry and the category 'Rest of industries' showed in Figure 19.

The steel sub-sector is more energy-intensive compared to other regions and the largest industrial energy user in India. Further, the steel sector is also the source of the largest projected increase in industrial energy use over the period to 2040, from the current 1.9 EJ to 8.4 EJ, about a four-fold increase (supporting output that increases by more than five-times). The steel industry in India consists of relatively efficient large, private sector steel plants, alongside less efficient public steel plants and a significant number of mini blast furnaces that cannot reach the energy efficiency levels of larger plants due to their small scale. Roughly a third of India's steel is produced in electric arc furnaces and a similar proportion in small-scale induction furnaces (JPC, 2014), which use electricity as an energy input and where the scope for energy efficiency gains is limited. In the future, it is anticipated that the steel sector in India will become less reliant on Direct Reduced Iron (DRI)[17], turning more towards the traditional blast furnace route for steel-making and therefore depending less on electricity as a fuel. This shift, combined with increasing

[17] Direct reduced iron, also known as sponge iron, is produced from the direct reduction of iron ore.

energy efficiency gains, (particularly in blast furnaces, steel finishing and exploiting the waste heat potential in DRI production), and a modestly higher share of scrap metal contribute to the projected decrease in energy intensity by 15% from today levels to 2040. However by exploiting the full cost-effective potential to increase energy efficiency could improve 28% and save around 1.3 EJ in 2040 (Figure 22).

Figure 22 • Change in energy consumption in the industry sector by sector, 2013-2040

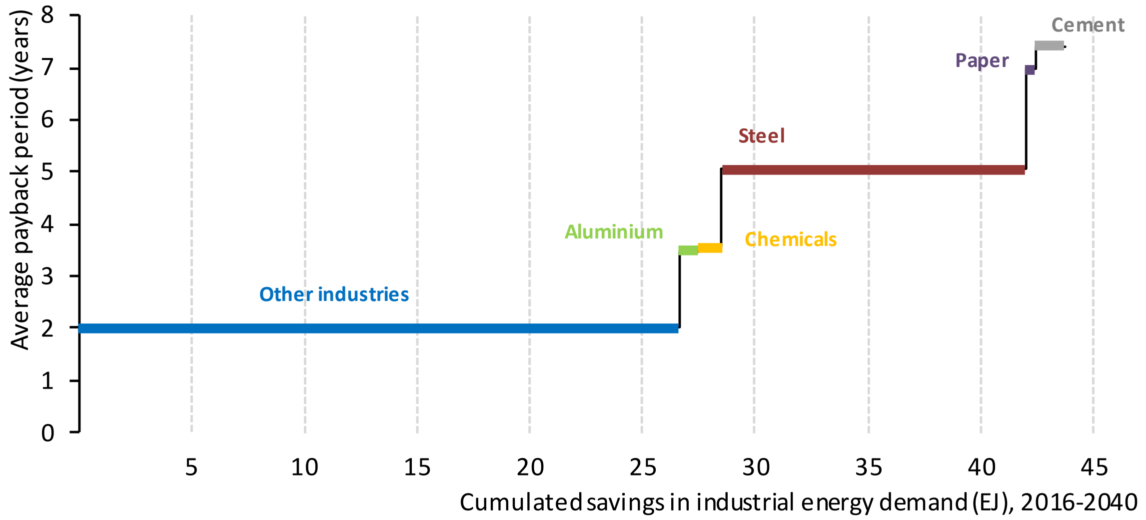


Note: Includes energy use in blast furnaces and coke ovens and chemical feedstock.

By tapping the full economic potential in each industry sub-sector we estimate that energy efficiency can lower cumulative energy demand by over 44 EJ in the period 2016-2040 at an average payback period of just over 3 years. Significant saving potential lies in non-energy-intensive industries, the brick industry and the steel industry. On average the cost of conserved energy (i.e. how much it costs to save a unit of energy) is only one-seventh of the energy price in the industry sector (Figure 23). Exploiting the potential will bring down energy costs and improve competitiveness although barriers do need to be addressed especially in SME's (see the focus on the brick industry).

The potential to save energy in the Indian industry sector is not limited to energy efficiency as material efficiency (delivering the same material service with less overall material input) can complement energy efficiency in reducing energy demand, increasing energy security, enhancing economic competitiveness and reducing greenhouse-gas emissions (IEA, 2015b). Material efficiency includes a set of diverse measures, such as increasing recycling, reducing the weight of consumer products, increasing fabrication yields and using energy-intensive materials more intensely. In addition, energy efficiency measures can help improve combustion and process control which can result in significant material savings through reduced wastage and reduced burning losses. The government's Zero Effect, Zero Defect initiative, launched in 2015, is the first step in the direction to encourage companies to reduce waste of natural resources. Implementing material efficiency strategies in the energy-intensive industries can save almost 2.6 EJ (or 20% of energy demand from these industries) in 2040, which is close to 60% of the overall energy efficiency savings in the same industries under the India Efficiency Scenario. Coal demand would be reduced by almost 2.1 EJ, demand for electricity and oil by around 0.3 EJ. Three-quarters of total savings would arise from steel production, which is also by far the most important energy-consuming industry sub sector. The demand for steel can be reduced by using steel components for longer, light-weighting steel products, particularly in buildings and by reducing losses during the manufacturing process. Additionally, modernising India's recycling industry, which is currently highly disorganised in the absence of a legal framework, would help to increase recycling rates, which are currently among the world's lowest, and thus replace energy-intensive primary steel with less energy-intensive secondary steel.

Figure 23 • Cost-effectiveness of extra investments in energy efficiency in the India Efficiency Scenario compared to the New Policies Scenario, 2016-2040



Note : The category 'Other industries' contains the bricks, sugar, textile industry and the category 'Rest of industries' showed in Figure 19.

Focus: The Indian brick industry

The Indian brick industry accounts for roughly one-seventh of the total industrial sector's energy demand. Estimates show that the Indian brick industry produces around 250 billion bricks a year (second only to China), employs 10 million workers and has around 100 000-140 000 brick kilns distributed around the country. As bricks are an important building material, it is expected that the brick industry will significantly increase its production as economic growth and urbanisation increases demand for buildings. Nevertheless, it is anticipated that the use of bricks will be gradually replaced over time by other building materials, notably cement and steel. The Indian brick industry is very different from many other energy-intensive industries in India as it is dominated by many SMEs often with very poor energy performance. Energy does not rank very highly as a priority for these enterprises and government efforts have faced difficulties addressing energy consumption in the unorganised economy and have historically focused on larger companies. Brick companies are often located in clusters[18] in rural areas in which good quality clay is available (mainly in the Indo-Gangetic Plain in the North, where 65% of bricks are produced) (Maithel, et al., 2012).

Brick production in India is also very different from that in many other countries. In the United States, the European Union and China, Vietnam and Bangladesh, the use of mechanised tunnel kilns is much more prevalent than in India. Such technologies allow for higher degrees of energy efficiency and are less labour-intensive. In India, brick making is still very labour-intensive and is often carried out under very harsh conditions for workers. The predominant technology in India is the so-called fixed chimney bull trench kiln (FCBTK), which is used to make around 70% of bricks, with around 25% being produced in brick clamps[19] (Maithel, 2013). These are (especially

[18] Clusters are sectoral and geographical concentrations of enterprises that produce and sell a range of related or complementary products and, thus, face common challenges and opportunities (UNIDO, 2001).

[19] A brick clamp is a traditional method of burning bricks by stacking un-baked brick with fuel under or in between them.

the latter) relatively energy-inefficient methods of producing bricks and cause severe local pollution in production seasons.[20] Further, the production of clay (i.e. removing top soil) is an environmental concern. Improving energy efficiency in this sector will have numerous benefits to brick producers, local communities and brick workers. There are numerous possibilities for improving energy efficiency in this industry even in the short term.

The fact that the brick companies in India are mostly small-scale is important to keep in mind when analysing energy efficiency options as these entities have specific behavioural patterns and limitations in their operating possibilities. Managers are typically very reluctant to change technology to make long-term gains as any perceived risk of short-term disruption or losses can have serious consequences for a small producer. Further, such enterprises normally run on low cash flows whereby they rarely have the necessary funds to invest, and they are often reluctant (and sometimes unable) to raise finance elsewhere. In order to compete with larger companies these small-scale enterprises typically rely on the cheapest available technology with the highest likelihood of successful production, which naturally creates a degree of inertia in production methods and reluctance to changing to more efficient methods. Studies show that economic barriers (such as lack of finance) and behavioural barriers to the adoption of energy efficiency equipment are the most important to tackle in this sector (Nagesha & Balachandra, 2006) (Thiruchelvam, Kumar, & Visvanathan, 2003).

The barriers mentioned above are significant challenges in the short term to achieve a large shift towards the most energy-efficient technologies in brick making. For instance, one of the most energy-efficient brick production technologies, the so-called vertical shaft brick kiln (VSBK), could reduce fuel consumption by 20-50% or more compared to FCBTK's, but has higher initial capital requirements and longer payback periods. However, their practical application in India and other neighbouring countries has been challenging (Heierli & Maithel, 2008). Box 5 presents a non-fired brick option, known as Fly ash-Lime-Gypsum (FaL-G), developed in India that is seen as a potential breakthrough technology that can reduce emissions substantially (IIP, 2014).

Box 5 • A potential technological breakthrough

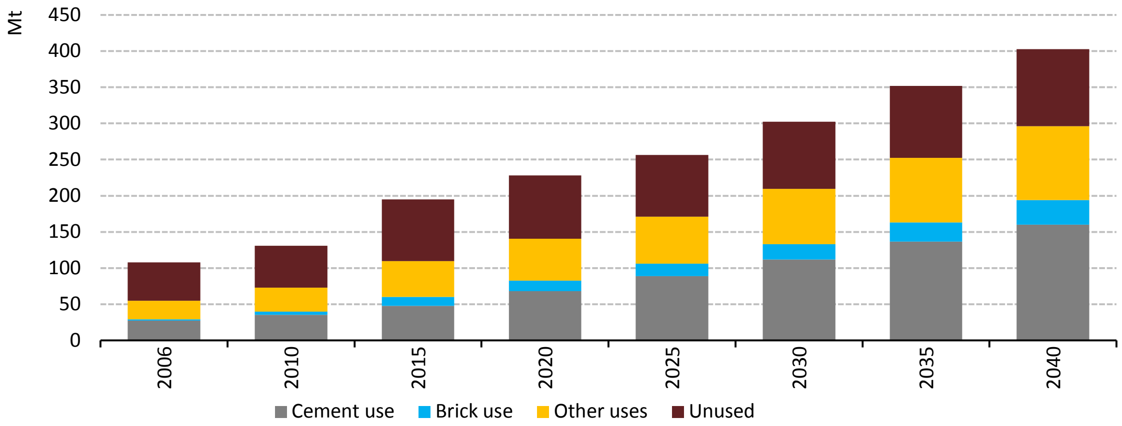
The Fly ash-Lime-Gypsum (FaL-G) is a process by which bricks is produced using fly ash and without need for the use of coal and top soil and therefore provides an effective alternative for clay bricks. Therefore, it can provide a series of other environmental and health benefits to nearby populations. Basically, the fly ash is mixed with lime and gypsum, which are by-products from the acetylene and chemical industry, respectively. This helps avoid of a sintering process and the fly ash bricks have proven to be well received by the building industry due to its high strength, uniform quality and lower requirements of mortar plastering. Furthermore, in a brick form, the fly ash is non-toxic as the lime keeps it inert. However, its wider adoption is a challenge due to the popularity of clay bricks and easy availability of top soil for brick making near brick production sites. By 2012, over 16 000 FaL-G factories were established across India capable of producing approximately 48 billion bricks (IIP, 2014).

One more promising possibility in the short term is therefore retrofitting FCBTK production sites to so-called zig-zag firing methods, which could reduce fuel requirements by around 15%. It has been estimated that such retrofitting would have a payback period of around 1 year with relatively low capital costs (Maithel, et al., 2012) (Maithel, 2013). Further, a shift towards producing hollow or perforated bricks (the standard in most developed countries) will reduce

[20] Brick making in India is usually seasonal as bricks are formed from mid-October to end-December and are subsequently set to dry in open air.

clay consumption and the weight of bricks thereby reducing demand for energy in the firing process.

Figure 24 • Estimated fly ash generation in India and uses in the New Policies Scenario, 2006-2040



Source: (CEA, 2015) and IEA analysis.

