ENHANCING ENERGY EFFICIENCY IN INDIA: ASSESSMENT OF SECTORAL POTENTIALS

INDIA ENERGY EFFICIENCY SERIES

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JUNE 2017

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LAYOUT:

Magnum Custom Publishing, New Delhi

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Please use the following reference when quoting this publication:

Vishwanathan, S.S., Garg, A., Tiwari, V., Kankal, B., Kapshe, M., Nag, T. (2017)

Enhancing Energy Efficiency in India: Assessment of Sectoral Potentials

Copenhagen: Copenhagen Centre on Energy Efficiency, UNEP DTU Partnership.

ISBN: 978-87-93458-13-0

FOREWORD

Improving energy efficiency is critical to achieving the ambitious goals of the Paris Agreement under the UN Framework Convention on Climate Change. Most global and regional studies show that enhanced energy efficiency policies and actions can dramatically reduce energy use and associated greenhouse gas emissions. This is reflected in the fact that 167 countries included action on enhanced energy efficiency in the Intended Nationally Determined Contributions they submitted as the foundation for the Paris Agreement.

Energy efficiency delivers not only reductions in energy consumption and emissions, if implemented properly, it will also provide opportunities for economy-wide multiple benefits, such as improved health and well-being, cleaner air and more jobs.

In spite of the political ambitions and potential for deriving multiple benefits from action, there are many common barriers and market failures that often prevent countries from moving at the expected pace in implementing the actions on energy efficiency that have been identified.

Many of these barriers and failures need to be overcome by individual countries and cities, but best practice examples of proven solutions are extremely useful in showing what works and how it can be made to happen. This report presents an analysis of energy efficiency opportunities and actions in a number of key sectors in India aimed at inspiring other countries. The assessment highlights some of the conditions for success that will be essential for replication in other parts of the world.

In terms of the future growth of energy and related greenhouse gas emissions, China and India stand out from other countries, due to their rapid economic development, large populations, rapid urbanization and growing industrial sectors. Both countries are focused on decoupling both energy use and emissions from economic growth. In their Intended Nationally Determined Contributions submitted under the Paris Agreement, both countries have included strategies to pursue improved energy efficiency across the main sectors of their economies.

This report is a part of the China and India Energy Efficiency report series that emerged from the High Impact Opportunities studies supported by the UNEP DTU Partnership in China and India. In India, the study was carried out by the Indian Institute of Ahmedabad (IIMA) and Energy Efficiency Services Limited (EESL), New Delhi. The other two reports published on India are *Best Practice and Success Stories on Energy Efficiency in India*, and *High Impact Opportunities for Energy Efficiency in India*. All the reports can be downloaded for free at www.energyefficencycentre.org.

This report, *Enhancing Energy efficiency in India: Assessment of sectoral potentials*, presents a model based assessment of the potential for improvements in energy efficiency in key sectors of the Indian economy. It also identifies a set of short, medium and long term High Impact Opportunities for energy efficiency, which in combination with various technological options and policies, have potential to provide required future energy services much more efficiently. The process of identification of HIOs included stakeholders' consultation and experts opinions on the potential for scaling up the identified technological and policy options.

I would like to thank the national experts and practitioners, who have contributed to this publication. I am sure that the publication will be of value to policy-makers, practitioners and researchers in India, as well as providing inspiration to other countries on how to move forward with energy-efficiency policies and action paving the way to further gains in energy efficiency.

John Christensen
Director
UNEP DTU Partnership

ACKNOWLEDGEMENT

We greatly appreciate Subash Dhar and Jyoti Painuly for reviewing the report. We appreciate the inputs received from Surabhi Goswami and Mette Annelie Rasmussen on the layout design. We would also like to thank Robert Parkin for proof-reading the English language in this publication.

Finally, we would like to thank Xianli Zhu for her constant encouragement and the Copenhagen Centre on Energy Efficiency for providing the opportunity to undertake this study.

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LIST OF ACRONYMS

AIM	Asia-Pacific Integrated Model
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
ATC	Aggregate commercial and technical losses
BEE	Bureau of Energy Efficiency
BUR	Biennial Update Report
CAN	Urea and Calcium Ammonium Nitrate
CO_2	Carbon dioxide
CEA	Central Electricity Authority
CIL	Coal India Limited
COP	Conference of Parties
DAP	Di-ammonium Phosphate
GAA	Global Action Agenda
GDP	Gross Domestic Product
GHG	Greenhouse gas emissions
GVA	Gross Value Added
EE	Energy Efficiency
EEFP	Energy Efficiency Financing platform
HIOs	High Impact Opportunities
IEA	International Energy Agency
INDC	Intended Nationally Determined Contributions
IPCC	International Governmental Panel on Climate Change
LBNL	Lawrence Berkeley National Laboratory
LEAP	Long-range Energy Alternatives Planning System
LED	Light Emitting Diode
MARKAL	MARKet ALlocation
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impact
MOP	Muriate of Phosphate
MOSPI	Ministry of Statistics and Programme Implementation
MT	Million Tonnes
MTEE	Market Transformation on Energy Efficiency
NAPCC	National Action Plan on Climate Change
NEP	National Environmental Policy
NITIAYOG	National Institution for Transforming India
NMEEE	National Mission for Enhanced Energy Efficiency
O&M	Operations and Maintenance
PAT	Perform, Achieve and Trade
PJ	Peta Joule
POLES	Prospective Outlook on Long-term Energy Systems
POP.	Population
SEC	Specific Energy Consumption
SEforALL	Sustainable Energy for All
SLNP	Street Light National Programme
SAPCC	State Action Plan on Climate Change
TIMES	The Integrated MARKAL-EFOM System
T&D	Transmission and Distribution
TPES	Total Primary Energy Supply
UJALA	Unnat Jyoti by Affordable LEDs for All
USD	United States Dollars
WEO	World Energy Outlook
ZED	Zero-Effect, Zero Defect

EXECUTIVE SUMMARY

Economic development will lead to higher demand for various end-use goods and services in India. Energy-efficient technologies provide a way forward to achieve economic growth at relatively lower costs due to associated multiple benefits such as resource conservation, lower energy consumption, higher productivity and lower emissions intensity per unit of output.

The report undertakes the following analysis to identify High Impact Opportunities (HIOs):

- An assessment of the potential for improvements in energy efficiency and identifying different technological options to support the Sustainable Energy for All (SEforALL) target in selected sub-sectors in India;
- Identification of policies and measures to achieve the SEforALL energy efficiency target in the sub-sectors.

Sectoral analysis of energy efficiency is conducted using AIM/End-Use, a bottom-up energy system model, by assessing the energy saving potential of various technology options. These technology options include a combination of existing technologies, best available technologies and more advanced technologies likely to exist in the future. The total impact of each individual option is estimated using the cost of conserved energy and the total energy saving potential at the national level.

The sectoral analysis from the model is used to guide the identification of High Impact Opportunities (HIOs). The process also included stakeholder consultation and expert opinions on the potential for scaling up a technology option based on its technological maturity level and its contribution to SEforALL's objectives of energy access, improving energy efficiency and encouraging renewable forms of energy.

This report examines HIOs in the short term (till 2020), medium term (2020 to 2030) and long-term (2030 to 2050) perspectives. HIOs identified (Table I) before 2020 include light-emitting diode (LED) lighting, energy-efficient (EE) pump-sets for agriculture; a 'perform, achieve and trade' (PAT) scheme for eight energy-intensive sectors, and metro rail. LED lighting is expected to penetrate deeply by 2020 and will not remain an HIO beyond that date. Even if technological changes occur in LED lighting after 2020, they will not result in any appreciable energy savings at the national level; the break-even point for incremental improvements to energy-efficient technologies would take longer. From 2020-2030, our analyses indicate that a perform, achieve and trade (PAT) scheme would remain a major HIO along with energy-efficient pump sets. Emerging HIOs include energy-efficient fans, solar power, smart grids, super-critical pulverized coal technology, and measures to reduce T&D losses. PAT will continue to remain an HIO even after 2030 if the 'Make in India' programme continues. Energy-intensive industries will move gradually towards a narrower specific energy consumption band, while the residential sector will shift towards cleaner fuels like electricity and solar. Smart grids will play a crucial role in monitoring, thereby conserving energy in urban areas. Metro will remain an important HIO in the transport sector, increasing the share of public transport as one of the most convenient modes of travel.

TABLE I. HIOs for the future

SECTOR	HIO – SHORT TERM 2015-2020	HIO – MEDIUM TERM 2020-2030	HIO – LONG TERM 2030-2050
Agriculture	Energy-efficient (EE) Pumps	EE Pumps	EE and Solar Pumps
Residential	LED, advanced space cooling systems, cleaner cooking	Energy-efficient fans, advanced space cooling systems, cleaner cooking (LPG, biofuels)	Advanced space cooling systems (AC with cool roof), solar concentrators for cooking, city/housing complexes based heating and cooling systems
Transport	Metro	Metro, Electric vehicles (EV)	Metro, Electric vehicles (EV)
Industry	PAT	PAT (enhanced sectoral and plant coverage)	PAT (enhanced specific energy consumption targets)
Power	Transmission and commercial (T&C) loss reduction, super-critical (SC) coal-based power plants	Super-critical (SC) and ultra-mega power plants (UMPP), T&C loss reduction, solar and wind, smart grids	SC and UMPP, storage technologies, solar/wind and other new and renewable sources, smart grids

CHAPTER 1

INTRODUCTION

TABLE 1: Selected Indicators for 2000, 2005, 2010 and 2014

	PER CAPITA TPES (TOE / CAPITA)	PER CAPITA ELEC. CONS. (MWH / CAPITA)	CO_2/POP. (TCO_2 / CAPITA)	CO_2/GDP ($KGCO_2$ / 2010 USD)	TPES/GDP (TOE/ '000 2010 USD))	CO_2/TPES (T CO_2/TOE)
World 2000	1.64	2.32	3.79	0.47	0.2	2.31
World 2005	1.77	2.58	4.16	0.47	0.2	2.34
World 2010	1.87	2.87	4.4	0.46	0.2	2.35
World 2014	1.89	3.03	4.47	0.44	0.19	2.36
India 2000	0.42	0.39	0.85	1.08	0.53	2.02
India 2005	0.45	0.47	0.94	0.94	0.45	2.09
India 2010	0.56	0.64	1.3	0.93	0.41	2.3
India 2014	0.64	0.8	1.56	0.92	0.38	2.45

Source: IEA, 2016.

India is currently the fourth largest consumer of primary energy in the world after China, the United States and Russia, with a global share of 6 per cent in 2015. With numerous policies and strong support from the government to transition to clean, more efficient and secure energy system, improvements in technology, including in energy efficiency, would play an important role in meeting India's Intended Nationally Determined Contributions (INDCs). Various studies on energy scenarios using top-down and bottom-up modelling have analyzed the energy use at a national level focusing on the technological and economic variables. Climate change, energy security and environmental considerations have been the motivation for these studies (Shukla, Garg and Dholakia, 2015; NitiAayog, 2015a; CSTEP, 2015; IEA, 2015a; NitiAayog, 2014b). With limited sources of energy and high dependence on imports of coal and oil, energy efficiency became the focus of a law[1] adopted in 2001 to reduce energy consumption through conservation. This, along with renewables, has become a crucial strategy to reduce the carbon emissions in the medium term (NitiAayog, 2015; IEA, 2015b; BEE, 2014).

India's per capita energy supply, electricity consumption and carbon emissions are much lower than the world average, as shown in Table 1. However, India's energy intensity and carbon intensity in relation to GDP and the carbon intensity of its energy supply are much higher. It can be observed that, in order to reduce the figures for energy and carbon intensity, mitigation actions are required that include switching to new and renewable forms of energy and emphasizing energy conservation by improving energy efficiency on both the supply and demand sides.

1 *Energy Conservation Act, 2001.*

The Energy Conservation Act was introduced in 2001 to minimize energy consumption through various measures, including improvements in technology. End-use energy efficiency is central to these measures, as every kilowatt of energy saved in end-use will result in energy saved in generation, after accounting for auxiliary consumption and T&D losses.[2] The Bureau of Energy Efficiency (BEE) was set up after the 2001 Act was passed to deploy the policies and directives introduced under it, and the Act was followed by the Electricity Act in 2003 and the establishment of the National Mission for Enhanced Energy Efficiency (NMEEE) in 2008. The NMEEE was approved by Ministry of Power as a part of a National Action Plan on Climate Change (NAPCC) as result of India's commitment to reduce greenhouse gas emissions. One of the main objectives of the Planning Commission's Twelfth Plan (2007-2012) was to reduce the energy intensity of end-use sectors, addressed through NMEEE instruments that include Perform, Achieve and Trade (PAT),[3] Market Transformation on Energy Efficiency (MTEE), financing demand side management through the Energy Efficiency Financing platform (EEFP) and enhancing efficiencies in various end-use sectors, especially power (MOP, 2001; BEE, 2016).

This study presents a baseline and new policy scenarios based upon India's National Determined Contributions. It also describes the multiple on-going policies and programmes of various ministries that give a picture of India's energy consumption by 2020, 2030 and 2050 res-

2 *End-use efficiency can also apply to technologies that do not consume electricity.*

3 *A detailed description of the PAT scheme is available in the Report on Good Practices and Success Stories on Energy Efficiency in India.*

pectively. It reports on energy efficiencies in prioritized sectors and focuses on high-impact opportunities (HIOs) in order to provide future policy recommendations to accelerate the diffusion and adoption of energy-efficient best practices through a combination of regulatory, economic, institutional and awareness-raising (informational) instruments.

1.1 ENERGY DEMAND AND FUEL MIX IN KEY SECTORS

Energy demand in India nearly doubled from 2000 to 2013, even though its per capita energy consumption remains one of the lowest in the world at 32-34 GJ (gigajoules) per capita in 2013 as compared to 17-19.5 GJ per capita in 2000 (MOSPI, 2015; WEO, 2015).[4] There are still widespread differences in energy dynamics across India's states and regions due to its size and heterogeneity in income levels and resource availability. Almost 75 per cent of the country's energy demand is met by fossil fuels. There have been rapid changes in India's energy system in the past fifteen years, but coal still constitutes the maximum share in the fuel mix, followed by renewables, oil and natural gas. The overall share of primary energy demand for coal decreased from 65 per cent in 2000 to 54-58 per cent in 2011-2013.[5] Total primary energy intensity of GDP decreased from 838 PJ/Million INR in 2000 to 712 PJ/Million INR in 2011, despite the increases in energy demand and population.[6]

Figures 1 and 2 present the fuel mix of primary energy demand in the power and other sectors.[7] While the amount of coal used has increased in all sectors, the share of coal in the fuel mix in the power sector has declined in the past fifteen years, while it has increased in the other sectors. The share of oil has remained constant, while the shares of natural gas, nuclear, hydro-power and renewables[8] have increased in all sectors, including power. This is due to the increase in demand for energy in the transport and residential sectors, in addition to policies since 2002 that have favoured cleaner and renewable sources of energy. There is a difference between government and WEO reports in the calculation of total primary energy demand, possibly because of how the data have been collected and presented in these reports.

The demand for oil and gas has increased over the past three decades, though the demand for coal imports fluctuates depending on its availability. The government of India has been planning to end imports of thermal coal completely by increasing the production of indigenous coal, increasing the capacity of coal washeries and reallocating the coal blocks in a transparent manner (Economic Times, 2016). The government also plans to reform its coal policy by allowing Indian coal prices to be determined by the international market instead of by Coal India Limited (CIL), which may lead to competition between domestic and international suppliers in the future (Gandolphe, 2016). Biomass data have not been presented for all the years selected, as it was specifically included only after 2002 in WEO reports and after 2011-12 in the selected government reports.

Consumption of energy across sectors has been increasing at CAGR of 5.3% per year since 2000. As shown in Figures 2 and 3, coal is used in major sectors, though it contributes most to energy demand in the power and industry sectors. Oil contributes mainly to the transport sector, while electricity is used all sectors. Figure 3 shows the fuel mix in the industry, residential and transport sectors for the years 2000, 2005 and 2013.

The demand for coal from industry increased more than threefold between 2000 and 2013 due to increasing demand for energy in the iron and steel and cement industries. In the same period the demand for oil increased two-fold in the transport sector due to growing passenger numbers and freight. Biomass has remained the major source of energy in the residential and commercial sectors, essentially for cooking and heating purposes. Electricity demand has more than doubled in the residential and commercial sectors, being driven by the increasing use of electrical appliances in both urban and rural areas.

Energy intensity has traditionally been used as a proxy to measure the energy efficiency[9] of a sector or an economy. India's energy intensity has been decreasing since mid-2000s, which indicates the decoupling of energy use vis-à-vis growth in GDP. The energy intensity of the industrial sector is decreasing, as shown in Table 2. Steps have been taken to reduce energy intensity since the early 2000s through regulatory and economic instruments. On the other hand, a combination of factors, including population growth and increasing incomes, has led to subsequent increase in the demand for travel and transportation of goods, resulting in higher energy intensities

4 *Assuming constant population levels, the final value of energy consumption per capita varies according to the source of data.*

5 *The share of biomass has not been taken into account in making these calculations, as MOSPI reports do not record it, and WEO reports for India only include it after 2002.*

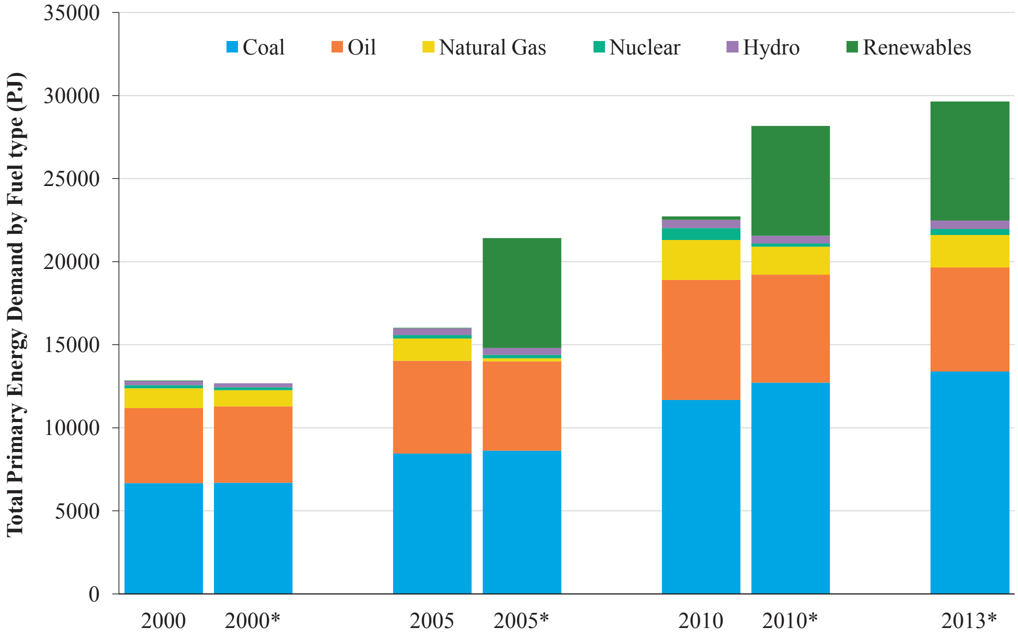
6 *Primary energy demand data from MOPSCI and energy statistics; GDP data from Economic Survey 2015-16.*

7 *Other sectors include industry, transport, residential, commercial and agriculture.*

8 *Renewables includes only solar and wind in these calculations.*

9 *In this study, the energy efficiency of technology and industry is treated as being improved by improving technology efficiency and/or fuel efficiency.*

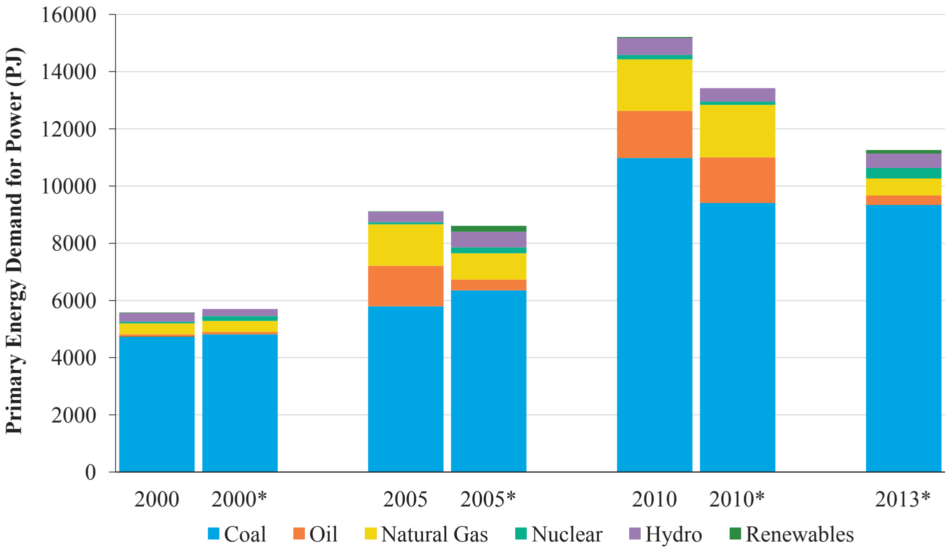
FIGURE 1: **Total primary energy demand by fuel type (in PJ)**



Coal includes coking coal, non-coking coal and lignite

*Source: BUR (2015), WEO (2002, 2008, 2012, 2015)**

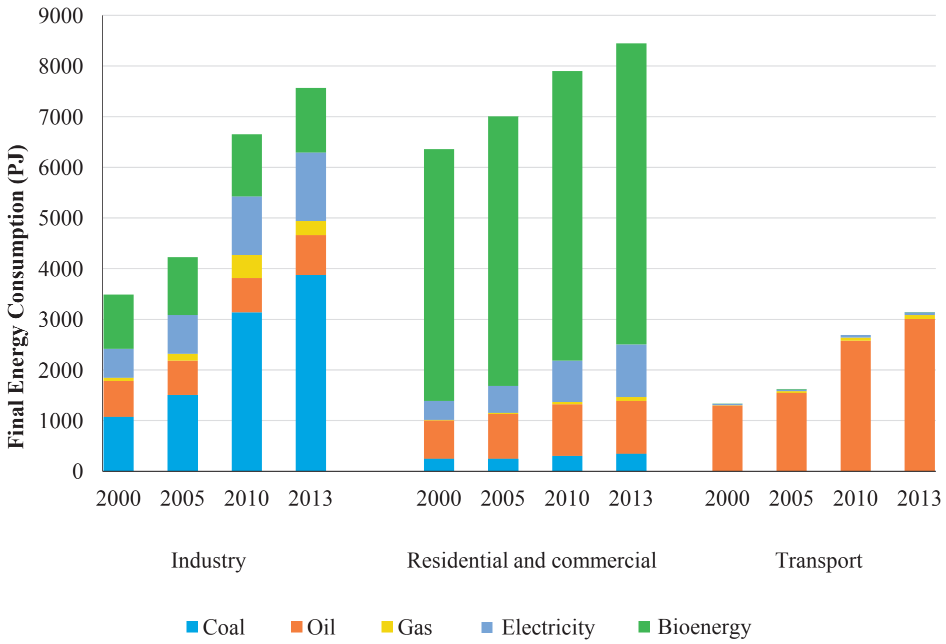
FIGURE 2: **Primary energy demand by fuel type for power sector (in PJ)**



Coal includes coking coal, non-coking coal and lignite

*Source: BUR (2015), WEO (2002, 2008, 2012, 2015)**

FIGURE 3: Sector-wise final energy consumption (in PJ)



Source: IEA (2000, 2005, 2010, 2013)

in the transport sector. Nevertheless, since 2001 efficient and cost-effective strategies have been devised and implemented to reduce the energy intensity of vehicles through emissions standards, as shown in Table 2. From a comparison with the global average, it can be observed that there is still a huge scope for improvement in these sectors in order turn India into an energy-efficient economy.