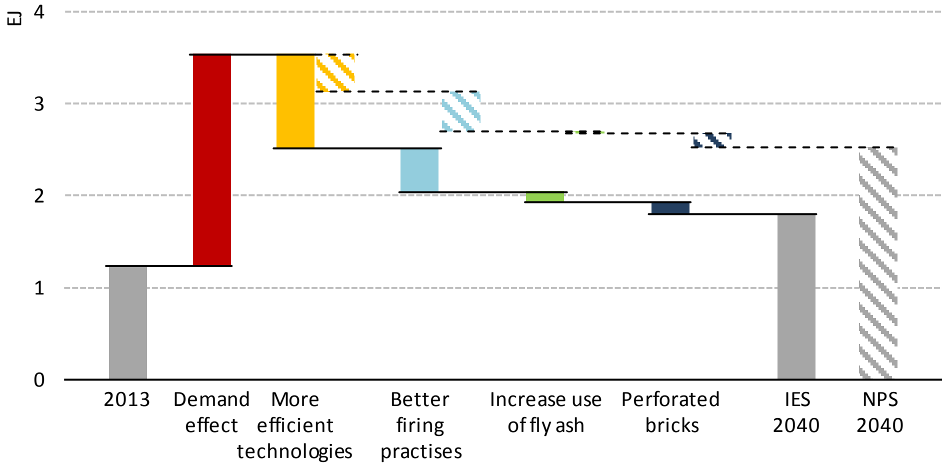
As Indian coal has a high ash content (three quarters of current coal production has an ash content of 30% or greater) the generation of fly ash (a residue when burning coal for electricity generation) has been increasing at roughly the same rate as the increase in coal consumption (CEA, 2015). Looking at India's projected growth in coal consumption the amount of generated fly ash could rise to be the level of 400 Mt in 2040 (see Figure 24).[21] In 1994, the government of India launched the Fly Ash Utilization Program (FAUP) in order to raise awareness about the usefulness of using fly ash in other industries and the degree of utilisation has risen to between 50-60% during the last decade. Most of the used fly ash (around 40%) is used as a substitute for a share of the energy-intensive clinker in the cement industry. Around 12% is used in brick making, a share that has increased during the last decade. If mixed with the right type of clay, fly ash will act as an internal fuel when fired, which allows the producer to use less fuel for making clay bricks. Further, specific fly ash bricks can be manufactured without any need of burning at all (Kumar, Mathur, Sinha, & Dhatrak, 2005). Several barriers have been identified in order to realise government ambitions for the use of fly ash. The cost-effective use of fly ash is especially dependent on the availability of fly ash in the proximity of the brick making site – if not closely available, transportation costs can be prohibitively high. Further, as many clay brick enterprises are part of the unorganised economy, they are rarely subject to government taxes. Upgrading to better technology would increase the likelihood of being forced into the organised part of the economy and the use of modern fuels (electricity and natural gas). Even if this was not the case, unorganised enterprises have a harder time obtaining sufficient loans from banks in order to make the investments necessary to upgrade (TERI, 2009).

In the New Policies Scenario, we estimate that the energy intensity in this industry will drop by around 30% by 2040 with a gradual move toward more efficient technologies, better firing practices (for each technology), a continued trend towards the use of fly ash and a gradual shift towards producing hollow and perforated bricks. These savings are already dependent on the removal of a range of barriers described above and the availability of financing for producers. If such efforts to remove barriers are strengthened even further we estimate the potential to decrease energy intensity would be in the area of 50-60% compared to today. The largest savings potential is in changing technology. If brick clamps are phased-out, most FCBTK's adopt zig-zag firing methods and other more efficient technologies are taken up energy consumption could

[21] Several factors will influence the amount of fly ash generated for instance increased coal washing.

drop around 1 EJ in 2040. Better firing practices, increased use of fly ash and perforated brick could save around 0.7 EJ of energy in 2040 (see Figure 25).

Figure 25 • Estimated energy saving potentials in the India Efficiency Scenario, 2013-2040



Note: Because of interactions between options saving potentials are indicative.

The importance of clusters in addressing energy efficiency in India has been acknowledged and the BEE has initiated a programme with the aim of increasing energy efficiency in SMEs in 25 clusters by, amongst other things, knowledge sharing. In order to enhance the use of fly ash in India the government has tried several options. For example, in 1999 the Ministry of Environment and Forests issued a notification which mandated clay brick producers within 50 km of a coal/lignite thermal power plant to use at least 25% of fly ash in the clay mix and for fly ash to be freely available (Dhadse, Kumari, & Bhagia, 2008). In 2003, this notification was amended to increase the distance to within 100 km and in 2016 to 300 km (MOEF, 2016). These policies have been criticised for resulting in low-quality fly ash which limits its potential reuse, since producers had no incentive to support the use of fly ash and guarantee its quality (TERI, 2009).

Policy Recommendations for Energy Efficiency in Industry

The Indian government is making a considerable effort to increase the share of manufacturing in the GDP of the country. Therefore the manufacturing industry is at the heart of India’s future growth through the “Make in India” programme. The reliable provision of energy is central to the success of the programme and energy efficiency can enhance the programme’s effectiveness, helping reduce the energy costs for industry and enabling industry to become more competitive in the international market. Furthermore, energy efficiency can help minimize the impact of growing energy consumption on energy security and air pollution.

The Indian government recognises the importance of energy efficiency in industry and has made significant progress in developing and establishing new industrial energy efficiency programmes, with the PAT scheme bringing together the best local and international industrial energy efficiency experience. Lessons learnt from Phase 1 of the PAT scheme are now being used to improve and expand it to cover other large industries. It will be important for the government to continue to monitor the effectiveness of the programme and set penalties for non-compliance. While the cement and fertilizer industries have shown noteworthy progress reaching best global standards, there are still opportunities for further improvement in the steel and paper industries as well as SMEs in industries such as brick-making. A circular economy approach with material resource efficiency and greater industrial cooperation can provide even greater efficiency and economic benefits. ESCOs can play a key role in implementing energy efficiency projects and delivering energy savings across all the industrial value chain from large to small industries. Overall, there are several energy efficiency policies that could help further improve energy efficiency in the industrial sector, and help reach the potential savings indicated under the India Efficiency Scenario by 2040. Below is a list of three key policy recommendations that could help make a difference.

Adoption of Energy Management Systems

The industrial sector in India, particularly SMEs, still requires considerable hand holding in the identification and implementation of energy efficiency projects. The key challenge typically faced is understanding in detail how energy is used, what can be improved and how to finance it.

The government should require large energy intensive industries to conform to an energy management protocol and provide the necessary tools to implement the management system. The adoption of an energy management protocol, such as the ISO 50001 or equivalent, could help large energy intensive industries to i) identify and assess energy saving opportunities by measuring, recording and benchmarking energy consumption such as through the PAT scheme, and ii) implement actions to capture identified energy saving opportunities.

It can also be combined with incentives (e.g. tax credits, low-interest loans, guarantee mechanisms for energy savings) to those industries that successfully implement the energy management system and invest in energy efficiency measures. For SMEs in the industrial sector, when energy management systems are not a viable option, the government should consider a requirement for regular energy audits (e.g. every four years). The energy audits can help identify potential measures for implementation by SMEs.

To complement and ensure the success of the energy management systems and energy audits there is need to offer training and capacity building. In many cases there might not be sufficient technical experts suited to identify energy efficiency measures that can be realistically implemented at reasonable costs. The government should work with universities, technical colleagues and industrial associations to ensure the knowledge and human resources are made available to the market.

High Efficiency Industrial Equipment and Systems

Standard efficiency motors (IE1) still have a significant share of the market and the penetration of premium efficiency motors (i.e. IE3 – approximately 5% more efficient than IE1) has been slow (ICA, 2016). There are currently no minimum energy performance standards (MEPS) for motors in India. However, since 2009, there is a voluntary energy performance label for three-phase motors to help influence consumers in their purchase decision.

The Indian government should consider the adoption of mandatory MEPS for three-phase motors in India to trigger greater penetration of premium efficiency motors in the country. MEPS should be extended to other industrial equipment such as compressors, pumps, fans and boilers as well as improvement of overall system efficiency. Furthermore, the Indian government should explore extending EESL’s replacement programmes to cover three-phase motors and other industrial equipment and systems including variable-speed drives. Supplementary measures to be considered include providing information on equipment and system energy performance, training initiatives, audits, technical advice and documentation, and tax incentives for the purchase of high efficient equipment and retrofit of existing systems to make them more efficient.

Energy Efficiency Services for Small and Medium Enterprises

SMEs account for 45% of the manufacturing output in India and are key to the growth envisioned under the "Make in India" programme. Majority of SMEs (e.g. food, brick and textile industries) offer a huge potential for energy efficiency improvements. The BEE and the Small Industries Development Bank of India should continue to help SMEs overcome their main barriers to energy efficiency by developing and implementing tailored policies and measures. These policies can include support mechanisms for undertaking energy audits, provision of simple guidelines and manuals, training and capacity building, subsidies and tax incentives, and support to access financial support and share financial risks such as the existing Partial Risk Guarantee and Partial Risk Sharing Facilities in India. They can also include a list of equipment that is preapproved for a variety of incentives, including enhanced capital allowances (taxes) and borrowing at preferential interest rates.

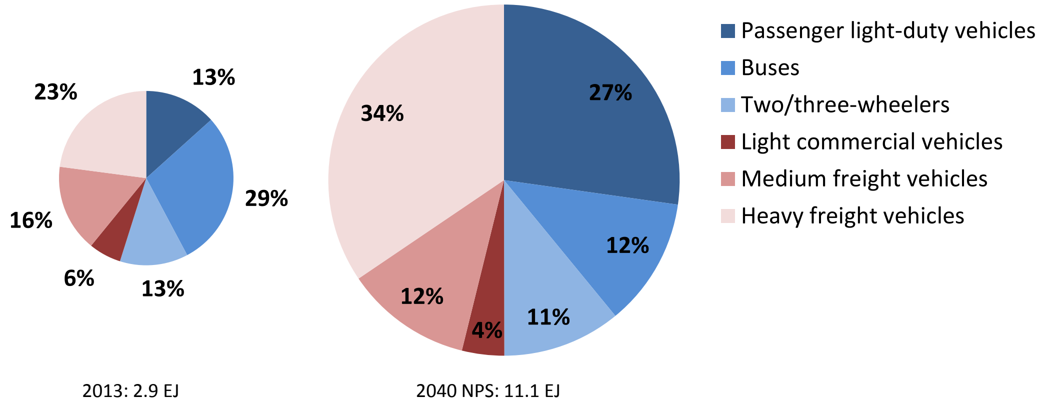
Transport

Energy use in India's transport sector accounts for 14% (3.1 EJ in 2013) of final energy consumption, which is a significantly smaller share than in many other countries. This is primarily as a result of low personal vehicle ownership (with fewer than 20 vehicles per 1000 inhabitants compared to the world average of almost 130) and extensive public transport networks. India has a total of 65 000 kilometres of railways, which is more than the Earth's circumference, with 11 000 trains running everyday (approximately 60% are passenger trains), 1.1 billion tonnes of duty per year, serving more than 20 million passengers per day (same as the population of Sri Lanka) and more than 8 billion passengers per year (IR, 2016a) (IR, 2015).

The use of energy per capita for transport purposes in India is 2.5 GJ, one-sixth of the world average and the number of flights is 0.07 trips per capita, well below that of other emerging economies (Airbus, 2015). Energy use in the transport sector, however, is set to increase rapidly. It is the fastest-growing of all the end-use sectors in India with a growth rate averaging 6.8% per year since 2000. Around 90% of the increase is attributable to growing use of oil products in road transport. In the New Policies Scenario, growth in energy demand from transport continues to outpace growth in all other sectors, and transport fuel demand reaches 11.7 EJ in 2040, 94% of which is demand in road transport. The vast majority of final energy demand in transport (96% in 2013) is supplied by gasoline and diesel.

Road transport fuel demand has grown rapidly in the past decade to 2.9 EJ in 2013, around 60% of which is used for passenger transport (i.e. in PLDVs, buses and two/three-wheelers). PLDVs still play a relatively minor role in India's overall transport system, as average income levels are low, but following the same patterns of development as elsewhere in terms of how economic growth drives vehicle ownership, the Indian population – in particular in urban areas – will increasingly use personal vehicles to satisfy demand for mobility, amplifying problems such as congestion, accidents and air pollution. In our projections the share of passenger cars increases sharply to 2040, by which time they account for 27% of fuel consumption in road transport, as car ownership rises to a nationwide average of 175 vehicles per 1 000 inhabitants (Figure 26). In terms of energy consumption PLDVs and heavy duty vehicles will dominate road transport as they are projected to account for over 60% in 2040.