1.2 POLICY ENVIRONMENT FOR ENERGY EFFICIENCY

The Energy Conservation Act (2001), Electricity Act (2003) and the Integrated Energy Policy (2006) provide the legal framework for creating an energy-efficient economy through a combination of public policy instruments and technology. The National Action Plan on Climate Change (NAPCC), released in 2008, focuses more sharply on energy efficiency through its mitigation actions using eight missions, one of which includes the Mission on Enhanced Energy Efficiency (NMEEE). The premise of this mission is based on a concept of energy conservation that involves reductions in energy use through the efficient or optimized use of energy, lower use of a service, or both. The Mission seeks to support and strengthen market mechanisms to increase energy efficiency through regulatory and economic means, as well as increasing the availability of information to stakeholders.

In addition to NMEEE, INDC and climate mitigation and adaptation measures to reduce carbon emissions through reductions in energy use have been introduced through programmes at the national, state and local levels, which cover both the supply and demand sides of energy management. Strategies to decrease emission intensities through energy-efficiency improvements have been suggested in the 12th Five-Year Plan and reported in the first biennial update report (BUR, 2015). The different strategies, selected by their objectives and descriptions, are shown in Table 3.

1.3 INDIA'S INDC AND ENERGY EFFICIENCY

India's INDC constitutes a step forward in contributing to global efforts to combat climate change, along with its ongoing efforts by committing itself to reducing the emission intensity of its GDP by 33-35 per cent of its 2005 level by 2030. This is an improvement over the voluntary pledge made in 2010 to reduce this figure by 20-25 per cent over 2005 level by 2020. Action on this pledge has

TABLE 2: Energy intensity in selected sectors

SECTOR	INDUSTRY / TECHNOLOGY	UNIT	INDIA (2000)	INDIA (2012)	GLOBAL AVERAGE (2005 OR 2010)	SOURCE	
						India	Global
Industry	Aluminium	PJ/MT		20.95	16.6	PAT (2012)	
	Iron and steel	PJ/MT	28.99	21.44	18.68		WSA, 2016
	Cement	PJ/MT	3.16	2.98	2.72		IEA, 2007
	Brick kiln	PJ/MT	1.11	0.7-1	1.35		CWR, 2012
	Paper and print	PJ/MT		27.28			
	Chemicals	PJ/MT	6.55	3.58			
	Fertilizer	PJ/MT	34.22	16.42	28		ECOFYS, 2015
Transport	2-wheelers	PJ/bpkm	0.37-0.55	0.47	0.37-0.6	Das and Parikh (2004); TERI (2012)	IEA, 2016
	3-wheelers	PJ/bpkm	0.78-1		0.54-1		
	4-wheelers	PJ/bpkm	1.27-1.61	0.28-0.97	0.85-3.5	Das and Parikh (2004); Singh (2006)	
	Bus	PJ/bpkm	0.2-0.3	0.21-0.52	0.2-1.1	Das and Parikh (2004); TERI (2012)	
	Rail	PJ/bpkm	0.18	0.16	0.05-0.06		
	Metro			0.09			
	Diesel locomotives	PJ/bpkm		0.11	0.1-5		IEA, 2016
	Electric locomotives	PJ/bpkm		0.05			

already been set in motion through the implementation of a series of policies and programmes in the past decade in each of the major end-use sectors. Energy efficiency remains one of the most cost-effective measures because it not only conserves energy at end-use, but also saves on the cost of the energy produced. Concerns regarding energy affordability, accessibility, availability and security, as well as environmental considerations, have only amplified the interest in the energy efficiency potential of all sectors.

In addition to being cost-effective, energy efficiency suggests the existence of a clean, emission-free resource. India's first BUR outlines the numerous policies, plans, missions, programmes and schemes (Table 3) that have initiated energy savings in all the major end-use sectors. The power and industry sectors are considered the most energy-intensive sectors in India, followed by the transport and residential sectors. Both the technical efficiency of a device that converts fuels to the required form of energy and type of fuel determine the demand for energy in any sector.

The primary energy supply from various energy sources is about 27,000 PJ in India, with an installed capacity of 236 GW (excluding renewables) as of 2015 (CEA, 2015). With a population growth of 1.2 per cent per year,[10] India has to meet the basic needs of its people and provide them access to affordable energy while helping to address problems of climate change. New and renewable forms of energy have been used to add capacity both on and off the grid. Currently, India has around 38 GW of installed capacity from renewable sources, including wind, small hydro, biomass, cogeneration, waste to power and solar power. Transmission and distribution (T&D) losses are currently about 23 per cent a year.[11] The mitigation strategies under NMEEE, which include increasing thermal efficiency by using supercritical technology, and reductions of aggregate commercial and technical (ATC) losses

10 *World Bank databank (2016). Source: http://data.worldbank.org/indicator/SP.POP.GROW?locations=IN*

11 *Central Electricity Authority (2016). Source: http://www.cea.nic.in/reports/monthly/executivesummary/2016/exe_summary-01.pdf*

TABLE 3: Objectives and description of selected acts, policies and plans for this study

ACT / POLICY / PLAN / MISSION / PROGRAMME	SECTORS	OBJECTIVE	DESCRIPTION
Energy Conservation Act, 2001	All	Energy security, energy efficiency	Legal framework for efficient use of energy and its conservation
Electricity Act, 2003	Power	energy accessibility, energy efficiency	Legal framework across various sectors for use of electricity
Integrated Energy Policy, 2006	All	Clean energy, energy efficiency	Meet demand for energy services through technically efficient, economically viable and environmentally sustainable approach
National Mission on Enhanced Energy Efficiency (NMEEE)	Industry	Energy efficiency	Reduce specific energy consumption (SEC) by EE technology and fuel switching; increasing thermal efficiency of power plants
National Sustainable Habitat Mission - Standards and Labelling Programme; UJALA[1] and SLNP[2] Programmes	Residential and commercial	Energy efficiency	Scale up and adoption of EE star-rated appliances in addition to designing sustainable buildings
National Sustainable Habitat Mission	Transport	Energy efficiency	Promoting urban public transport
National Mission on Sustainable Agriculture - Energy Efficiency of agriculture pump sets ; Micro-Irrigation Scheme	Agriculture	Energy and resource efficiency	Phasing out diesel pumps, promoting energy efficiency by adopting EE pumps and encouraging micro-irrigation
National Solar Mission	Residential, commercial, agriculture	Energy security	Adopting solar rooftops for water heating and electricity, street lighting, scaling up solar water pumps

1. UJALA: Domestic Efficient Lighting Program (DELP), relaunched as a UJALA scheme.

2. SLNP: Street Light National Programme.

Source: BUR, 2015

are being implemented in order to improve the energy efficiency of the power sector.

With a growth rate of 7.5% in 2015-16, the industrial sector requires energy-efficient measures to reduce its overall carbon emissions. 478 designated consumers in eight core energy-intensive industries were mandated to decrease their consumption by means of the Perform, Achieve and Trade (PAT) scheme. In 2015, refineries, railways and distributed companies were added to the list. The government's Make in India campaign envisages a million medium and small-scale industries promoting energy and resource efficiency through the policy of Zero-Effect, Zero Defect (ZED). In a bid to meet the sustainable development goals for energy, the government has launched numerous schemes for the transformation of cities and villages. The Smart Cities Mission and the Atal Mission for Rejuvenation and Urban Transformation (AMRUT)[12] require the residential sector in urban and rural areas to provide access to affordable energy-efficient housing. In transport, measures have been taken to focus on low-carbon transport by promoting public transportation (bus and rail transits) and dedicated freight corridors.

The INDC enhances these ongoing policies, programmes and schemes through the introduction of new, more efficient and cleaner technologies in thermal power plants, increasing the share of renewables in the total fuel mix to forty per cent by 2030, and promoting energy efficiency in end-use sectors by phasing out older technologies and fuel-switching.

Numerous studies in the past have brought out the magnitude of the energy savings, costs and benefits of various measures. This study presents the energy consumption of the selected sectors and their energy intensities. Furthermore, it discusses the high-impact opportunities to improve energy efficiency in industry, transport, residential and agriculture sectors through various scenarios.

12 Smart Cities Mission and AMRUT cater to a hundred cities, five hundred cities and slums and villages respectively.

1.4 ENVIRONMENTAL IMPACTS OF ENERGY USE: CO_2 EMISSIONS AND LOCAL POLLUTION

Rapid growth, urbanization and increasing demand for energy has not only led to mounting environmental pressure on resources (energy, water, land) but also increase in the emission of local and global pollutants. The burning of fossil fuels leads to emissions of Greenhouse Gases (GHG) such as carbon dioxide, methane and local pollutants like oxide of sulphur and nitrogen and various types of particulate matter. This has resulted in deterioration of the ecosystems in the country, and increased local air pollution, impacting the health of the natural environment as well as human beings.

In 2010, India emitted 1574 million tons (MT) of CO_2, of which the energy sector emitted 1441 MT, contributing 92% of total GHG emissions in that year (BUR, 2015). Electricity generation accounted for 52% of total CO_2 emissions, followed by industrial sector at 19% and the transport sector by 12%. Eleven major cities of India are the most polluted in the world with poor air quality causing public health issues. Local pollution comes from thermal power stations, vehicle tailpipes, brick kilns, industrial activities and biomass (cooking and heating). Sulphur dioxide (SO_2) concentrations have been below the limits due to the low-sulphur content of coal combustion, while concentrations of nitrogen oxides and particulates will increase with growing urbanization and motorization. As of 2015, there were 0.59 million and 1 million premature deaths due to outdoor and indoor air pollution respectively (WEO, 2016).

India is one of the most vulnerable countries to the impact of fossil fuel energy use, which results in greenhouse gas emissions along with other forms of pollution. The possible consequences include extreme variations in weather conditions leading to extreme events, coastal flooding, rises in sea levels and the impacts on agriculture, industry, the residential and commercial sectors, human health, and ecosystems such as Himalayan glaciers. Environment is one of top social concerns for citizens and consumers in India (BUR, 2015). The local pollutants that are observable may rank more highly, though with increasing extreme events (droughts and floods) and uncertain precipitation, the impacts of GHG emissions will only worsen in the future. India is taking proactive steps to mitigate as well as adapt to this unreliable climatic future through various missions.

1.5 HIGH-IMPACT OPPORTUNITIES

High Impact Opportunities (HIOs) form part of the action agenda of the Sustainable Energy for All (SEforALL) initiative, launched by the then UN Secretary General in September 2011, with three interconnected goals to be achieved by 2030. These include universal access to modern energy, doubling the energy-efficiency improvement rate and doubling the share of renewables in primary energy, all by 2030. The SEforALL initiative created a Global Action Agenda (GAA) to achieve its goals which covered eleven action areas under two categories, namely sectoral and enabling action areas. The sectoral action areas cover energy-related issues in all major sectors. The enabling action areas emphasize cross-cutting mechanisms to support through (a) planning policies; (b) business models and technology innovation; (c) finance and risk management; and (d) capacity building and knowledge sharing. HIOs are thus defined as action- individual as well as collective-based because of their significance in achieving the three main objectives for SEforALL and the ability to make an impact by 2030. These actions focus on forging lasting commitments by building strong partnerships to enhance access that will drive positive outcomes (SEforALL, 2016).

This report first describes the overall energy consumption and efficiencies in the main sectors and sub-sectors in India. It reviews past success stories and emerging options in the each of the sub-sectors to focus on the HIOs that will be crucial in improving energy efficiencies across sectors. Section 2 explains the methodology, socio-economic drivers used to set up the model and the criteria for the selection and modelling of the HIOs. This is followed by description of the end-use demand of key sectors in Section 3 and details of the policies implemented to enhance energy efficiency in Section 4. Section 5 provides the storylines and results of key energy and climate change policies in each sector from the model. It presents the national-level projections, followed by the impact of HIOs in the short and long terms in every sector and related GHG emissions. Finally, it lists the selected technologies as HIOs for the short, medium and long terms.

CHAPTER 2

METHODOLOGY AND SOCIO-ECONOMIC DRIVERS

This chapter provides an overview of the methodology used in the study and the key socio-economic drivers that are assumed in it.