Figure 26 • Road transport energy consumption in India in the New Policies Scenario, 2013 and 2040



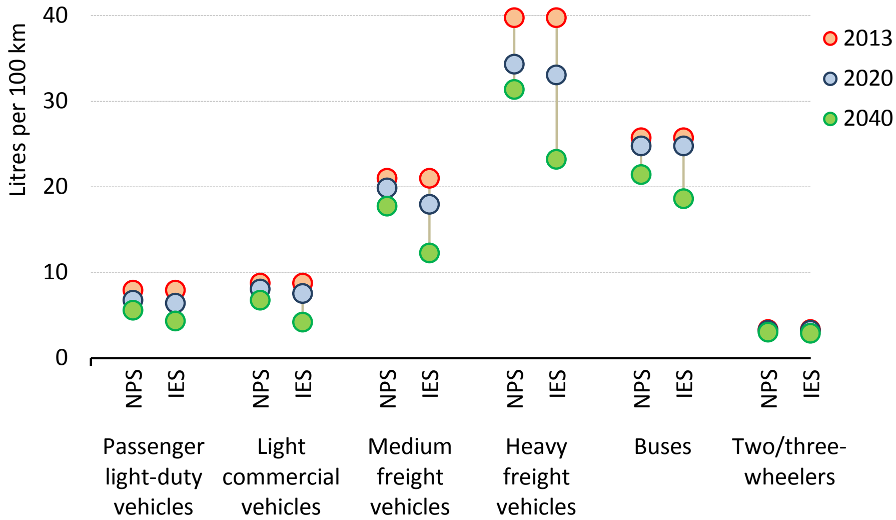
Note : Blue coloured categories are road passenger transport. Red coloured categories are road duty transport. NPS = New Policies Scenario.

In order to curb rising energy demand in the transport sector, effective transport policies must be developed and implemented and the sooner the better. Policies should consider how energy efficiency can both support economic growth and dampen energy use. Energy efficiency policies for transport can be grouped into three broad categories: those that allow travel to be "avoided"; those that "shift" travel to more efficient modes; and those that "improve" the efficiency of vehicle and fuel technologies. India has already incorporated many of these options, for instance in the cases of the Smart Cities Mission and the development of Delhi's metro rail system (following earlier systems in Kolkata and Chennai), the latter being an example that is being considered by the authorities in many of India's other large cities such as Lucknow, the capital city of Uttar Pradesh. Good city planning can help to slacken growing transport activity and support shifts to efficient modes, but this will require early co-ordination between urban and transport planners, in particular where the development of a public metro system is envisaged, to ensure dedicated spaces for pedestrians and public transit networks. In terms of inter-city rail, Box 6 highlights what the Indian Railways is doing to improve energy efficiency in the sector.

Box 6 • Energy Efficiency in the Indian Railways

The Indian Railways account for approximately 2.5% of total electricity consumption in India and 25% of their revenue is spent on their growing energy bills (approximately $5 billion per year). The Ministry of Railways is working with several key partners to improve their energy efficiency through the adoption of energy efficient technologies. This includes the introduction of latest energy efficiency rolling stock technology to allow for regenerative braking and improved fuel consumption, the replacement of energy inefficient power supply systems, electrification of the railway network, introduction of self-powered trains to reduce speed differential between long distance and short distance trains, and replacement of lights in the train compartments with LEDs. The Indian Railways is also implementing energy efficiency in their buildings by replacing inefficient technologies with efficient lighting, fans and pumps, introducing control systems for lighting and escalators and implementing building management systems. The Indian railways have dedicated staff conducting regular energy audits to identify potential energy efficiency measures in their buildings. There is also a Center of Excellence, established by the Indian Railways Institute for Electric Engineers, that delivers energy efficiency training for staff (IR, 2016b) (UNDP, 2016).

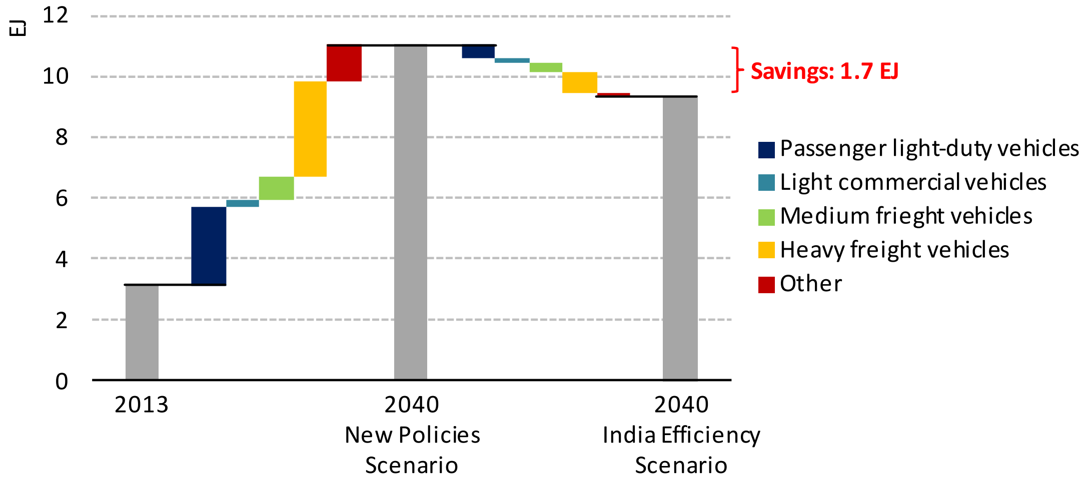
Figure 27 • Fuel economy of new transport vehicles in the New Policy Scenario and the India Efficiency Scenario, 2013-2040



NPS = New Policies Scenario. IES = India Efficiency Scenario.

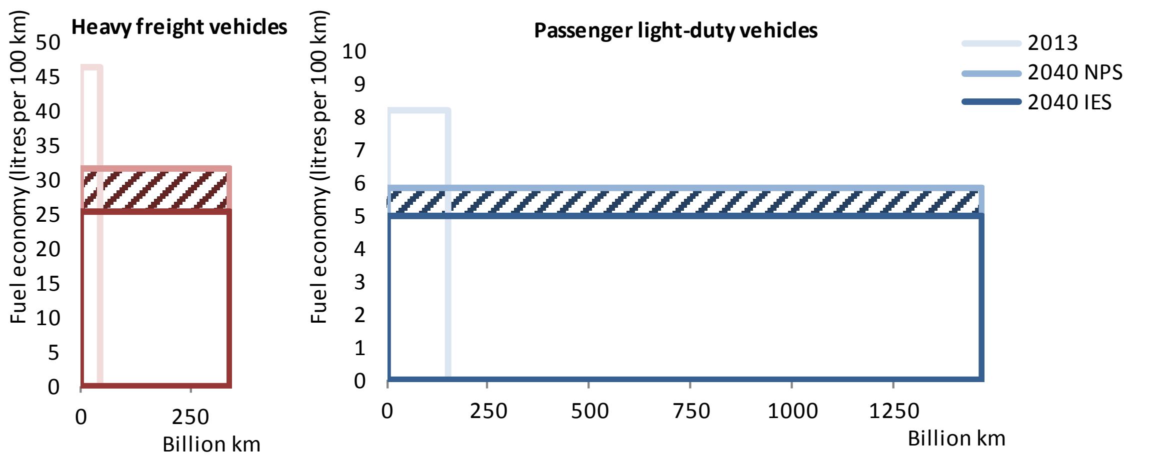
Efforts to increase fuel economy of vehicles have been implemented through mandated fuel economy standards for PLDVs, set to in be in force in 2017-2018, for which new sales will need to achieve an average fuel consumption of 4.8 litres per 100 kilometres (l/100 km) in 2022/23 (from around 6.0 l/100 km today). In the New Policies Scenario, we assume that average fuel consumption per new vehicle drops to 4.3 l/100km in 2040. We estimate in the India Efficiency Scenario that, in exploiting the full economic potential for energy efficiency, fuel economy could drop to 3.3 l/100 km by 2040 (Figure 27). This would save 0.4 EJ in 2040 relative to the New Policies Scenario, which is about one-sixth of the increase from today to 2040 in this transport category (Figure 28). The largest potentials to increase fuel efficiency lie in heavy duty vehicles, where fuel economies can increase by around 40% in 2040 compared to current levels, which is about twice the improvement expected in the New Policies Scenario. If all economically viable efficiency potential is taken up total final energy consumption in the transport sector could be reduced by 1.7 EJ in 2040. Two-thirds of these savings would take place in heavy duty vehicles and PLDVs (for more on the former, see the focus section).

Figure 28 • Total final energy consumption in the transport sector by vehicle type in the New Policies Scenario and savings in the India Efficiency Scenario, 2013-2040



The cost-effectiveness of investments in improved fuel economy depends amongst other things on current fuel economy standards, the fuel prices, and the number of miles driven. Energy efficiency investments in medium and heavy duty vehicles tend to have shorter payback periods because they typically drive substantially more miles per year. Policy makers can affect the cost-effectiveness for instance by taxing fuels, which will increase the reward for saving fuel. Even though payback periods can be short several barriers can hinder investments. In the India Efficiency Scenario we estimate that energy efficiency investments in medium duty vehicles and heavy duty vehicles have an average payback period of about 2 years. For PLDVs we estimate that average payback periods of energy efficiency investments beyond the mandatory fuel economy standards included in the New Policies Scenario are about 7 years, which is well below the expected lifetime of such vehicles. Despite the longer payback period for more efficient PLDVs compared to heavy duty vehicles it will be important for policy makers to take advantage of the economically-viable potential of the PLDV fleet in India as it, on the whole, will drive far more kilometres than the heavy duty vehicles fleet (Figure 29).

Figure 29 • Average fuel economy of PLDVs and heavy duty vehicles and vehicle kilometres travelled in the New Policy Scenario and the India Efficiency Scenario

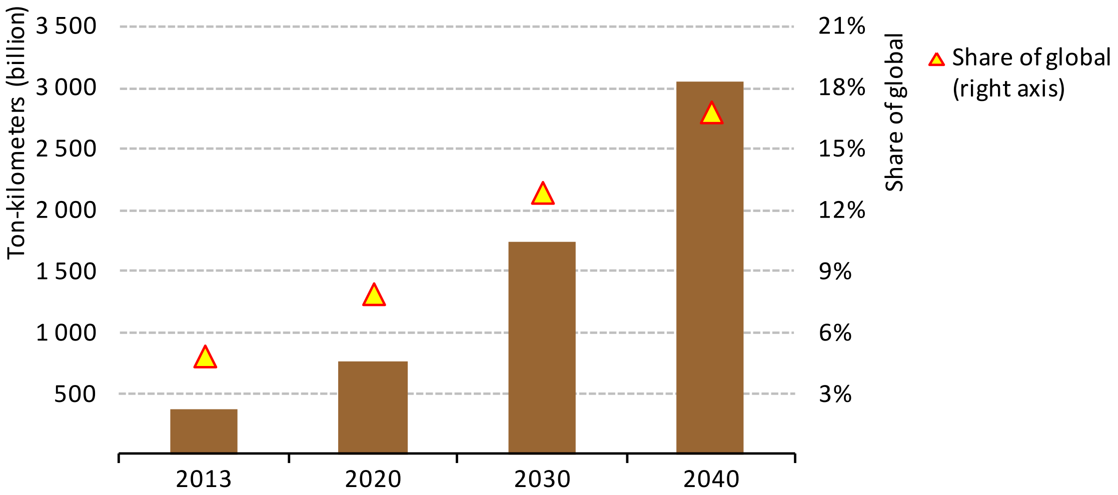


Note : NPS = New Policies Scenario. IES = India Efficiency Scenario. Patterned area indicates energy savings.

Focus: Heavy duty vehicles

India has a very low number of heavy duty vehicles per capita compared to the rest of the world. In 2013 there was almost 1 truck per 2 000 inhabitants in India, whereas in China that number was 5.6; in the United States 15.6; and the world average was 4.8. This can be explained by a smaller economy per capita, the tradition of rail transport and by the substandard quality and availability of roads (only about half of the roads are paved). Further, while heavy duty vehicles in most OECD countries travel in excess of 400-500 km per day, it has been estimated that even new heavy commercial vehicles in India are only able to cover distances of around 270 km per day, due to the poor quality of roads, heavy traffic, toll stations and multiple checkpoints (mostly at state borders). Despite the low distance ranges per truck heavy duty transport, India accounts for 5% of the world's heavy duty ton-kilometres. In the New Policies Scenario, heavy duty activity grows by an annual average growth rate of 8.2% in the period 2013-2040, which is linked to the high expected growth in value-added in the industry sector in India. As India becomes an important manufacturing hub globally, heavy duty in India will grow to account for 17% of the world's heavy duty transport by 2040 (Figure 30). Heavy-duty vehicles are already a major contributor to India's worsening urban air quality, which will only increase in the absence of emission standards.