2.1 METHODS AND MODELS

2.1.1 CHOICE OF MODEL

The aim of this study is to identify the most significant opportunities for energy efficiency. These opportunities could be within individual sectors, but they could also cross–cut them. Energy efficiency targets for India within the INDC are proposed at an aggregate level (in terms of energy intensity), and therefore models that provide coverage for the entire energy system are especially suited to this aim. Energy and environmental models typically represent the entire energy system and therefore are also quite well suited for this analysis.

Energy and environmental models can be classified as top-down (macro-economic) or bottom-up (techno-economic or accounting). Macro-level analyses are computed by means of top-down models, which are generally based on general equilibrium theories that include perfect market conditions or macro-economic frameworks that attempt to get closer to reality by taking into account the imperfections of market conditions. These models deal with general problems that require long-term 'policy solutions'. Macro-level analyses depict the overall functioning of the system generally at the national level using aggregate data to assess the economic cost and environmental effect of policies. Some of the most commonly used models include AIM/CGE, MERGE, ENV-LINKAGES, GCAM-IIM PACE and E3MG. One of the disadvantages in using aggregate level data is the neglect of heterogeneous data, which results in 'macro-bias' or an 'economic paradigm' that may not be able to predict trend-breaking events. Some of the other limitations including the inability to model governance and institutional measures, structural uncertainties, the non-assignment of probabilities and non-marginal changes, and its effect on welfare distribution (ICRIER, 2014; Shukla, 2013; Herbst, Toro, Reitze, and Jochem, 2012; Moll and Anton, 2007).

Micro-level analyses are associated with bottom-up models, which deal with disaggregated data on specific problems that require 'engineering solutions'. These are based on techno-economic perspectives, which use the partial equilibrium theory or the accounting framework with a shorter time duration. Some examples of PE models include MARKAL, MESSAGE, AIM-Enduse, and POLES, while the accounting framework models include LEAP, AIM-EXSS, 2050 Pathway Tool and the LBNL China End-Use Energy Model. These models are advantageous as they deal with technologies on the demand and supply sides at the sector level, evaluate technological progress and are able to calculate shadow prices. Using these models to make macro-economic decisions could lead to either the 'over-forecasting' or the 'under-forecasting' of scenarios. Limited information on interactions between sectors, a lack of links with the wider economy, no account taken of the risks of long payback periods, attributes of technologies and consumers' preferences are among the weaknesses of bottom-up models (Shukla, 2013; Moll and Anton, 2007).

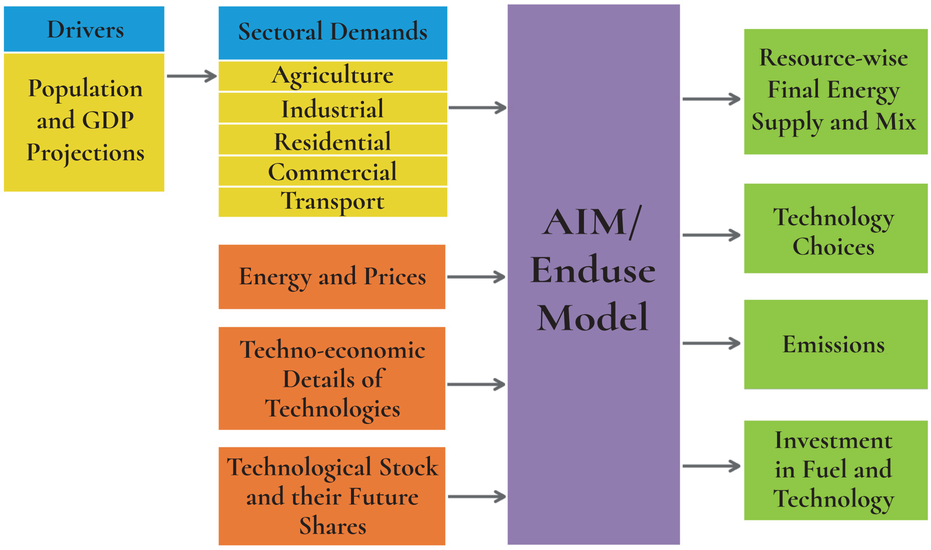
In the current study, AIM/Enduse has been used because it can provide a techno-economic perspective at the national level with sectoral granularity. Built on a disaggregated, sectoral representation of the economy, it provides a detailed characterization of technologies and fuel based on their availability, efficiency levels and costs. It is a bottom-up optimization model that estimates the current and future energy consumption and GHG emissions of all sectors. It uses linear programming to provide a set of technologies that will meet the exogenous service demand at the least cost while satisfying techno-economic, emissions- and energy-related constraints.

2.1.2 MODEL SET-UP

The AIM/Enduse model is a bottom-up energy, technology and services optimization model, (Figure 4). It accounts for final energy consumption and CO_2 emissions in end-use sectors based on actual energy use and the way energy services are performed by energy devices. It focuses on the selection of end-use technology in energy production and consumption. It calculates the future demand for energy services in different sectors and determines the optimal set of technologies that can be used to satisfy the service demand through total cost optimization. Based on the energy consumed by the selected set of technologies, the model estimates the future energy consumption of various devices, as well as of the system as a whole. The model minimizes the net present value of all system costs including capital, fuel, O&M and all the other cost components. In this study, an analysis of the timing of fuel and technology switchovers, levels of emissions and different ways of mitigating them by adopting countermeasures has also been carried out under two different scenarios. This has also helped in assessing the technologies and narrowing down the HIOs for each sector that will save energy, reduce emissions and in turn help in attaining the INDC targets.

In the AIM/Enduse model, the technology selections in a country's energy-economy-environment system are made using linear optimization. However, as the AIM/Enduse model only provides a broad framework, in analysing a sector or a country detailed model development is required. This facilitates analysis of the energy consumption, technology choices and emission trajectories in a given

FIGURE 4: Model structure of AIM/Enduse model



Source: AIM/Enduse Manual (2003)

context. Furthermore, a scenario analysis provides desirable future options in various competing situations for mapping emission reduction possibilities (Shukla, et al., 2004; Kainuma, Matsuka, and Morita, 2003).

The model has been set up for India for five major sectors and their respective services, technologies, reference years and discount rates. These sectors are agriculture, industry, power, residential (including commercial) and transportation. Multiple services in each sector have been examined to provide a better understanding of the sector. For example, fifteen industries have been selected to represent the industry sector, while passenger and freight characterize travel demand in the transport sector. Each service is further segregated based on the mode of transport used, such as road, rail, air and water. The technologies considered in the model range from those currently available to those that are still in the research and development stage. The new technologies and their years of introduction are based on various Indian and international reports and expert opinions.

Service demands are the main external drivers that trigger decisions regarding technology selection based on information on costs. The energy mix is derived from the technology mix. Finally, CO_2 emissions are derived from information on the emission characteristics of fuels, materials and technologies. The service demand estimates have been carried out exogenously. The methodology for demand projection used by Kapshe, et al. (2003) has been adapted in this study along with a few revisions. The share of technologies in the model is used to estimate the future scenario in the sector. The maximum shares for the base year are taken from various government and research publications. The model provides scope to present transitions in the economy through demand of service and share of technologies. The AIM/Enduse model contributes to addressing these issues by taking into account the likely shifts in technology choices due to the introduction of efficient policies. In the present study, the model has been used to support policy formulation by quantifying outputs. In this model the end-use demands for future years have been introduced exogenously. The model captures the latest commitments by the Government of India through its INDC report, submitted to the UNFCCC on 1 October 2015. The INDC initiatives on GHG mitigation and clean energy cover the period 2005-2030.

Various driving forces influence a combination of parameters based on which supply and demand for a service can be determined (Shukla, Rana, Garg, Kapshe, & Nair, 2004). These include:

a. Sectoral demand

The demand in each sector is dependent on various factors, which are described in detail in Section 3. This parameter explains the growth in service demand in each sector based on socio-economic drivers such as population and economic growth. This also depends on the service demand of each sub-sector or industry in every sector. 'Energy service' refers to a measurable need within a sector that must be satisfied by supplying an output from a device. It can be defined in either tangible or abstract term: thus, 'service

TABLE 4: Parameter for evaluation of the HIOs

PARAMETER	ELEMENTS
Technology	Maturity of the technology, ease of implementation, performance of technology (warranty period, hours of operations, lumen output etc.), energy savings (regular energy, avoided capacity addition, peak energy), prospect for Make in India (e.g. in terms of value, 30% of LED chips are imported), potential for obsolescence (potential for substitution by other technology, lifespan of generic technology and specific devices), energy inputs, present inventory, expected future penetration in numbers (2020, 2030 and 2050).
Economic	Present capital cost (retail/bulk), cost reduction trends, salvage value, scrap value, cost savings (regular energy, avoided capacity addition, peak energy), subsidy reduction/disincentive, feed-in tariff for additional power generated, financing model, O&M costs.
Social	Local employment, acceptability of technology.
Policy Intervention	Enabling policy interventions to support HIOs, replication and scaling up challenges.

demand' refers to the quantified demand created to satisfy the exogenous service demand.

b. Energy

Energy parameters are inserted in the model for each technology, along with energy prices. Energy inputs are entered in the form of specific energy consumption for each technology, the data for which were collected or estimated. As the model links energy supply with demand, electricity supply and demand are consistent across sectors.

c. Technology

The model selects a set of energy technologies in order to minimize the total annual cost of fulfilling the energy service demand under circumstances of energy and emission constraints, technology diffusion and so on. The selected payback period for technologies can impact on the simulation results of mitigation cost analysis. The payback period represents the time required to get back the investment in a project. The changes that are taken into account simultaneously in the AIM/Enduse model include: 1) selection of a new technology at the end of the service life of an older technology, or to meet an increase in service demands; 2) improvements in the energy efficiency of an existing technology; and 3) replacement of an existing technology by a new technology.

2.2 HIGH IMPACT OPPORTUNITIES

2.2.1 DEFINITION AND ROLE

HIOs are defined as 'specific actions that can advance the sustainable energy of a country within the larger global initiative' of achieving sustainable energy for all through energy access, improving energy efficiency and encouraging renewable forms of energy (se4all, 2016). In the case of India, HIOs have been selected based on their importance in achieving the EE objectives for SEforALL and the ability to make an impact by 2030. This report also considers HIOs up until 2020, along with medium and longer term HIOs for the period 2030-2050.

2.2.2 HIOs: IDENTIFICATION AND SELECTION

HIO identification involves adopting both a backward- and a forward-looking approach. In the backward-looking approach, about seventy case studies were identified in the Indian context across principal sectors and sub-sectors. These case studies took the form of implemented initiatives through policy and/or market interventions that had potentially impacted on society by significantly enhancing energy efficiency in a specific application. A stakeholder consultative process was followed to arrive at the sixteen technologies that could be considered potential HIOs from the selected case studies.

In the forward-looking approach, an additional set of initiatives were identified that had not been implemented but that contained a large potential for improvements to energy efficiency. The success stories identified using the backward-looking approach and potential initiatives identified using the forward-looking approach were further evaluated using four parameters (Table 4) to focus on the potential short-, medium- and long-term HIOs for India in each sub-sector.

The probable HIOs are presented in Table 5. These were then assessed based on expert opinions from industry according to the feasibility of the technologies to save energy and reduce carbon emissions. A combination of economic, social and policy interventions is required to enable adoption, adaptation and diffusion of the selected technologies chosen as HIOs through replication and scaling up.

TABLE 5: The probable HIOs

SR. NO.	SECTOR	HIO SUB-SECTOR	PROBABLE HIOS
1.	Residential and commercial	Modern cooking appliance and fuels	Improved cooking stove
			Solar cooking in tribal areas
			Village level biogas grid and Gobar Bank
		Buildings and appliances	LED lighting
			Star-rated appliances
			Building management system
2.	Transport	Transportation	Mass transit systems
			Technology transition for vehicles
3.	Electricity	Distributed electricity solutions	Solar home systems
			Roof-top solar electricity in industry
		Grid infrastructure and supply efficiency	Distributed local electricity grid
			Reduction in AT&C losses through smart metering in a smart grid
4.	Industry	Industrial processes	Waste-heat recovery in the iron and steel industry
			Waste-heat recovery in the cement industry
5.	Agriculture	Agricultural process	Energy efficiency in agricultural pump sets
			Drip irrigation

These HIOs were then modelled according to the assumed penetration to estimate the energy efficiencies and thus the energy savings in the reference and INDC scenarios from 2020 to 2050.

2.2.3 MODELLING THE HIOS

The present study analyses the impacts on energy efficiency of the implementation of HIOs. These measures, along with ongoing efforts, will require a focus on sector-specific actions to reduce emissions intensities by decreasing the energy intensity of technologies.

In developing scenarios to combat climate change, the focus has been on energy use, the primary generator of GHG emissions. Therefore, it becomes pertinent to look at policies that encourage the appropriate market transformations in order to improve energy efficiency, resulting in the conservation of energy and improved environmental conditions. The current development path in India is energy-intensive, though on-going national policies aim to decouple economic growth from energy demand. Model development takes into account ongoing measures and future targets. Alternative strategies and development paths have been studied in relation to two scenarios: a Business as Usual (BAU) scenario, which reflects the continuation of policies and practices with moderate changes; and an INDC scenario, which mimics the reduction of carbon from energy systems through policies and programs listed in the INDC document. This indicates India's resolve to ensure that its growth is sustainable and based on low carbon principles.

The analysis of HIOs for energy efficiency is carried out across sectors under two scenarios for the period from 2000 to 2050. The horizon years considered are 2020 (short-term), 2030 (medium-term) and 2050 (long-term). We model our analysis for the 2005-2030 period to synchronize with Indian INDCs.

2.3 SCENARIOS

A scenario has been defined as 'a coherent, internally consistent, and plausible description of a possible future state of the world (IPCC, 1994). It is not a forecast; each scenario is one alternative image of how the future can unfold.'[13] Scenario analysis should not be placed in the same category as predictions or forecasts. Rather, scenarios explore a plausible future by using a model to generate a set of outcomes based on the set of assumptions adopted. Scenario architecture provides a structure to the storyline used in the selected study. In the current study, we will be working with two scenarios, which are described as the Business as Usual (BAU) or baseline scenario and the INDC scenario.

13 *IPCC Definition and Roles of Scenarios:* http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=125

2.3.1 BUSINESS AS USUAL (BAU) SCENARIO

In the current study, the BAU scenario assumes the continuation of policy and economic dynamics. It takes into account the on-going mitigation and adaptation strategies that encompass the broad framework laid down by the National Environmental Policy (2006), the National Action Plan on Climate Change (2008) and the State Action Plans on Climate Change (SAPCC). The scenario also adopts the long-term policy interventions related to energy, technology and services in every major sector.

2.3.2 INDC SCENARIO

The INDC scenario takes into account India's contributions in response to the Conference of Parties (COP) decisions 1/CP.19 and 1/CP.20 for 2021 to 2030 in every major sector. The scenario sets an overall emission intensity reduction of 33-35 per cent from the 2005 level, akin to INDC. More specific interventions at the sectoral level are provided in Chapter 4.

2.4 SCENARIO DRIVERS

The key socio-economic drivers include demographics and economic growth.

2.4.1 DEMOGRAPHICS

Demographics covers population growth, number of households, rural-urban population distribution and household incomes. India's population, which stood at 350 million in 1947, increased steadily to 1,053 million in 2000 and is set to increase further, as indicated under various scenarios (Table 6). Rising trends in the urbanization of the population with increases in per capita incomes along with rural-urban distribution and household size have influenced and will continue to influence energy use patterns. The population projections vary according to the assumptions adopted for mortality rates, birth rates, fertility rates and migration. Table 6 provides population projections from various sources. The population projection reported in the planning commission scenario A (Table 6) has been selected for this study and for both scenarios.

2.4.2 ECONOMIC GROWTH

India's economic growth is the one of the key assumptions of the model, based on which the end-use demand for the current study has been decided. Based on expert opinions, an annual average growth rate of around 7 per cent has been assumed in the BAU scenario for the period between 2020 and 2030 (Table 7).

The output of an economy is generally expressed as its gross domestic product (GDP), and its rate of change is a tracker for the country's economic growth. It measures the 'domestic economic activity in every sector by summing up value added and the income generated in the specified period of time' (Mankiw, 2015).

2.5 END-USE DEMAND METHODOLOGY

Numerous studies have been issued for the projection of long-term demand for national energy planning (Shukla et al., 2015; CSTEP, 2015; WB, 2014; IESS, 2014; NitiAyog, 2014; NCAER, 2009). Correlations between growth in end-use demand and macro-economic growth are well established. Two broad approaches have been adopted by most studies in forecasting long-term economic growth. One is to start by projecting overall GDP growth followed by breaking it down into sectoral and sub-sectoral contributions. The other is first to project the individual sub-sectoral and sectoral value-added contributions, and then to aggregate them to arrive at total GDP. Various econometric models and assumptions are used at each stage of projection. The first approach is appropriate in the context of long-term demand projections for a de-

TABLE 6: Population projections (in million persons)

YEAR	PLANNING COMMISSION A[a]	PLANNING COMMISSION B[a]	PLANNING COMMISSION C[a]	UNDP[b]	WORLD BANK[c]
2000	1053	1053	1053	1053	1053
2010	1231	1231	1231	1231	1231
2020	1345	1306	1287	1326	1389
2030	1463	1553	1364	1461	1528
2040	1560	1341	1409	1572	1601
2050	1628	1295	1416	1657	1705

Note: the projections from all the sources have been considered from 2020.

Source a: Planning Commission, 2013; Source b: UNDP 2015; Source c: World Bank 2015 veloping country like India, which involves numerous uncertainties and non-econometric factors. Starting by projecting individual sub-sectoral growth followed by aggregation is likely to magnify the errors at each stage of aggregation. Starting with aggregated GDP projections followed by sectoral and sub-sectoral disaggregation, on the other hand, would at least ensure the macroeconomic consistency of the final projections at the sub-sectoral level (Shukla, Rana, Garg, Kapshe, & Nair, 2004). In the current study, the demand for end-use has been calculated following the second approach. Information has been gathered on the various sectors and their relevant subdivisions that drive energy consumption. For example, the energy consumed by energy-intensive industries in the industrial sector, various modes of transport in the transportation sector, and categories such as cooking, lighting and space cooling in the residential sector have been assessed for their end-use services.

The Indian economy is presently on a rapid path of development, with growth rates in the demand for most goods in end-use sectors being high. This will continue to grow, as India is expected to undergo significant change in the next twenty to fifty years. The history of developed countries shows that these growth rates become saturated in the long run with the modernization of the economy. The increasing growth rate followed by the trend towards saturation is best represented by the logistic curve. The logistic function used for demand projection is given in following equation (1):

$$Y_t = Y_0 \frac{\exp(a+bt)}{1+\exp(a+bt)} \quad \text{.......................................(1)}$$

where, Y_t is the level of demand at time t, and Y_0 is the asymptotic limit for the demand Y_t, estimated on the basis of expert opinion and the experience of developed countries. The parameters a and b are estimated by the linear regression of the log-log form of equation (1), given in equation (2), based on time series data.

$$\ln\left(\left((Yt/Y0\right) / \left(1 - Yt/Y0\right)\right) = a + bt \quad \text{..................(2)}$$

Under the reference scenario, a compounded annual growth rate of 6.2 percent from 2005 to 2050 is assumed, starting at 5.5 percent in 2035 and saturating at 2 percent by 2100 using the logistic curve method. The GDP ctions are then disaggregated into the gross value added (GVA) contributions from the industrial, transport, services and agricultural sectors. The shares of the industrial, transport and service sectors in GDP are steadily increasing at the expense of agriculture (Table 8).

TABLE 7: GDP projections (2000-50)

YEAR	GROSS DOMESTIC PRODUCT (TRILLION INR AT CONSTANT PRICES)	CAGR
2000	24.49	
2005	32.20	
2010	47.63*	
2015	67.09*	6.0%
2020	94.81#	7.2%
2025	132.38#	6.9%
2030	182.81#	6.7%
2035	245.77#	6.1%
2040	325.18#	5.8%
2045	421.62#	5.3%
2050	538.13#	5.0%

*Sources: *Economic Survey 2015-16; #expert opinion and logistic curve*

Sectoral demand may increase or decrease based on the market environment and customer demand. Historical trends have shown a decline in the share of the agricultural sector in overall GDP from 60 per cent in 1950 to 14 per cent in 2015-16 and an exceptional rise in the service sector to 64 per cent in 2015-16. The share of industry in GDP is projected from the logistic regression of past data and assumes a long-term saturation level of 29-31 percent in 2050. Next, using similar logistic regression, the projection for the service sector takes the form of its share in the balance of the future trajectory of non-industrial GDP (assuming a long-term saturation share of 61-63 per cent). Branching in this manner ensures consistency with the total GDP and Industry GVA projections. The share of transport in the balance of non-industrial and non-commercial GDP is then projected in a similar way (assuming a 25 per cent long-term saturation share). The projections for the GVA in the agricultural sector are automatically obtained as the final balance. To counter-validate for consistency, the projections for net-irrigated area are made separately using a logistic regression of past data. These are checked for correlation with the projections for the agriculture GVA.

The industry sector constitutes seven energy-intensive sub-sectors: aluminium, cement, chlor-alkali, fertilizer, iron and steel, paper and pulp, and textiles, in addition to other manufacturing units. Table 7 presents the GDP projections and Table 8 shows the past and present sectoral shares. The share for agriculture is assumed to decrease in the next decade, while the share of industry increases. The services share of GDP may slightly increase.

TABLE 8: Sectoral shares (%)

YEARS	AGRICULTURE	INDUSTRY	SERVICES	OTHER
2000*	18.76	27.32	50.37	3.55
2005*	15.46	27.99	53.74	2.81
2010*	12.29	28.23	57.32	2.16
2015*	11.50	26.50	60.00	2.00
2030	9	29	60.2	1.8
2050	7.4	34	57	1.6

*Sources: *Economic Survey 2015-16, Years 2030, 2050 based on authors' estimates*

CHAPTER 3

END USE DEMAND IN KEY SECTORS

This chapter describes the demand projections for the major sectors under the BAU scenario. It should be noted that the service demand remains the same under both BAU and INDC scenarios.

3.1 INDUSTRY

The industry sector contributed about 27 per cent to GDP in 2015-16. The industrial sector's consumption of electricity increased from 34 per cent in 2000 to about 44 per cent in 2015 (MOPSCI, 2016). The model covers over fifteen industries, though the study describes only seven of these energy-intensive industries, as they constitute more than 60 per cent of industrial energy consumption and are included in PAT cycle I (BEE, 2011). Per capita consumption (Table 9) in each sub-sector of the industry has been taken as a proxy for industrial service demand. Figure 5 gives the specific energy consumption of individual firms chosen under the PAT scheme in key energy-intensive sectors for 2011-12.

3.1.1 ALUMINIUM

Aluminium is the one of the most important base metals used in industry because it is a light metal. India has the fifth largest bauxite reserves in the world, with deposits up to 5 billion tonnes (BT), or around five per cent of total world deposits. India started its own aluminium production in 1943, became self-sufficient by 1989, and is now a net exporter of the final product. Total domestic production of aluminium was 2.04 million tons (MT) in fiscal year 2014-15 (IBoM, 2016). The domestic demand for aluminium is around 1.6 MT, with an estimated growth rate of 6-8 per cent. Figure 6 shows the trend in the growth of aluminium production in India over the last decade. The details relating to major players within the Aluminium sector are provided in Appendix A.

Aluminium is used primarily in power sector, with other sectors including the transport, construction and residential sectors.[14] The uses of aluminium in different sectors include power (48%), transport (15%), construction (13%), consumer durables (7%), machinery and equipment (7%), packaging (4%) and others (6%).[15] In the power (or electricity) sector, aluminium is used as a conductor for power cables used in the transmission and distribution of electricity. It is also used in switchboards, coil windings, capacitors, etc. Aluminium products like beverages cans, aluminium foil, plates and automotive components can be completely recycled.