Figure 30 • Ton-kilometres in heavy duty vehicles in India and the share of world total in the New Policies Scenario, 2013-2040

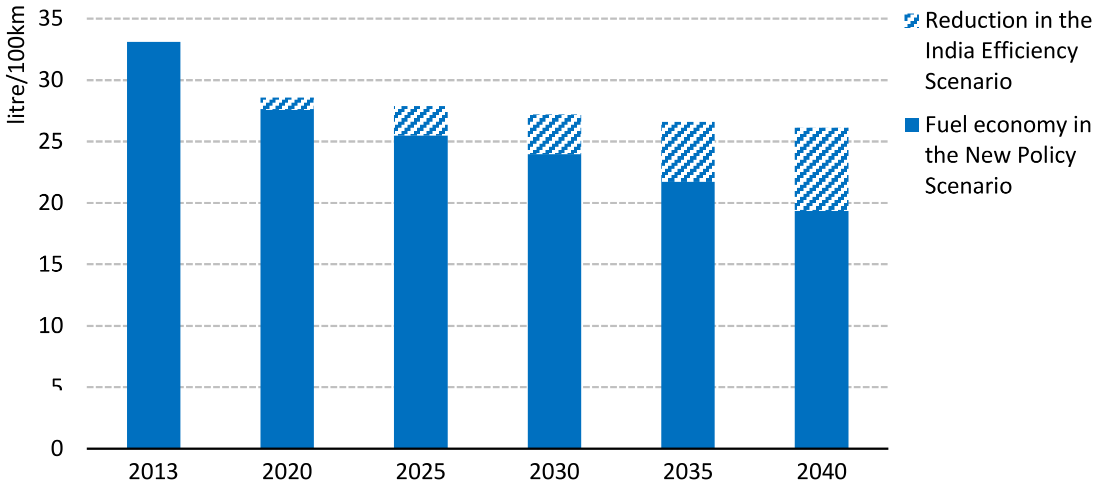


Note : Growth in ton-kilometres is in our modelling linked to growth in economic value-added in the industry sector.

Projecting the fuel economy of the Indian heavy duty vehicle fleet is not straightforward. With economic growth the heavy duty vehicle fleet will likely experience a structural shift towards larger vehicles with larger engines (India's fleet today have relatively lighter vehicles with smaller engines compared to China and the European Union (ICCT, 2015)), which will tend to increase the vehicle's fuel use. However fuel economy will improve, as technology improves and engines become more fuel efficient, low rolling resistance tyres penetrate the fleet, and more expensive aerodynamic vehicles and components become more widespread. In the New Policy Scenario, the latter effect dominates as the average fuel economy of the truck fleet falls from 46 litre/100km in 2013 to 32 litre/100km in 2040.

Looking at the economically-viable potential to increase fuel economy of new heavy-duty vehicles, we estimate that fuel economy could increase by around 25% in 2040 compared to the New Policies Scenario. Over the projection period this is an increase of about 40% from 2013 to 2040 in the India Efficiency Scenario compared to about 20% in the New Policies Scenario. This could save 0.7 EJ in 2040, which is over 40% of the total estimated potential for energy savings in road transport in the India Efficiency Scenario in 2040. These improvements could be reached at a relatively low cost with investments paying back in less than 2 years on average. Fuel economy standards for heavy-duty vehicles (and other trucks) are currently being considered in India (although they are not included in the New Policies Scenario), and analysis confirms the large potential and fast payback periods on capital investments to save energy to the benefit of consumers and the local environment.

Figure 31 • Fuel-economy improvement potential new heavy duty vehicles in the India Efficiency Scenario, 2013-2040



Policy Recommendations for Energy Efficiency in Transport

The transport sector is the fastest-growing of all the end-use sectors in India. Consequently, addressing energy efficiency is urgently needed before the resulting impacts of this growth are locked-in for the long-term. The gradual expansion of the road network, growing car ownership and use of heavy-duty vehicles and potentially electric vehicles will bring new challenges to the government. The India Efficiency Scenario highlights the benefits of improved efficiency in minimizing the growing energy demand of the transport sector. The key energy efficiency policy recommendations, in accordance with the Avoid-Shift-Improve model, needed to drive energy efficiency investment and reach this scenario are mentioned below.

Transport System Efficiency

Given India's existing public transport infrastructure and low vehicle ownership, policies to provide attractive alternatives to personalised motor vehicles and raise the prices of highly-inefficient vehicles should be prioritised. Passengers can be encouraged to use public transport by improving its efficiency, quality, convenience, safety and cost-effectiveness. Dedicated lanes for buses, bicycles and pedestrians, improved bus routes and modernised railways can help ensure high public transport use. Personal vehicles can be discouraged through differentiated vehicle taxation (i.e. "feebates") and increased fuel taxes at the national level, as well as parking restrictions, travel bans in city centres and congestion and road charging at the regional and municipal levels of governance.

Vehicle Fuel Economy Standards

Even with strong public transport policies in place, personal vehicle ownership is expected to increase. India has implemented mandatory fuel economy standards for passenger light-duty vehicles to 2022/23. The Indian government recently announced the aim to leapfrog to higher emissions standards for gasoline and diesel vehicles by 2020. The government should continue to expand fuel economy standards to cover all vehicle types including 2/3 wheelers and light-duty vehicles. These should be implemented now to periodically strengthen these standards in the years following the initial rollout date. This will send a clear signal to manufacturers and to the market. All fuel economy standards should be reviewed on a regular basis (e.g. every five years) and linked to vehicle tax regulations providing additional benefits to, such as, hybrid and electric vehicles. Although India's heavy-duty vehicle fleet has a relatively low activity level compared to other countries, heavy-duty vehicles are major contributors to worsening urban air pollution and predicted to grow significantly by 2040. Therefore, the Indian government should consider the adoption and implementation of mandatory fuel economy standards for heavy duty vehicles urgently[22].

Improved Vehicle Fuel Economy

The way vehicles are used and maintained influences their overall efficiency. Therefore, the Indian government should promote and support operational efficiency measures for both light and heavy-duty vehicles. These measures could include eco-driving as part of the process for obtaining a driver's license, ongoing information and awareness campaigns to educate drivers on preventative maintenance, and ensuring regular mandatory inspections for existing and new vehicles to confirm they are properly maintained and any losses in efficiency are reduced.

Buildings

Energy use in the buildings sector in India is projected to grow dramatically over the coming decades due to increasing urbanisation, growth in access to modern energy and population, and the impact of rising incomes on the ownership of appliances. From 2013, when almost 65% of the 9.0 EJ consumed in the buildings sector consisted of solid biomass, we project in the New Policies Scenario that by 2040 more than 60% of the 12.5 EJ used in the sector is modern fuels including either electricity (45%) or LPG and other oil products (16%). Urbanisation helps to improve access to modern fuels, such as electricity and LPG: but it can also – if not well planned – entrench inefficient patterns of energy use that can be very difficult to dislodge.

There are two components of energy use in the buildings sector: the residential sector and the non-residential sector (which includes, among others, public buildings, offices, shops, hotels and restaurants). In energy terms, the residential sector is almost six times the size of the non-residential sector (7.7 EJ compared to 1.3 EJ in 2013). The two sectors have very different patterns of energy consumption, as the dominant fuel in the residential sector is traditional use of solid biomass (which accounted for 73% of residential energy use in 2013) and the energy use in the non-residential sector is more varied with electricity and coal accounting for two-thirds.

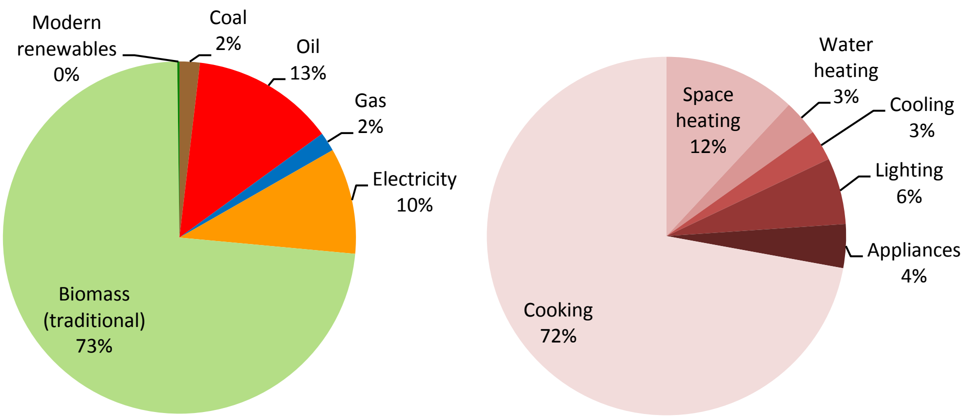
Residential buildings

In India today the residential sector in rural areas relies mainly on traditional use of solid biomass (e.g. fuel wood, charcoal, animal waste and agricultural residues), with oil a distant second (LPG for cooking, kerosene for cooking and lighting) followed by electricity (Figure 32). Two-thirds of the Indian population (an estimated 840 million people) rely on solid biomass as their cooking fuel (Government of India, 2012), due to the lack of other options that are easily available and affordable. This results in more than 70% of energy used in households in India being used for cooking (whereas cooking constitutes less than 5% of residential energy demand in OECD countries). In addition, approximately 29% of biomass energy use was located in urban areas and

[22] The IEA held a workshop on this topic in India in 2015 and is available to help with benchmarking and policy formulation guidance.

33% of residential energy consumption was in urban area in 2015 (owing to large rural biomass energy use share) (IEA, 2016b). There is a host of issues associated with the traditional use of solid biomass for cooking, including the release of harmful indoor air pollutants that contribute to respiratory and health issues and contributes to a large number of premature deaths, as well as environmental degradation as a result of deforestation and biodiversity loss. The use of efficient cook stoves could help reduce this impact.

Figure 32 • Fuel use in residential buildings, 2013



In the New Policies Scenario residential energy use is marked by a series of transitions, away from solid biomass and kerosene to LPG and from intermittent or non-existent electricity to a round-the-clock, reliable supply. As household income rises and electricity supply becomes more reliable, India is set to see a rapid increase in household electricity consumption, due to increased purchases of appliances, including air conditioners (Figure 33). In addition to contributing to the rapid increase in electricity consumption, energy efficient air conditioning is the largest contributor to energy savings in the India Efficiency Scenario (Figure 34).

In order to ease the growth in electricity consumption in the buildings sector (but also in industry and agriculture), the BEE set up an energy efficiency standards and labelling programme for appliances in 2006. Currently 10 out of the 21 standards are mandatory, but more are expected to become mandatory in the coming years and there are plans to extend the standards to other appliances. The energy labelling is only mandatory for 4 appliances. The programme focuses on the most widely used appliances (specific types of refrigerators and air conditioners are already mandatory), with voluntary standards and labels initially encouraging consumers to choose more efficient appliances followed by a switch to mandatory standards and labels once there is sufficient public acceptance. However, experience shows that the effect on lowered energy consumption is offset somewhat by an increase in the size and power of the appliances available on the market: for example, the average size of refrigerators has seen an increasing trend from the previous average of 165 litres towards 200-300 litres (TERI, 2006). Keeping future electricity consumption growth in the residential buildings sector in check will require a steady tightening of appliance energy efficiency standards and an effective compliance regime.

Figure 33 • Change in residential energy consumption by fuel, 2013-2040

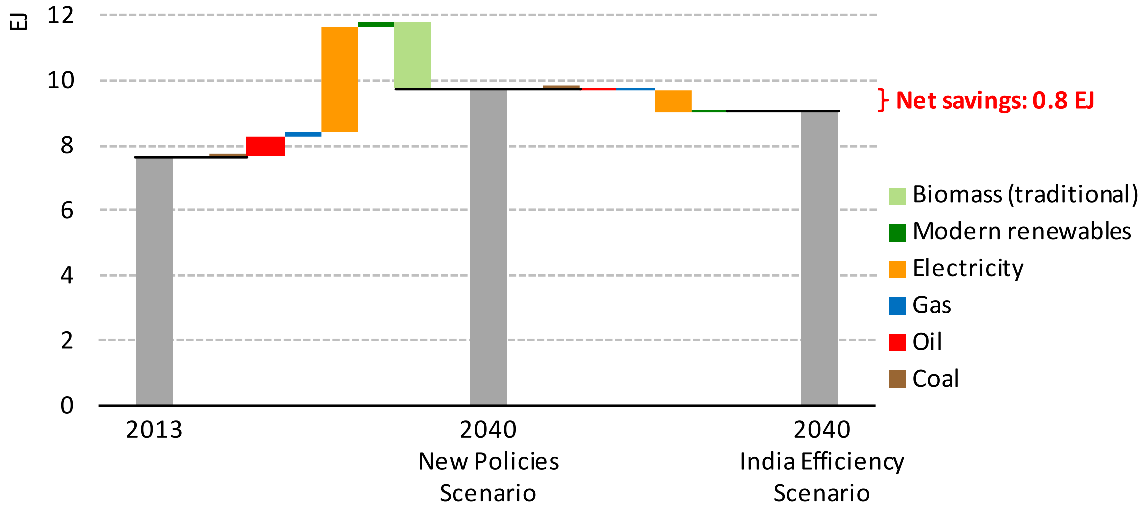
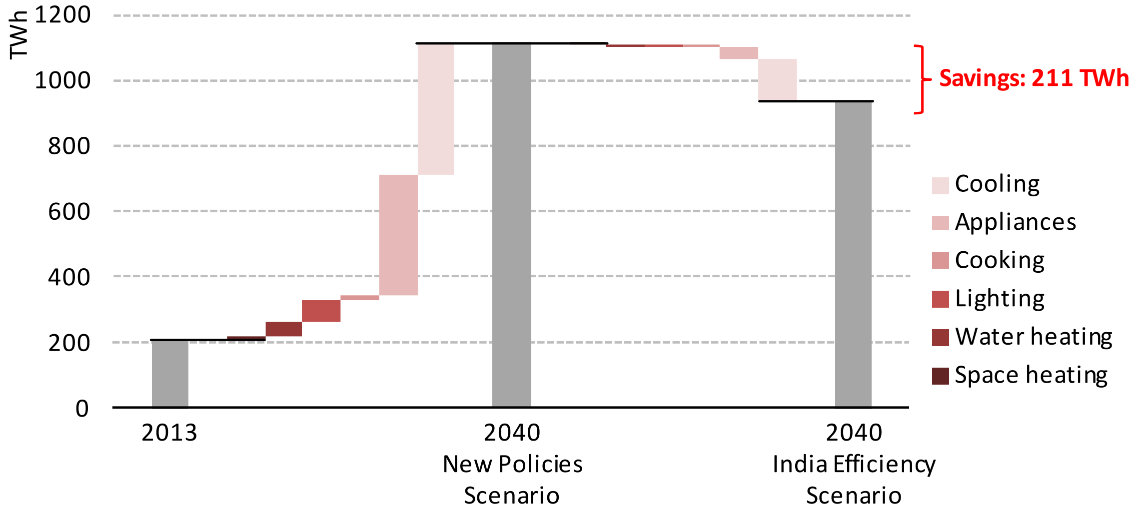