The primary demand for aluminium in India is expected to reach 6 MT by 2025 and 14 MT by 2050 (Figure 7), which equates to 4.1 kg of per capita aluminium consumption in 2025 and 8.6 kg per capita in 2050, whereas current per capita aluminium consumption is around 1.3 kg, with annual aluminium demand of 1.8 MT, indicating the immense growth potential for aluminium in India. Recycling has become important in the production of aluminium, as it uses between five and ten per cent of the energy used in its production, indicating very low emissions compared to normal production processes. It is expected that, in the years to come, recycling will reach a figure of about 35-40% of total aluminium consumption (IMYB, 2014a).

3.1.2 CEMENT

India is the second largest producer of cement in the world, with demand for cement expected to increase to about 550-600 MT by 2025. India produced 283 MT

14 Satpathy and Mohan, 2016 (http://niti.gov.in/writereaddata/files/document_publication/MWEC1.pdf); CRISIL Quarterly Industry Report 2016.

15 Indian Bureau of Mines, 2016 (http://ibm.nic.in/writereaddata/files/01092017164732IMYB2015_Aluminium_09012017_Adv.pdf)

TABLE 9: Per capita consumption of each industry sub-sector in comparison to the world average (Year 2015-16, Unit in kilograms/per capita)

	ALUMINIUM[a]	CEMENT[b]	CHLOR ALKALI[c]	FERTILIZER[d]	IRON AND STEEL[e]	PULP AND PAPER[f]	TEXTILE[g]
World	8	520	30	26.15	216.6	58	11
India	1.4	195	5.2	22.8	59.4	9	5.5

a. *http://niti.gov.in/writereaddata/files/document_publication/MWEC1.pdf*

b. *https://www.equitymaster.com/research-it/sector-info/cement/Cement-Sector-Analysis-Report.asp*

c. *http://www.ibef.org/download/Chemicals-January-2016.pdf*

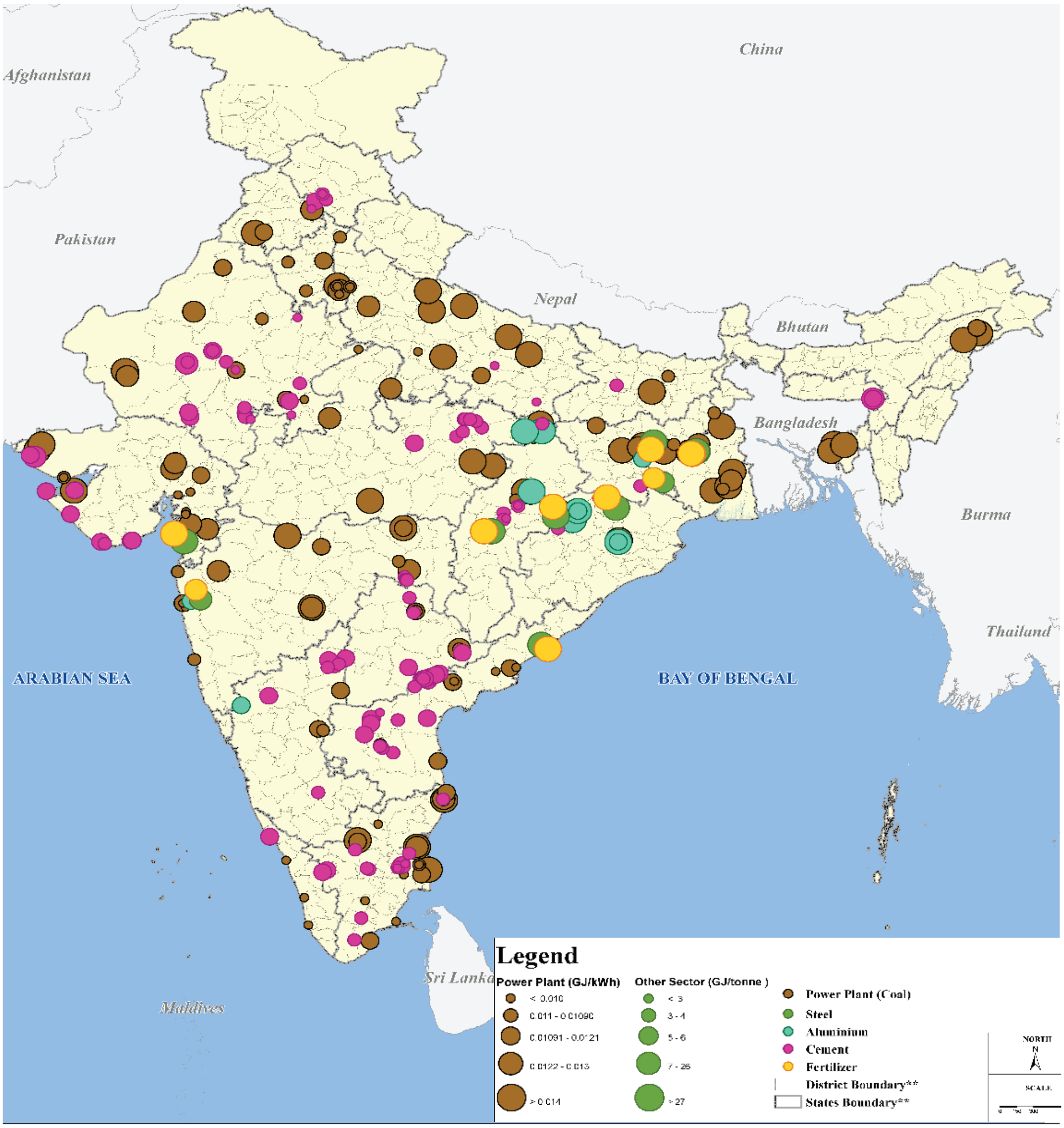
d. *FAO database.*

e. *http://economictimes.indiatimes.com/industry/indl-goods/svs/steel/india-to-equal-world-per-capita-steel-consumption-in-10-years/articleshow/52817065.cms*

f. *http://www.ibef.org/research/reports/indias-paper-demand-to-rise-53-per-by-2020*

g. *http://www.textileworld.com/textile-world/fiber-world/2015/02/man-made-fibers-continue-to-grow/*

FIGURE 5: Specific energy consumption of major energy-intensive industries (2011-12)



Source: Compiled from PAT cycle II notification

of cement in 2015-16 (Indiastat, 2016), with production growing at a rate of 7% a year. Figure 8 shows the trend in cement production in India over the past decade. India produces several varieties of cement, such as Ordinary Portland Cement (OPC), Portland Pozzolana Cement (PPC), Portland Blast Furnace Slag Cement (PBFSC), Oil-Well Cement, Rapid Hardening Portland Cement, Sulphate Resistant Portland Cement (SRPC) and White Cement. The details of cement capacity and the key producers are provided in Appendix A.

India's cement-manufacturing capacity is mostly concentrated near the main raw material sources, primarily limestone and coal (of which 0.25 tonnes is required to produce a tonne of cement). Many cement plants are situated near the coal belts in eastern Madhya Pradesh, primarily for two reasons: (i) lower freight costs form transporting coal; and (ii) the inability of domestic coal producers to fulfil cement plants' supply requirements due to falls in production and the prioritization of supply to power plants (IMYB, 2014b).