Figure 34 • Change in residential electricity consumption by end-use, 2013-2040



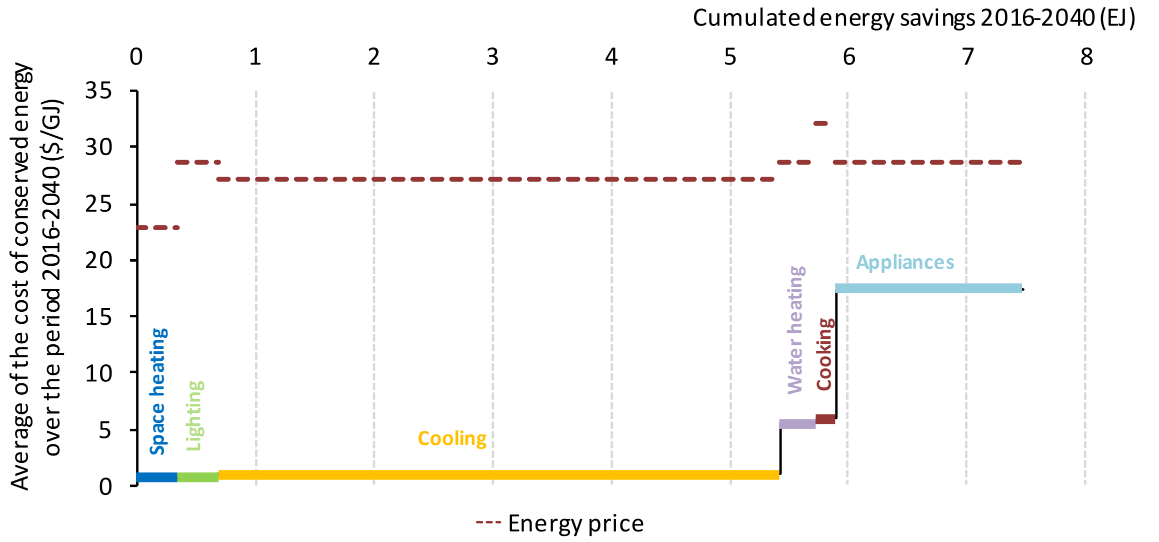
Approximately three-quarters of the anticipated residential building stock in India in 2040 has yet to be constructed; a consideration that has enormous implications for energy use in buildings, particularly a shift from biomass to electricity, throughout the projection period and for policy makers. Strong growth in construction pushes up energy consumption in order to produce the steel, cement, aluminium and other materials. The alternative is to risk locking in inefficient capital stock for the long term. The fact that much of 2040's building stock is yet to be built creates an opportunity for India to effectively implement and strengthen its efficiency standards through building energy codes. With this in mind, in 2007 India launched an Energy Conservation Building Code (ECBC) that sets minimum energy standards for new non-residential buildings (those with energy requirements above a certain threshold). The code is voluntary until made mandatory by individual state governments, who can also amend it to suit local climatic conditions; but ECBC has already been adopted for central government buildings and in a majority of states, and the aim is to extend coverage across the country by 2017.[23] The BEE has

[23] Other initiatives, such as the Green Rating for Integrated Habitat Assessment (GRIHA) programme launched by The Energy Resources Institute (TERI) and the BEE's Star Rating scheme that targets existing commercial buildings have also gained traction, but remain voluntary.

released guidelines for energy-efficient multi-storey residential buildings, although there is little in the way of mandatory regulation for residential buildings. Furthermore, with the focus on reducing the energy used and energy demand for cooling, and as part of its drive for efficient "smart" cities, innovative options for newer and more efficient technologies such as district cooling systems are starting to be explored.

Looking beyond current and new policies to curtail increases in energy use in the residential sector, significant potential to save energy exists. In the India Efficiency Scenario, all economically-viable investments to increase energy efficiency in the residential sector have been made, and we estimate that about 7.5 EJ can be saved cumulatively over the period 2016-2040 if appropriate policies can overcome economic and behavioural barriers. Potential savings include substantial energy savings by increasing energy efficiency in air conditioners and appliances. These cumulative electricity savings have an estimated average cost of conserved energy of about 5 $/GJ, which is less than a third of the average price paid for the energy, meaning that it costs $1 to save $3 (Figure 35).

Figure 35 • Cost of energy savings in the residential sector in the India Efficiency Scenario, 2016-2040



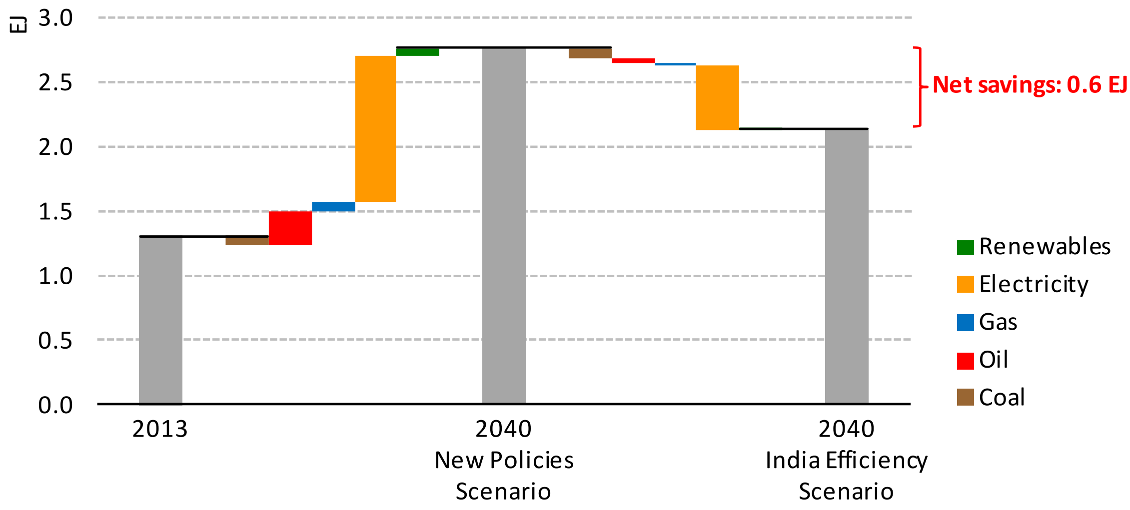
Non-residential buildings

The commercial and public service sector has been the major driver of growth in India's economy, accounting for around 60% of the increase in GDP between 1990 and 2013. This is rooted both in a robust increase in the supply of services but, crucially, also in the increasing share of high-value segments including financial intermediation, information and communications technology, and professional and technical services, which have enabled total factor productivity in the commercial and public services sector to more than double. However, despite its dominant share in the economy, the non-residential buildings sector only accounts for 6% of total final energy consumption in India. This sector, which tends to be concentrated in urban areas, is already largely dependent on electricity, but also on coal and bioenergy.

In the New Policies Scenario the increase in energy consumption in the non-residential buildings sector – including a jump in demand for space cooling – is projected to be predominantly based on electricity growth (with India's building codes and minimum energy performance standards serving to moderate the rate of growth) (Figure 36). However, we estimate that strengthening minimum energy performance standards can significantly reduce the increase and save 0.6 EJ in

2040. This reduction potential is almost equal in absolute terms to the potential in the residential sector even though the residential sector is projected to be over three times larger than the non-residential sector in 2040. The largest energy savings potentials are in lighting and appliances, which roughly account for half the estimated savings.

Figure 36 • Change in non-residential sector consumption of fuel, 2014-2040



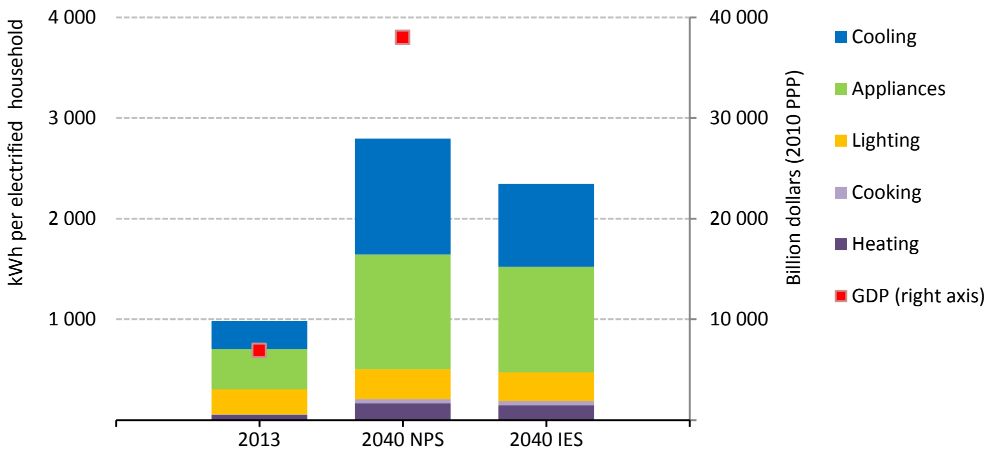
Focus: Space Cooling

Space cooling is a building end-use that encapsulates the projected growth of overall building energy use due to trends in population and wealth. Space cooling is a growing area of concern in India and many other countries for multiple reasons including i) an increasing desire for and ability to achieve personal temperature comfort through air conditioning, ii) changes in building design and construction type from heavy (high thermal mass) materials to low-cost and quick construction materials, iii) a general increase in population in warmer climates due to high birth-rates and population shifts from colder climates to warmer climates, iv) a general trend towards increasing annual average temperatures and an increasing occurrence of extreme temperatures as a result of climate change, and v) an increasing quantity of personal electronic devices that generate heat as a by-product.

Each of these reasons have varying levels of importance and impact on increasing energy use for space cooling, with the increasing desire at the individual level for improved personal thermal comfort in our homes, places of work, and places of public gathering being the largest. This desire, fuelled by economic development and personal wealth increase, is a welcomed sign of progress. In India, economic growth is a key priority, and space cooling energy use will increase as a result of economic growth.

While the demand increase for space cooling is significant and inevitable in hot locations with increasingly wealthy populations, the energy savings potential is also significant (Figure 37). The combination of: i) efficient space cooling equipment such as inverter (variable speed) systems; ii) advanced sensors and controls; and iii) improved building envelopes results in the largest projected energy savings to 2040 in residential buildings in the India Efficiency Scenario (Figure 37) occurring in the space cooling end-use. The expansion of space cooling based on air-conditioners also provides India with an opportunity to transition from harmful and non-climate friendly refrigerants to refrigerants with lower ozone depleting substances (ODS) along with lower global warming potential (GWP).

Figure 37 • Annual electricity consumption per electrified household in India, 2013-2040



At present, the predominant appliance used for space cooling is an evaporative air cooler (i.e. a fan system with water). However, as incomes rise, more people are in a position to afford air conditioners, which can consume at least five-times as much electricity as an evaporative air cooler. The market for air conditioners is already growing rapidly: sales of around 1 million units in 2003-2004 rose to more than 3 million units in 2010-2011 (Phadke, Abhyankar, & Shahh, 2014) and very strong further growth is expected, with one estimate putting annual sales at more than 50 million units by 2050 (Chaturvedi & Sharma, 2015).