FIGURE 6: Trends in aluminium production in India

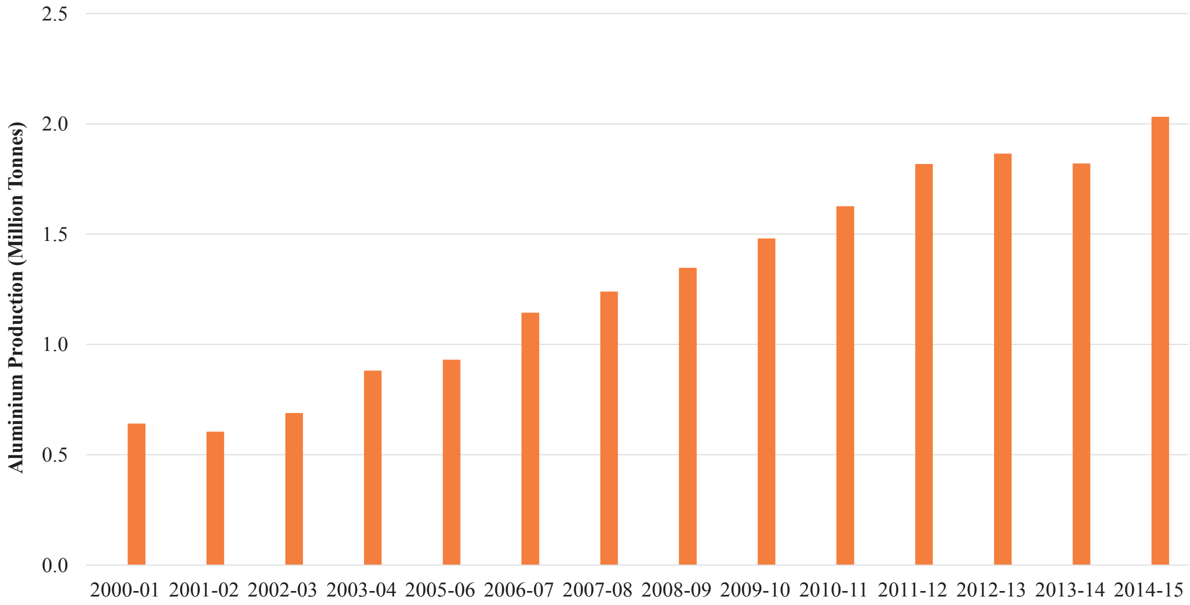


FIGURE 7: Demand projections for aluminium

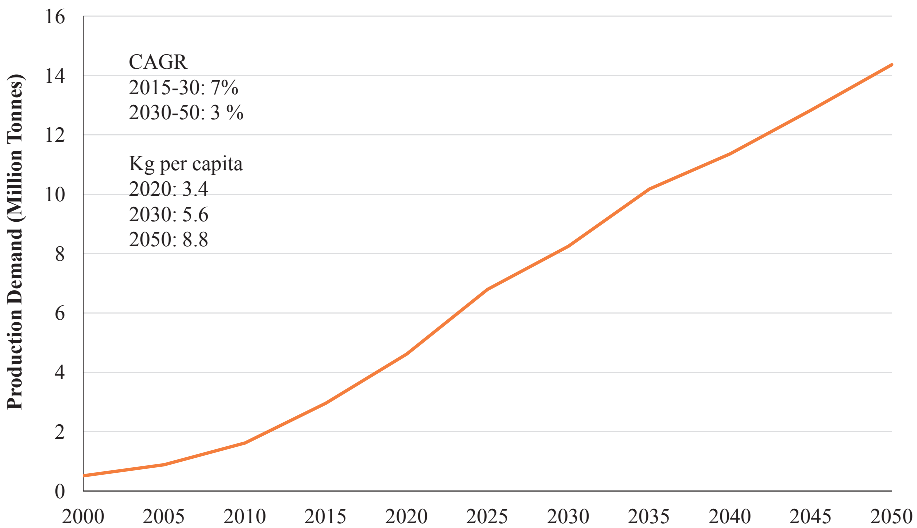


FIGURE 8: Trends in cement production in India

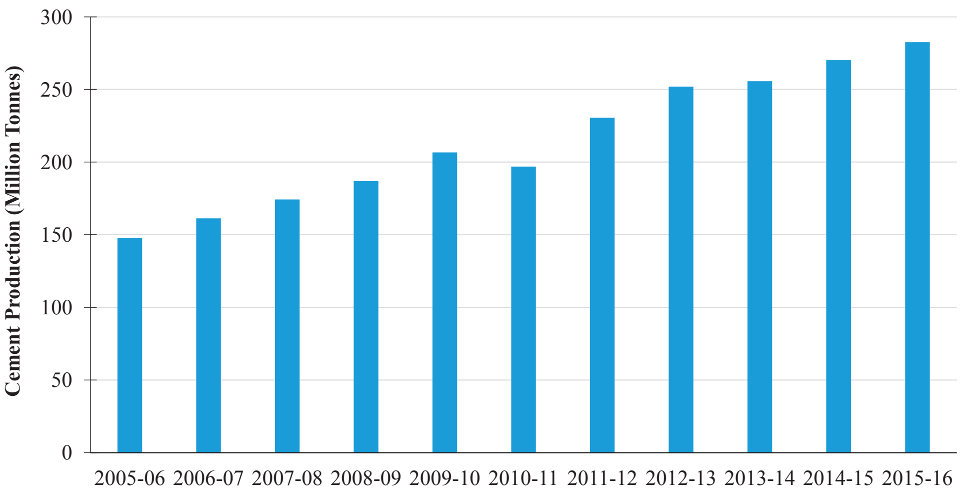
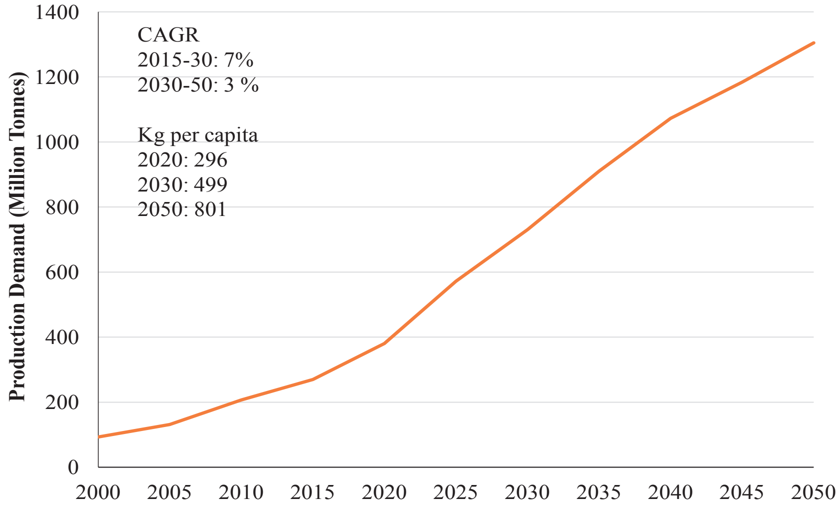


FIGURE 9: **Demand projections for cement**



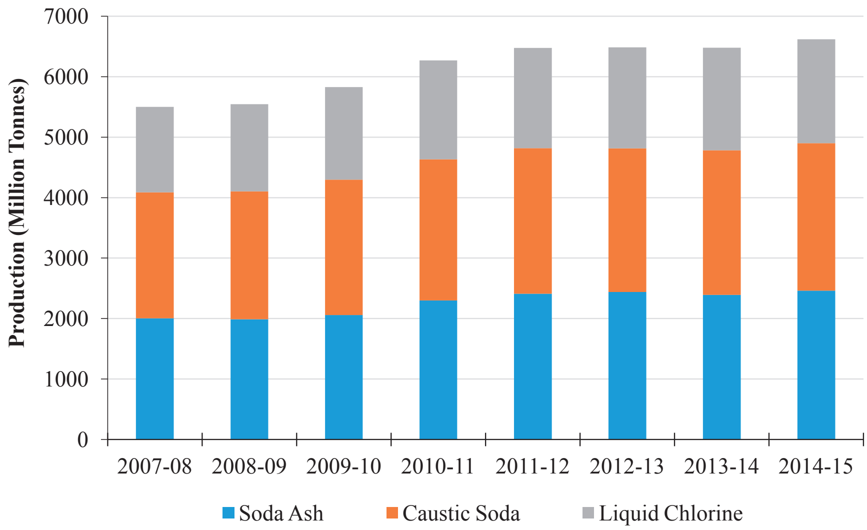
Current average per capita cement consumption (195 kg) in India is much lower than the world average (520 kg). Demand in the eastern and western regions is growing, though there has been a decline in demand in the south and centre. Cement demand is dependent on demand from the infrastructure, housing, commercial and industrial sectors. The housing sector accounts for about 67 per cent of total consumption, followed by the infrastructure, commercial and industrial sectors at 13, 11 and 9 per cent respectively.[16] Future demand for cement is estimated to increase by 6.8 per cent between 2015 and 2030 and 2.9 per cent in 2030-2050. Figure 9 shows that cement demand is projected to increase to 500 MT by 2035 and 1250 MT by 2050.

3.1.3 CHLOR ALKALI

The chlor-alkali industry in India mainly produces caustic soda, chlorine and soda ash. The chlor-alkali sector witnessed a CAGR of 2.68 per cent over the 2007-2015 period. In 2014-15 total capacities of soda ash, caustic soda and liquid chlorine were 2.95 MT, 2.93 MT and 1.97 MT respectively. The major players include Aditya Birla Group, Gujarat Alkali, DSCL and Reliance industries. Production trends for the chlor-alkali industry are shown in Figure 10.

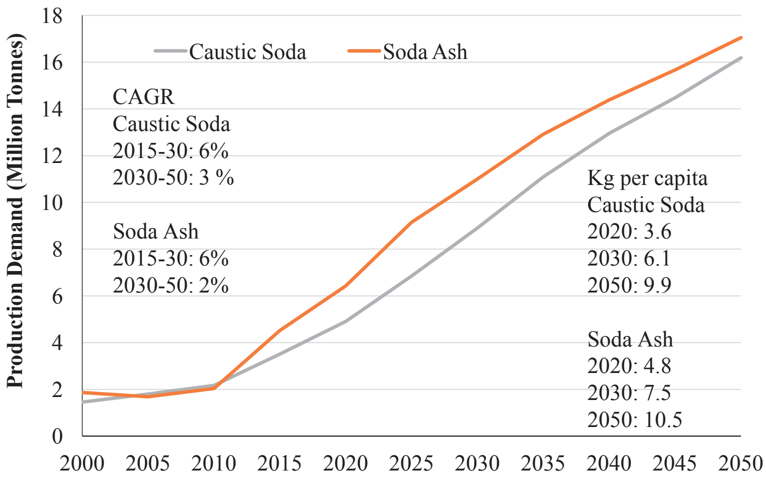
16 CRISIL 2016; http://www.ibef.org/industry/cement-india.aspx

FIGURE 10: **Production in the chlor-alkali industry 2007-2015**



Source: DoCandP, 2015

FIGURE 11: **Demand for chlor-alkali in India**

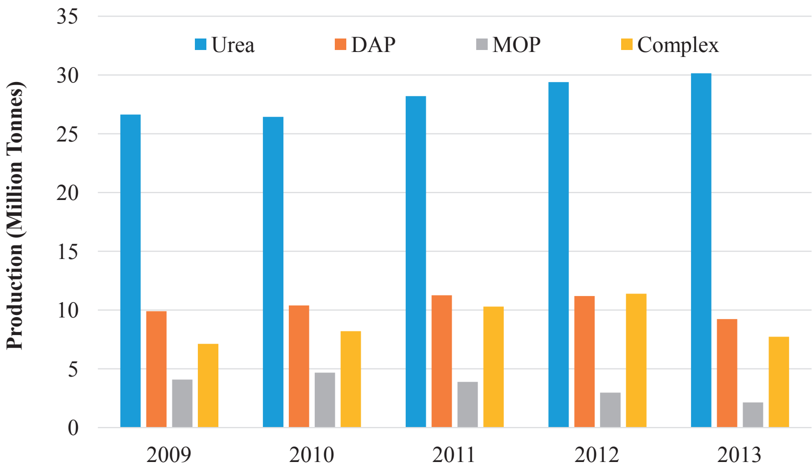


Chlor alkalis are used as feedstock in various industries, and have been grouped in reports as the inorganic chemicals, is composed of caustic soda, soda ash and chlorine. Globally, the caustic chlorine industry is driven by the supply and demand for chlorine. However, in India, the key driver of demand is caustic soda (PAT, 2015). In 2014-15, approximately 74,000 tons (kT) of chlor alkali were exported (5.7% decrease between 2007 and 2014) while 1134 kT (12.4% increase between 2007 and 2014) were imported to India.

The demand for caustic soda and soda ash is expected to increase by about 4-6 per cent from 2014-15 to 2019-20 (Figure 11), as it depends on the growth in demand from its end-users (alumina, textiles, paper, inorganic and organic chemicals, soaps and detergents, pesticides). Textiles use caustic soda in the mercerizing process, while alumina uses it in refining bauxite and the production of alumina. The paper and pulp industry uses caustic soda in the pulping and bleaching processes. The alumina, textile and paper industries account for about 49 per cent of caustic soda consumption, while glass, soaps and detergents account for 56 per cent.[17] For the current study, based on its growing demand, the CAGR of caustic soda will be about 6.4 and 3 per cent, and the CAGR of soda ash about 6.1 and 2.2 per cent between 2015-30 and 2030-50 respectively.

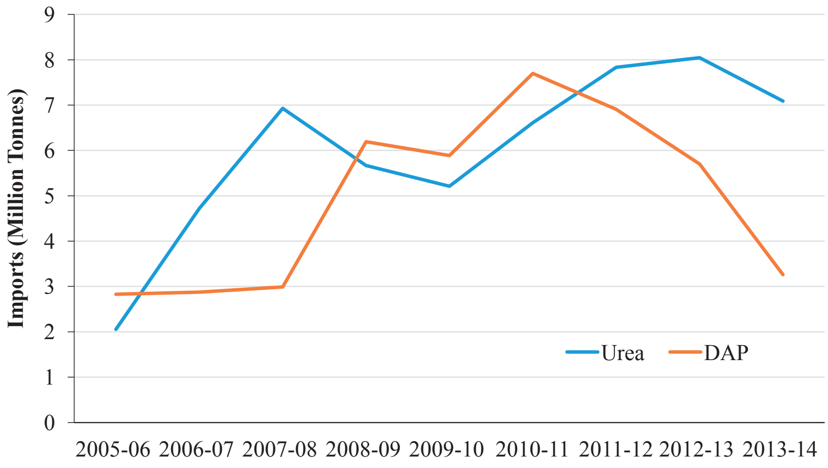
17 *CRISIL industry reports 2016.*

FIGURE 12: **Production of fertilizers (MT)**



Source: Department of fertilizers, Ministry of Chemicals and Fertilizers

FIGURE 13: Trends in fertilizer imports in India



Source: (DoF, 2010 and 2014)

3.1.4 FERTILIZER

Given the nitrogen-phosphorus-potassium (NPK) imbalance in the soil, as well as increasing crop production with an increase in the gross sown area, the demand of fertilizers has gone up in the past four to five years. Urea and calcium ammonium nitrate (CAN) are nitrogenous fertilizers, single super phosphate (SSP) is the main phosphatic fertilizer, muriate of potash (MoP) is the main potassium fertilizer, and di-ammonium phosphate (DAP), which contains both nitrogen and phosphate, is one of the major compound fertilizers used in India. The details of production (Figure 12), production capacity and key producers are provided in Appendix A. Demand for nitrogen has been steady, while demand of non-nitrogen consumption has declined. In 2013-14, total fertilizer capacity was 36 million tons (MT), which comprised 21.6 MT of nitrogenous fertilizers, accounting for 68 per cent of total consumption of nutrients.

The gaps in production and consumption were bridged through imports. Imports have been rising in recent years (Figure 13), accounting for almost 67% of consumption in 2010.

The growth rate for fertilizers has slowed in the past couple of years, but it is expected to grow at a CAGR of about 1.1 per cent in 2015-30 and of about 0.8 per cent in 2030-50 (Figure 14).