In addition to the ownership rate of air conditioning equipment, the hours of comfort achieved by the air conditioning equipment and an increased desire for lower temperatures also plays a large role in enabling large increases in space cooling energy use. Space cooling energy use increases from 10% to 27% of the household energy use from 2013 to 2040 in the NPS (Table 4) as a result of the increased comfort achieved.

Table 4 • Average household cooling equipment ownership and energy use in the New Policies Scenario

	Average ownership rate				Average household consumption*		Share in sector total consumption**	
	Rural		Urban					
	2013	2020	2013	2040	2013	2040	2013	2040
Cooling equipment	0.7	1.2	1.3	1.9	290	761	10%	27%

Note: * Average annual consumption in kilowatt-hours for new cooling equipment sold in India in 2013 and 2040; ** The share in sector total consumption is the share of each category of appliances in the total consumption of the residential sector (excluding solid biomass

Policy Recommendations for Energy Efficiency in Buildings

Buildings hold great potential for cost-effective energy savings. Barriers such as split incentives between tenants and landlords, lack of awareness of efficient technologies, absence of qualified technicians and high initial investment costs threaten market-driven energy savings measures. Governments can eliminate these barriers and achieve building sector energy savings by implementing a package of policies. In India, there are several government agencies at both central and state level that are responsible for regulating energy use in buildings. Coordination between these agencies as well as alignment of policy targets and goals is essential to enable effective implementation of energy efficiency in the building sector.

Building Energy Codes & Performance Standards

Governments should require all new buildings, as well as buildings undergoing renovation, to be covered by energy efficiency codes and with appliances that meet MEPS that aim to minimise life-cycle costs. India has started this effort with the launch of the ECBC in 2007 and the continued adoption by the states to enforce the building code on non-residential buildings. However, India could develop a building energy code roadmap that outlines improvements to the building energy code and standards over time with specific implementation and compliance goals. This roadmap could address both new and existing buildings, set targets for state adoption of future building energy codes and set targets for the enforcement of building energy codes across both residential and non-residential building sectors. This roadmap can consider both short-term and long-term goals for energy efficiency of buildings, including o goal of achieving net-zero energy consumption in buildings within the roadmap timeline.

Energy Performance of Building Components, Systems, Appliances and Lighting

Governments should establish policies to improve the energy efficiency performance of building components, such as windows and cooling systems, to improve the overall energy performance of both new and existing buildings. India has developed a number of product standards that help to reduce the energy consumption in buildings as well as a successful mandatory star labelling programme for appliances to help in consumer decision-making. The Indian government should continue to ensure that product test standards and measurement protocols are regularly expanded, updated (e.g. every 3-5 years) and aligned with the development and use of international test standards and measurement protocols. The Indian Government should aim to accelerate the market transformation of energy efficient products through incentives and other measures. This effort should continue by developing standards for more building components and systems and by changing from voluntary to mandatory MEPS and voluntary high energy performance standards. These two levels of standards for products help to strengthen private investment in the supply chain of high efficiency building components.

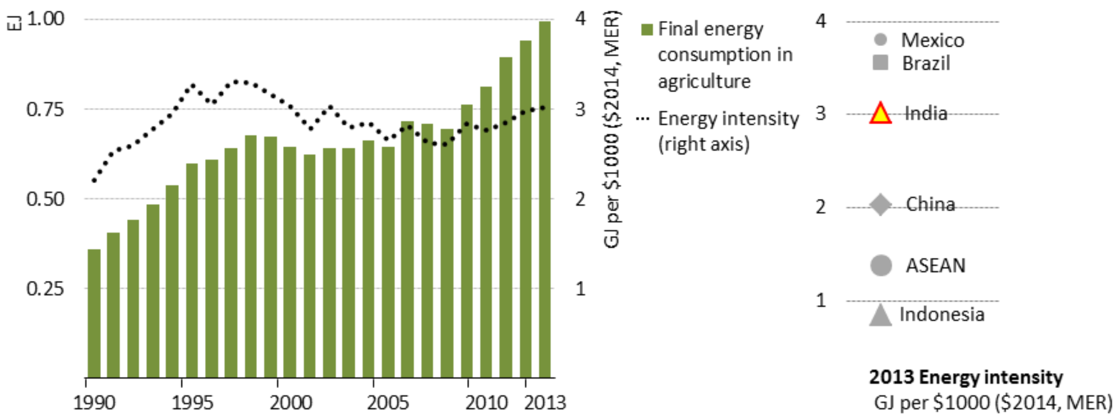
Building and Component Energy Labels and Certificates

Governments should require building energy performance labels or certificates that provide information to owners, buyers and renters. Governments should adopt and regularly update the criteria to achieve the energy efficiency labels across the full spectrum of products, taking into account proven international practices. India currently has a rating and certification industry infrastructure for voluntary building energy performance and green building programmes, such as LEED or GRIHA. The government could consider implementing mandatory energy labels, certificates or disclosure of energy consumption requirements for both whole buildings and building components, such as equipment or appliances. For example, the certificates and labels can be used at point of sale or lease or as part of mandatory disclosure to prospective tenants or owners.

Agriculture

The agriculture sector in India engages half of the country's population and but produces only 17% of the Indian GDP (Figure 38). Final energy consumption is 1 EJ (5% of total final Indian energy consumption), which is roughly the same amount as the total final energy consumption in all end-use sectors in Bangladesh. Irrigation and land preparation account for most of energy demand in the agriculture sector (with the former accounting for about two-thirds) and is produced almost exclusively from electricity and diesel. Electricity used in irrigation pumps accounts for roughly 60% of total final energy consumption in the sector. Diesel (and other oil products) used primarily in tractors accounts for the remaining 40% of total final energy consumption. The intensive use of diesel and electricity makes the agriculture sector an important energy consumer as it is responsible for 15% and 18% of the total final consumption of diesel and of electricity, respectively.

Figure 38 • Final energy consumption in the agriculture sector and energy intensity of value-added, 1990-2013

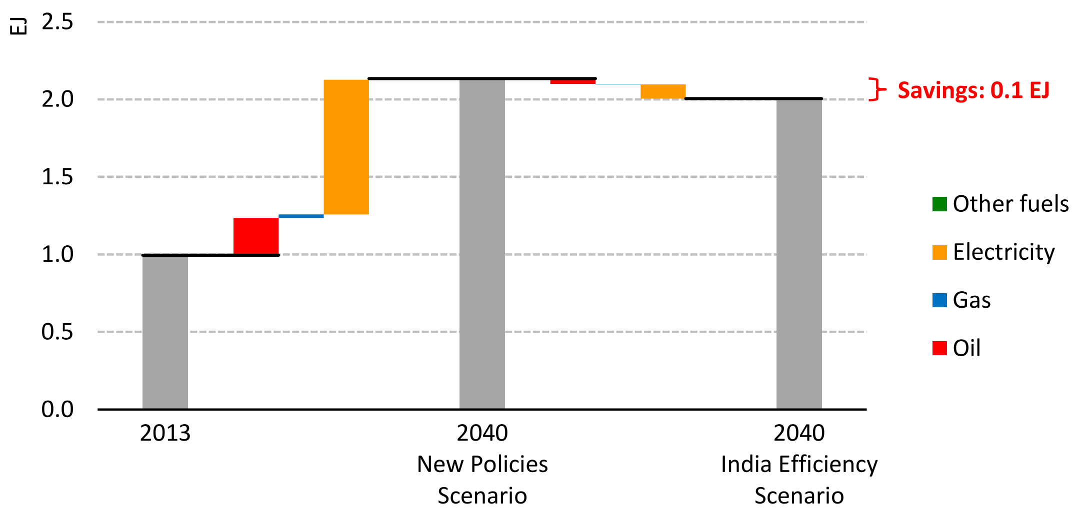


India's existing energy efficiency policies in the agriculture sector are managed by the BEE in the form of demand side management programmes (called Agriculture Demand Side Management, Ag DSM – see Box 7) promoting market-based partnerships on enhancing efficiency in irrigation pumps for instance with an ESCO business model setup. Further, energy efficient diesel and electrical irrigation pumps can get a star-rated label by the BEE and the MOP launched a National Energy Efficient Agriculture Pumps Programme in April 2016, implemented by EESL, to replace at total of 200 000 pump-sets with high efficient pump-sets together with smart controls (PIB, 2016).

Since independence, the agriculture sector in India has experienced what has been called a 'green revolution' as investments in irrigation infrastructure, electricity subsidies to farmers and financial incentives to mechanise production processes have increased both agricultural output and energy demand. For instance grain production (i.e. rice, wheat, maize and coarse cereals) in India has doubled since 1980 (MOA, 2014). In the same period final energy consumption in the whole agriculture sector increased tenfold. The energy intensity of the value-added in the Indian agriculture sector reached a stable level around 1995 and has been constrained by inefficient use of energy in particular by inefficient pump sets, over-consumption of electricity (because of highly subsidised tariffs and lack of metering) and poor irrigation performance. In contrast, the energy intensity of India's GDP as a whole dropped 50% from 1990 to 2013.[24] Inefficient irrigation performance has also resulted in significant water extraction often from groundwater reserves: in 2010, more water was extracted in India for agricultural use alone than the amount extracted in China overall.

In the future, demand for food is expected to grow and crops are expected to diversify, as living standards rise and the population grows, increasing the need for fertilisers. The agriculture sector is also likely to become increasingly more mechanised: although modern techniques have already led to large improvements in productivity, there is significant scope for further gains. For example, tractor use is under 16 per 1 000 hectares in India compared with an indicator of 212 in Italy and 461 in Japan (MOA, 2013). Farm mechanisation is generally expected to push energy consumption higher, although the pace of change will be limited by the fragmented nature of land ownership, which mitigates against the economies of scale that mechanisation can bring. As a result, we project in the New Policies Scenario energy consumption in agriculture to increase by 1.1 EJ to 2.1 EJ by 2040 (Figure 39), with electricity (consumed by irrigation pumps) accounting for 68% of the 2040 share and oil products (mostly diesel) a further 30%.

Figure 39 • Energy demand increase in agriculture in the New Policies Scenario by fuel and savings in the India Efficiency Scenario, 2013-2040



The potential to go beyond the New Policies Scenario and increase energy efficiency in agriculture even further is projected to be a conservative 0.1 EJ in 2040 in the India Efficiency Scenario (over two-thirds of the additional savings occur in electric irrigation pumps; see focus section below) as the New Policies Scenario already includes a range of policies promoting energy efficiency for instance a shift towards metered electricity consumption, promotion of micro–irrigation, groundwater management and a continued gradual reform of energy prices (electricity subsidies are assumed to be phase out by 2025). However, the efficiency savings in the New Policies Scenario should not be taken for granted and the implementation and progress of these policies should be closely monitored in order to ensure that savings are realised.

[24] The energy intensity mentioned here is the total final energy consumption divided by India's GDP (in market prices) in order to make a fair comparison with Figure 38. Figure 2 shows energy intensity defined as the total primary energy demand divided by India's GDP (in market prices).

Focus: Electrical irrigation pumps

There are significant energy efficiency gains to be had within India's irrigation system, one of the most extensive in the world and one that has supported the increase in cropping intensity of farmland. The system relies heavily on electric pumps, (around 70% of the stock of pumps in operation (Ghosh & Agrawal, 2015), mostly of very low efficiency (20-35%) (BEE, 2009). Moreover, flood irrigation, with an estimated water use efficiency of only 35-40%, remains the most widely used method (a significant reason why agriculture is responsible for a remarkable 90% of annual freshwater extraction). Tackling these two issues would help to reduce the over-use of electricity in the sector as well as reducing water consumption; but this is a challenging task for policy makers, requiring a carefully integrated approach – as witnessed by the mixed results of efforts at reform in Andhra Pradesh, Gujarat and West Bengal, among others. The risk of unintended consequences is high. A significant push to improve the uptake of efficient water pumps and to introduce solar water pumps are laudable efforts from an energy policy perspective; but if they are not accompanied by changes in agricultural and irrigation practices (requiring in turn a strong consultative and educational effort with farmers), they risk missing out on some of the potential gains, as well as increasing water consumption

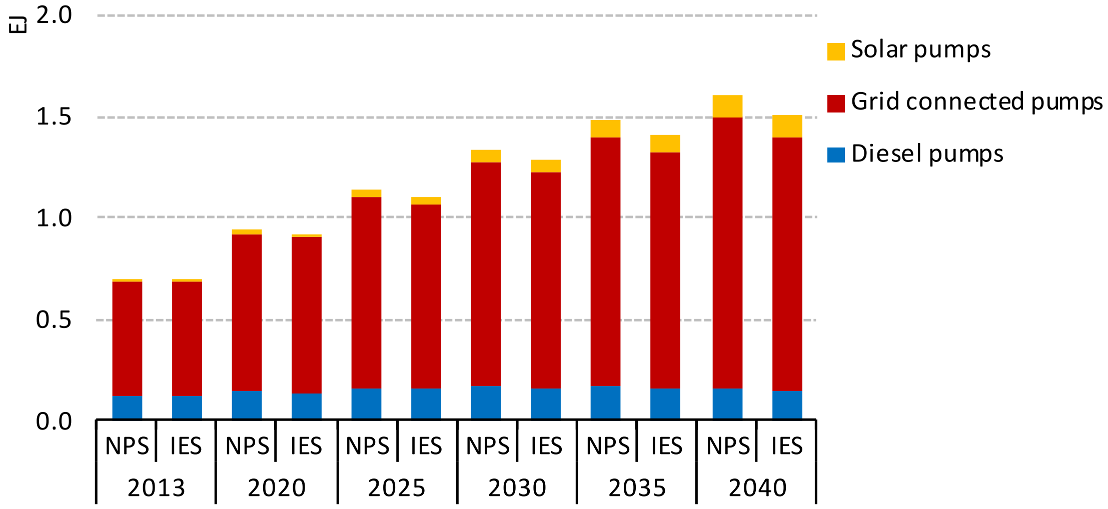
Box 7 • Agricultural Demand Side Management (DSM) Potential

In 2012, the Ministry of Power stated that power consumption in the pumping sector will increase sharply, leading to more public funds being used to cover electricity subsidises. For this reason, the Ministry of Power, through EESL, has been promoting the implementation of Agriculture DSM projects and efficient agriculture pump programmes to promote energy savings while reducing the burden of subsidies. Agriculture DSM has been successfully implemented in the state of Karnataka, with 590 pump sets replaced leading to 37% energy savings and translating into lower subsidy payments from the State Government (BEE, 2016a). Furthermore, in April 2016, the Ministry of Power launched a National Energy Efficient Agriculture Pumps Programme to replace 200 000 inefficient pump-sets by 2019.

However, to ensure the long-term sustainability of the Agriculture DSM programme implies that it has to be more than just replacing existing inefficient pump-sets. Complementary measures such as energy efficiency educational and capacity building programmes tailored to farmers should be considered. For example, the Advanced Pumping Efficiency Programme in California (US) - an educational and financial incentive programme to improve electrical pumping efficiency - has saved annually 1.2 GWh and $120 000 in Alpaugh (an agricultural rural area) by combining public-private partnerships and providing training on pump management and irrigation practices to farmers.

In the New Policies Scenario, the average efficiency of electric pumps is improved by around 25%, compared with today's levels, and more widespread adoption of drip irrigation techniques leads to further efficiency gains for irrigation. Oil consumption for irrigation remains essentially flat, as more and more diesel pump sets are replaced by electric ones – currently the sales of electric pump sets exceed sales of diesel pump sets by a factor of 2.5. By the end of the projection period, electricity meets close to 90% of the energy demand for irrigation, with a rapidly growing share of demand being met by solar-powered pumps. In the India Efficiency Scenario the average efficiency of electric pumps only increased slightly as efficiency improvements in the New Policies Scenario are already significant. As a result energy demand for irrigation in 2040 is only 6% lower in the India Efficiency Scenario compared to the New Policies Scenario.

Figure 40 • Energy demand for irrigation by source in India in the New Policies Scenario and the India Efficiency Scenario, 2013-2040



Policy Recommendations for Energy Efficiency in Agriculture

The agricultural sector, with its growing demand for energy, is of vital importance to the Indian population and economy. Energy efficiency is a necessity for the sector as it can help reduce both the energy costs for farmers as well as reduce the burden on state utilities and government that subsidise the sector's energy use. Making energy more affordable for farmers can help improve their profitability and productivity levels (i.e. tonnes / kWh). Recognising this fact, the MOP has been making successful inroads into agricultural demand side management across the country. The energy efficiency policy recommendations below highlight some of the measures already in place and propose additional measures to further enhance energy efficiency implementation in the sector, and in line with the IEA's India Efficiency Scenario.

Minimum Energy Performance Standards and Labels for Electric Pumps

Power consumption in the pumping sector is rising and there are about 20 million electric pumps in India consuming approximately 18% of the country's total electricity consumption. The government should continue to support the phase-out of inefficient pump-sets through the regular update of MEPS and consider making the star-rated energy performance label for irrigation pumps mandatory. Star-rated pumps are about twice as more efficient as pumps currently in use in the market (TERI, 2015). In parallel, the BEE and EESL should continue to expand their nationwide Agriculture DSM programmes for replacement of existing pumps with five star-rated ones. Based on case studies to date, there has been average energy savings of 25-35% under these programmes. To avoid the overuse of water resources, the replacement of inefficient pumps should be complemented with irrigation best practices.

Private Sector Investment in Agricultural Energy Efficiency

To secure a sustained energy efficiency market in the agricultural sector, the government should enable and facilitate private investment. For instance, using public-private funds to create dedicated businesses or energy services companies (ESCOs) in highly intensive irrigation states along with capacity building on the economic and energy opportunities to the farmers, can result in a new market for private services delivering energy efficiency to the sector. Further development of the pumping sector can offer a set of new skills to farmers regarding pumping efficiency and water and irrigation systems management broadening the diversity of and distribution of labour.

Remove Energy Subsidies

Low energy prices in the agricultural sector, as a result of energy subsidies, can result in higher energy and water consumption and reduce the demand for energy efficiency investment. As energy consumption rises, these subsidies combined with lack of metering can result in a major financial burden to state governments and utilities in India. The government should consider reviewing the current subsidy scheme for the sector in order to reduce this burden as well as assess opportunities for improved metering. For instance, in China, metered electricity tariffs were introduced to farmers so that they were more conscious of their energy consumption, which lead to an uptake of energy efficiency measures within their pumping management systems and better management of the use of electricity to improve communities' livelihoods.

Annex A: World Energy Model

Since 1993, the IEA has provided medium- to long-term energy projections relying on the World Energy Model (WEM). The model is a large-scale simulation model designed to replicate the functioning of energy markets and impact of energy policies, and is the principal tool to generate detailed energy and emissions projections for the *World Energy Outlook*. The WEM is a partial-equilibrium model consisting of three main modules: final energy consumption (covering the residential sector, commercial and public service sector, agriculture, industry, transport and non-energy use), energy transformation (covering power generation, heat production, refiner and other transformation) and energy supply (covering coal, oil, natural gas and biomass). Much of the data on energy supply, transformation and demand, as well as energy prices, is obtained from the IEA's own databases and economic statistics. The current version of WEM includes energy developments up to the year 2040 in 25 regions with twelve countries being individually modelled.

The same macroeconomic and demographic assumptions are used in all scenarios unless otherwise specified. Projections are based on the average retail prices of each fuel used in final uses, power generation and other transformation sectors. These end-use prices are derived from assumptions about the international prices of fossil fuels and subsidy/tax levels. Rates of population growth for each WEM region are based on the most recent medium-fertility variant projections contained in the United Nations Population and Development Database. Demand for energy service (useful energy in the case of the buildings sector) of the WEM is price-elastic and econometrically projected based on multiple factors. The demand for energy service is satisfied by a set of technologies chosen according to their specific costs, technology availability and market barriers. The efficiency of end-use devices, their adoption and the demand for energy services are all affected by different policies.

More details can be found in the model documentation:
www.worldenergyoutlook.org/weomodel/

Annex B: Data Tables

Table A1 • Economic and demographic assumptions in the New Policies Scenario for selected countries, 2013-2040

							Average annual growth rates	
		2000	2013	2020	2030	2040	2000-2013	2013-2040
India	GDP ($2014 billion, PPP)	2,778	6,883	11,446	22,517	37,915	7.2%	6.5%
	- Industry sector share	*31%*	*32%*	*33%*	*34%*	*34%*		
	- Services sector share	*41%*	*51%*	*54%*	*56%*	*58%*		
	- Agriculture sector share	*28%*	*17%*	*13%*	*10%*	*8%*		
	Population (millions)	1,042	1,252	1,359	1,495	1,599	1.4%	0.9%
	GDP per capita ($2014, PPP)	2,665	5,497	8,421	15,061	23,715	5.7%	5.6%
Brazil	GDP ($2014 billion, PPP)	2,096	3,259	3,583	5,212	7,242	3.5%	3.0%
	- Industry sector share	*28%*	*27%*	*27%*	*27%*	*27%*		
	- Services sector share	*66%*	*68%*	*68%*	*68%*	*68%*		
	- Agriculture sector share	*5%*	*5%*	*6%*	*6%*	*5%*		
	Population (millions)	175	200	211	223	229	1.1%	0.5%
	GDP per capita ($2014, PPP)	12,013	16,266	16,971	23,398	31,569	2.4%	2.5%
China	GDP ($2014 billion, PPP)	5,009	16,798	25,907	43,563	59,091	9.8%	4.8%
	- Industry sector share	*39%*	*44%*	*41%*	*38%*	*36%*		
	- Services sector share	*43%*	*47%*	*52%*	*57%*	*60%*		
	- Agriculture sector share	*18%*	*9%*	*7%*	*5%*	*4%*		
	Population (millions)	1,269	1,365	1,411	1,432	1,414	0.6%	0.1%
	GDP per capita ($2014, PPP)	3,946	12,310	18,357	30,429	41,781	9.1%	4.6%
Indonesia	GDP ($2014 billion, PPP)	1,268	2,548	3,743	6,317	9,281	5.5%	4.9%
	- Industry sector share	*51%*	*47%*	*47%*	*47%*	*46%*		
	- Services sector share	*31%*	*39%*	*40%*	*42%*	*44%*		
	- Agriculture sector share	*18%*	*14%*	*13%*	*11%*	*10%*		
	Population (millions)	209	250	269	293	311	1.4%	0.8%
	GDP per capita ($2014, PPP)	6,066	10,198	13,891	21,526	29,809	4.1%	4.1%
Southeast Asia (excl. Indo)	GDP ($2014 billion, PPP)	1,870	3,590	5,051	7,938	11,210	5.1%	4.3%
	- Industry sector share	*37%*	*36%*	*36%*	*36%*	*37%*		
	- Services sector share	*47%*	*52%*	*53%*	*54%*	*55%*		
	- Agriculture sector share	*15%*	*12%*	*11%*	*10%*	*9%*		
	Population (millions)	311	366	393	426	448	1.2%	0.8%
	GDP per capita ($2014, PPP)	6,005	9,815	12,842	18,655	24,997	3.9%	3.5%
Mexico	GDP ($2014 billion, PPP)	1,601	2,096	2,634	3,718	4,828	2.1%	3.1%
	- Industry sector share	*45%*	*39%*	*39%*	*38%*	*37%*		
	- Services sector share	*51%*	*57%*	*58%*	*59%*	*61%*		
	- Agriculture sector share	*4%*	*3%*	*3%*	*3%*	*3%*		
	Population (millions)	101	118	128	139	147	1.2%	0.8%
	GDP per capita ($2014, PPP)	15,867	17,704	20,628	26,742	32,856	0.8%	2.3%
South Africa	GDP ($2014 billion, PPP)	458	694	816	1,088	1,425	3.3%	2.7%
	- Industry sector share	*32%*	*27%*	*27%*	*25%*	*23%*		
	- Services sector share	*65%*	*70%*	*71%*	*73%*	*75%*		
	- Agriculture sector share	*3%*	*3%*	*3%*	*2%*	*2%*		
	Population (millions)	44	53	56	59	61	1.5%	0.5%
	GDP per capita ($2014, PPP)	10,403	13,054	14,686	18,591	23,216	1.8%	2.2%

Table A2 • Energy intensities in selected countries in the New Policies Scenario

	TPED/GDP (toe per $1000, 2014 PPP)				TPED/GDP (GJ per $1000, 2014 PPP)			
	2013	2020	2030	2040	2013	2020	2030	2040
India (NPS)	0.113	0.089	0.064	0.050	4.715	3.72	2.68	2.11
India (IES)	0.113	0.087	0.058	0.042	4.715	3.65	2.44	1.78
Brazil	0.089	0.089	0.075	0.063	3.734	3.72	3.12	2.66
China	0.181	0.132	0.088	0.068	7.571	5.51	3.70	2.85
Indonesia	0.084	0.068	0.051	0.043	3.506	2.84	2.12	1.79
ASEAN	0.106	0.092	0.072	0.060	4.433	3.84	3.01	2.52
Mexico	0.091	0.075	0.059	0.051	3.821	3.14	2.48	2.15
South Africa	0.201	0.176	0.143	0.121	8.400	7.36	5.99	5.06

Note : NPS = New Policies Scenario, IES = India Efficiency Scenario

Table A3 • End-user prices in India ($per GJ, $2014)

Sector	Fuel	Scenario	2013	2020	2030	2040
Industry	Electricity	NPS	26	28	31	31
		IES	26	28	30	31
	Coal	NPS	2	2	2	3
		IES	2	2	2	3
	Gas	NPS	15	14	17	19
		IES	15	14	17	19
	Oil	NPS	20	22	30	32
		IES	20	22	30	32
Residential	Electricity	NPS	18	23	30	29
		IES	18	23	29	27
	Coal	NPS	6	6	6	7
		IES	6	6	6	7
	Gas	NPS	5	8	17	18
		IES	5	8	17	18
Transport	Gasoline	NPS	36	33	41	44
		IES	36	33	41	44

NPS = New Policies Scenario, IES = India Efficiency Scenario

Table A4 • Coal consumption in India the New Policy Scenario and savings in the India Efficiency Scenario, 2013-2040

	New Policies Scenario, PJ				Energy savings in India Efficiency Scenario, PJ		
	2013	2020	2030	2040	2020	2030	2040
Primary energy demand	**14 290**	**19 950**	**28 940**	**39 150**	**- 620**	**-3 890**	**-8 320**
Power generation	**9 330**	**12 550**	**16 640**	**22 170**	**- 520**	**-2 800**	**-5 690**
Other energy sector	**630**	**1 080**	**2 150**	**2 990**	**- 30**	**- 210**	**- 420**
Blast furnace and coke ovens	610	1 060	2 030	2 750	- 30	- 210	- 420
Final energy consumption	**4 330**	**6 320**	**10 150**	**13 990**	**- 70**	**- 880**	**-2 210**
Residential buildings	**140**	**150**	**150**	**140**	**0**	**0**	**0**
Space cooling	0	0	0	0	0	0	0
Space heating	60	60	50	50	0	0	0
Water heating	30	30	30	30	0	0	0
Lighting	0	0	0	0	0	0	0
Cooking	50	60	60	70	0	0	0
Appliances	0	0	0	0	0	0	0
Non-residential buildings	**380**	**450**	**430**	**320**	**- 10**	**- 60**	**- 80**
Industry	**3 810**	**5 720**	**9 580**	**13 530**	**- 60**	**- 820**	**-2 120**
Iron and steel	1 050	1 820	3 500	4 730	- 50	- 360	- 730
Chemicals	60	90	150	200	0	0	- 10
Cement	400	590	890	1 140	0	- 40	- 40
Paper	70	100	140	160	0	- 10	- 20
Aluminium	60	100	170	230	0	- 10	- 20
Other industry	2 160	3 010	4 730	7 070	0	- 400	-1 310
Transport	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Road	0	0	0	0	0	0	0
Domestic aviation	0	0	0	0	0	0	0
Other (rail, pipeline, navigation)	0	0	0	0	0	0	0
Agriculture	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-energy use	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Petrochemical feedstocks	0	0	0	0	0	0	0

Table A5 • Natural gas consumption in India the New Policy Scenario and savings in the India Efficiency Scenario, 2013-2040

	New Policies Scenario, PJ				Energy savings in India Efficiency Scenario, PJ		
	2013	2020	2030	2040	2020	2030	2040
Primary energy demand	**1 870**	**2 440**	**4 320**	**6 230**	**- 10**	**- 280**	**- 830**
Power generation	**580**	**770**	**1 860**	**2 890**	**- 10**	**- 200**	**- 580**
Other energy sector	**250**	**220**	**250**	**340**	**0**	**0**	**0**
Blast furnace and coke ovens	0	0	0	0	0	0	0
Final energy consumption	**1 040**	**1 450**	**2 210**	**2 990**	**0**	**- 80**	**- 250**
Residential buildings	**130**	**140**	**190**	**280**	**0**	**- 10**	**- 20**
Space cooling	0	0	0	0	0	0	0
Space heating	0	0	20	50	0	- 10	- 20
Water heating	30	40	60	80	0	0	0
Lighting	0	0	0	0	0	0	0
Cooking	110	100	110	160	0	0	0
Appliances	0	0	0	0	0	0	0
Non-residential buildings	**30**	**50**	**70**	**100**	**0**	**0**	**- 10**
Industry	**530**	**760**	**1 180**	**1 480**	**0**	**- 50**	**- 160**
Iron and steel	30	30	40	30	0	0	0
Chemicals	510	560	700	790	0	- 10	- 40
Cement	0	0	0	0	0	0	0
Paper	0	0	0	0	0	0	0
Aluminium	0	0	10	10	0	0	0
Other industry	0	170	440	650	0	- 40	- 120
Transport	**60**	**100**	**220**	**440**	**0**	**- 10**	**- 60**
Road	60	100	220	440	0	- 10	- 60
Domestic aviation	0	0	0	0	0	0	0
Other (rail, pipeline, navigation)	0	0	0	0	0	0	0
Agriculture	**10**	**10**	**20**	**30**	**0**	**0**	**0**
Non-energy use	**270**	**380**	**520**	**650**	**0**	**0**	**0**
Petrochemical feedstocks	270	380	520	650	0	0	0

Table A6 • Oil consumption in India the New Policy Scenario and savings in the India Efficiency Scenario, 2013-2040

	New Policies Scenario, PJ				Energy savings in India Efficiency Scenario, PJ		
	2013	2020	2030	2040	2020	2030	2040
Primary energy demand	**7 370**	**9 590**	**13 790**	**19 190**	**- 50**	**- 550**	**-2 020**
Power generation	**340**	**360**	**440**	**480**	**0**	**- 30**	**- 60**
Other energy sector	**750**	**790**	**870**	**1 000**	**0**	**0**	**0**
Blast furnace and coke ovens	0	0	0	0	0	0	0
Final energy consumption	**6 280**	**8 440**	**12 490**	**17 710**	**- 50**	**- 520**	**-1 960**
Residential buildings	**1 000**	**1 110**	**1 290**	**1 600**	**0**	**- 20**	**- 30**
Space cooling	0	0	0	0	0	0	0
Space heating	10	10	20	20	0	0	- 10
Water heating	140	150	170	190	0	0	0
Lighting	270	160	10	0	0	0	0
Cooking	590	790	1 100	1 380	0	- 10	- 10
Appliances	0	0	0	0	0	0	0
Non-residential buildings	**140**	**190**	**300**	**390**	**0**	**- 20**	**- 50**
Industry	**780**	**1 000**	**1 430**	**1 880**	**0**	**- 80**	**- 230**
Iron and steel	20	30	30	30	0	0	0
Chemicals	300	360	460	510	0	- 10	- 30
Cement	200	250	310	320	0	- 10	- 10
Paper	0	0	0	0	0	0	0
Aluminium	20	20	30	40	0	0	0
Other industry	230	340	600	980	0	- 50	- 180
Transport	**3 010**	**4 340**	**6 950**	**10 820**	**- 40**	**- 400**	**-1 620**
Road	2 790	4 060	6 550	10 270	- 40	- 400	-1 620
Domestic aviation	70	100	170	280	0	0	0
Other (rail, pipeline, navigation)	140	180	230	270	0	0	- 10
Agriculture	**410**	**510**	**610**	**650**	**- 10**	**- 10**	**- 40**
Non-energy use	**950**	**1 290**	**1 900**	**2 370**	**0**	**0**	**0**
Petrochemical feedstocks	470	780	1 200	1 520	0	0	0

Table A7 • Electricity consumption in India the New Policy Scenario and savings in the India Efficiency Scenario, 2013-2040

	New Policies Scenario, PJ				Energy savings in India Efficiency Scenario, PJ		
	2013	2020	2030	2040	2020	2030	2040
Primary energy demand	**1 110**	**1 550**	**2 250**	**3 090**	**- 60**	**- 400**	**- 760**
Blast furnace and coke ovens	0	0	10	10	0	0	0
Total final energy consumption	**3 200**	**4 830**	**8 030**	**11 790**	**- 210**	**-1 160**	**-2 390**
Residential buildings	**750**	**1 180**	**2 330**	**4 010**	**- 60**	**- 310**	**- 650**
Final energy consumption	210	330	820	1 650	- 30	- 210	- 470
Space heating	10	10	20	40	0	0	- 10
Water heating	30	70	130	200	0	- 10	- 20
Lighting	190	250	370	420	- 10	- 10	- 20
Cooking	0	10	20	60	0	0	0
Appliances	300	510	970	1 640	- 20	- 70	- 130
Non-residential buildings	**480**	**750**	**1 190**	**1 620**	**- 40**	**- 220**	**- 510**
Industry	**1 350**	**2 030**	**3 250**	**4 600**	**- 110**	**- 570**	**-1 150**
Iron and steel	220	360	640	810	0	- 40	- 120
Chemicals	70	110	160	190	0	- 20	- 30
Cement	80	120	180	220	0	- 20	- 50
Paper	30	50	60	70	0	0	- 10
Aluminium	100	180	300	410	0	- 30	- 70
Other industry	840	1 210	1 920	2 900	- 90	- 470	- 880
Transport	**60**	**70**	**90**	**110**	**0**	**0**	**0**
Road	0	0	0	0	0	0	0
Domestic aviation	0	0	0	0	0	0	0
Other (rail, pipeline, navigation)	60	70	90	110	0	0	0
Agriculture	**580**	**800**	**1 170**	**1 450**	**- 10**	**- 50**	**- 90**
Non-energy use	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Petrochemical feedstocks	0	0	0	0	0	0	0

Table A8 • Biomass consumption in India the New Policy Scenario and savings in the India Efficiency Scenario, 2013-2040

	New Policies Scenario, PJ				Energy savings in India Efficiency Scenario, PJ		
	2013	2020	2030	2040	2020	2030	2040
Primary energy demand	**7 890**	**8 740**	**9 100**	**8 760**	**- 20**	**- 280**	**- 670**
Power generation	**540**	**920**	**1 320**	**1 780**	**0**	**- 120**	**- 220**
Other energy sector	**180**	**190**	**210**	**230**	**0**	**0**	**- 10**
Blast furnace and coke ovens	0	10	30	50	0	0	- 10
Final energy consumption	**7 170**	**7 630**	**7 560**	**6 750**	**10**	**- 160**	**- 450**
Residential buildings	**5 610**	**5 780**	**5 090**	**3 620**	**0**	**0**	**0**
Space cooling	0	0	0	0	0	0	0
Space heating	840	860	760	530	0	0	0
Water heating	0	10	20	40	0	0	0
Lighting	0	0	0	0	0	0	0
Cooking	4 770	4 910	4 310	3 050	0	0	0
Appliances	0	0	0	0	0	0	0
Non-residential buildings	**280**	**320**	**340**	**310**	**10**	**10**	**10**
Industry	**1 270**	**1 510**	**2 010**	**2 470**	**0**	**- 160**	**- 420**
Iron and steel	0	0	0	0	0	0	0
Chemicals	0	20	60	110	0	0	- 10
Cement	0	20	60	120	0	0	0
Paper	30	40	60	60	0	0	- 10
Aluminium	0	0	0	0	0	0	0
Other industry	1 240	1 440	1 830	2 180	0	- 160	- 400
Transport	**10**	**30**	**120**	**350**	**0**	**0**	**- 40**
Road	10	30	120	350	0	0	- 40
Domestic aviation	0	0	0	0	0	0	0
Other (rail, pipeline, navigation)	0	0	0	0	0	0	0
Agriculture	**0**	**0**	**0**	**10**	**0**	**0**	**0**

Annex C: Definitions

Acronyms and abbreviations

BEE	Bureau of Energy Efficiency
CCS	carbon capture and storage
CO_2	carbon dioxide
DRI	Direct reduced iron
E4	Energy Efficiency in Emerging Economies Programme
ECBC	energy conservation building code
EESL	Energy Efficiency Services Limited
ESCOs	Energy Service Companies
FCBTK	fixed chimney bull trench kiln
GDP	gross domestic product
GWP	global warming potential
IEA	International Energy Agency
IES	India Efficiency Scenario
INDC	Intended nationally determined contribution
LED	light-emitting diodes
LPG	liquefied petroleum gas
MEPS	minimum energy performance standards
NPS	New Policy Scenario
ODS	ozone depleting substances
OECD	Organisation for Economic Co-operation and Development
PAT	Perform, Achieve and Trade
PLDV	passenger light-duty vehicle
PPP	power purchasing parity
PRSF	Partial Risk Sharing Facility
SMEs	small and medium-sized enterprises
TFC	total final consumption
TPED	total primary energy demand
WEM	World Energy Model
WEO	World Energy Outlook

Units of measure

bcm	billion cubic metres
EJ	exajoule
GJ	gigajoule
Gt	gigatonne
Gtoe	gigatonnes of oil-equivalent
GW	gigawatt
GWh	gigawatt hours
km	kilometre
mb/d	million barrels per day
MBtu	million British thermal units
Mtce	million tonnes of coal equivalent
Mtoe	million tonnes of oil-equivalent
MW	megawatt
TWh	terawatt hours

Annex D: References

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Printed in France by IEA, October 2016