FIGURE 14: Demand for fertilizer

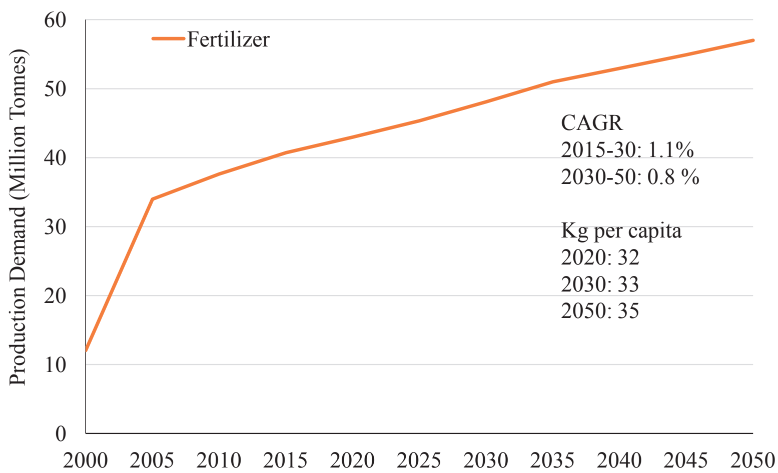


TABLE 10: Trends in steel production in India (MT)

CATEGORY	2010-11	2011-12	2012-13	2013-14	2014-15
Pig Iron	5.7	5.4	6.9	8.0	9.7
Sponge Iron	25.1	19.6	14.3	18.2	20.4
Total Finished Steel (alloy + non alloy)	68.6	75.7	81.7	87.7	91.5

3.1.5 IRON AND STEEL

The rapid rise in steel production has resulted in India becoming the third largest producer of crude steel in 2015, and the country continues to be the largest producer of sponge iron or direct reduced iron (DRI) in the world (MoS, 2016). The coal-based route accounts for 90% of total sponge iron production in the country. The details of steel capacity in terms of technology are provided in Appendix A.

In 2014-15, production of total finished steel (alloy + non alloy) was 91.46 MT, a growth of 4.3% over 2013-14. Production of pig iron in 2014-15 was 9.7 MT, a growth of 22% over 2013-14 (Table 10).

The major producers in the steel industry include the Steel Authority of India Limited (SAIL), Tata Steel, and Rashtriya Ispat Nigam Limited.[18] Iron and steel are freely importable and exportable under existing policies. Figure 15 shows the trends in India's imports and exports of finished steel.

The demand for steel depends on the end-users, which include the infrastructure, oil and gas, automobiles, construction and consumer durable sectors, and it is expected to rise, with an expected CAGR of 5.8 per cent from 2015 to 2030 and 2.5 per cent from 2030 to 2050 (Figure 16).

18 http://www.ibef.org/download/Steel-January-2016.pdf, http://steel.gov.in/overview.htm, http://planningcommission.gov.in/aboutus/committee/wrkgrp12/wg_steel2212.pdf

3.1.6 PULP AND PAPER

With an increase in the digital and social media services, the demand for paper globally is experiencing a gradual decline. However, the paper and pulp industry is expected to boom in India. It has been estimated that the demand for paper will increase to 18.2 MT in 2019, with a growth rate of 6.2 per cent between 2015 and 2019. The increased government spending on education, corporate expenses on stationary, rising use of packaging in the retail sector and the growing service sector are the drivers of the demand for paper in India.

The government's policies on literacy, increased consumerism and the expansion of organized retail are expected to increase demand by 53 per cent by 2020 compared to 2000. The paper industry is classified into writing and printing, paperboard (industrial), specialty paper and newsprint, which accounted for 31, 46, 4 and 19 per cent of production respectively in 2014-15. Figure 17 presents the future CAGR, per capita and total production demand from 2015 to 2050 for the paper and pulp industry.

FIGURE 15: Trends in imports and exports of finished steel

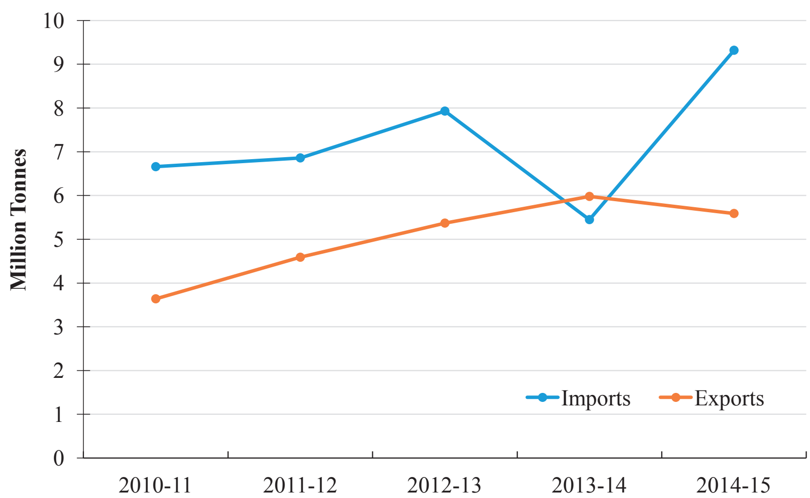
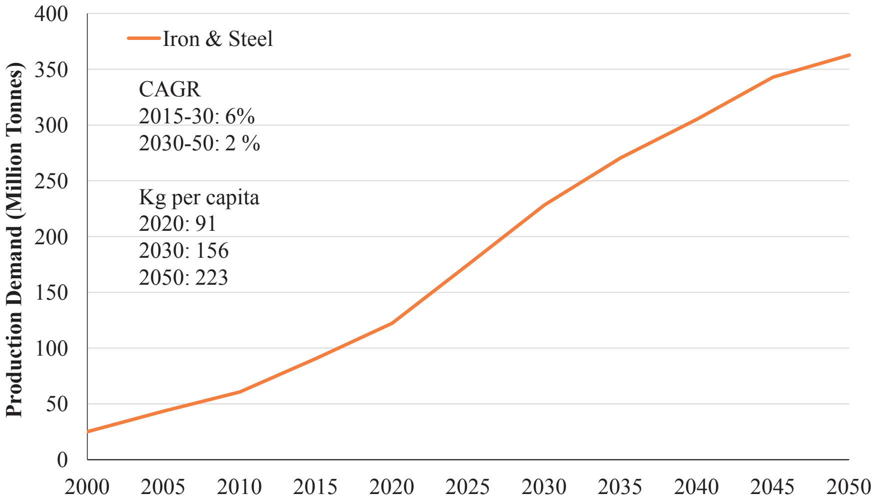


FIGURE 16: Demand for iron and steel



3.1.7 TEXTILES

Textile is one of the oldest industries in India, dating back several centuries, and employing over forty million workers directly and sixty million indirectly. Textile contributes 11 per cent to India's exports, a figure that is expected to grow at 4-6 per cent over the next four years. The industry in India is characterized by two sectors, namely the unorganized and organized sectors. The unorganized sector, being labour intensive, is operated by small and medium-scale industries in handlooms and handicrafts, while the organized sector consists of spinning, apparel and garment manufacture. The informal (unorganized) sector uses traditional production methods, while the formal sector is mechanized, with economies of scale.

The textile and agricultural sector are closely linked, the latter producing raw materials (especially cotton) for the former. The textile industry contributes about 5 per cent to India's GDP.[19] Demand for textiles is expected to reach about 95 billion metres by 2025 and 150 billion metres by 2050 (Figure 18).

3.2 RESIDENTIAL SECTOR

Rapid urbanization and increased levels of income have created demands for an improved quality of life. The increased penetration of electrical appliances and changes to cooking fuels account for the increasing demand for commercial energy in the residential sector. With urbanization expected to affect forty 50 per cent of the population in 2050 (Table 11), household energy demand

19 http://www.ibef.org/industry/textiles.aspx, http://www.india-opportunities.es/archivos/publicaciones/Textiles-and-Apparel-January-2016.pdf

FIGURE 17: Future demand for pulp and paper

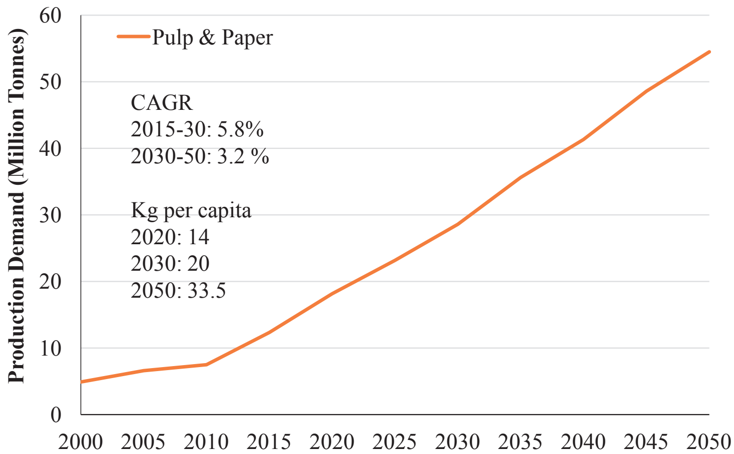
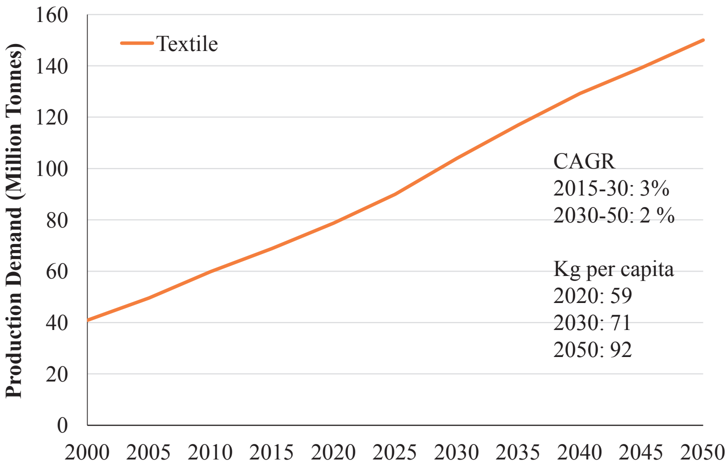


FIGURE 18: Demand for textiles in India



will also increase in the future. The demand for domestic appliances has been estimated based on the number of households and data collected from the National Sample Survey Office (NSSO) survey. The energy intensity of appliances by fuel type is then used to calculate energy demand in the residential sector. Table 12 compares assets used per thousand households according to the NSSO surveys for 2000-01 and 2010-11.

TABLE 11: Rural-urban population distribution ('000's)

YEAR	1990	2014	2030	2050
Rural	646911	857198	835107	805652
Urban	221979	410204	625636	814399
% Urban	26%	32%	43%	50%

Source: NSSO (2010, 2015), UN (2015)

For the current study, household energy consumption is based on the following service categories:

1. Cooking
2. Lighting
3. Cooling
4. Water heating
5. Other, include refrigeration and ICT services

The penetration of electric appliances has been observed to increase among all classes in both rural and urban areas. The ownership of assets is projected to increase with increases in income, though the quantity of assets will vary across classes of expenditure. The type and quantity of fuel consumption (including electricity) also differ between rural and urban households. Table 13 lists the technologies used to meet the demand in each of the above categories.

TABLE 12: Household-wise ownership of assets

	2000		2011	
	RURAL	URBAN	RURAL	URBAN
Number of HH (million)	135.6	51.9	168.6	80.9
Electric fan (per 1000 HH)	263	658	635	927
AC/Air cooler (per 1000 HH)	17	109	59	235
Washing machine (per 1000 HH)	6	89	29	213
Refrigerator (per 1000 HH)	27	229	94	438
Lighting-kerosene (per 1000 HH)	510	110	265	32
Lighting-electricity (per 1000 HH)	470	880	727	961

Source: NSSO (2000, 2011)

TABLE 13: Technologies used in the residential sector

CATEGORY	TECHNOLOGY USED
Cooking	Cook stoves: biomass, energy efficient (EE) biomass, electric, EE electric, LPG, and biogas stoves, solar cookers, solar concentrators
Space cooling	Fans, EE fans, super-efficient fans, air conditioners (AC), AC (5-star), EE AC, EE AC with cool roof
Lighting	Incandescent lamps, kerosene lamps, CFL, LED
Water heating	Geysers, coal stoves, natural gas heaters, solar water heating systems
Other	Refrigeration, ICT: TVs, computers etc., smart grid

The demand for energy in households is projected based on a combination of their past trends, global trends, intensities in private final consumption expenditure (PFCE) and expert opinion about future shares. Future per capita income trajectories were estimated based on assumptions about future GDP, population projections and urbanization rate. The future ownership of assets is provided Table 14.

3.3 TRANSPORT

The transport sector accounted for more than 15% of total energy demand in 2015. The increase in energy demand from this sector presents a challenge to energy security, since more than 95% of demand is met by oil, almost 75 per cent of which is imported. Another concern is related to its impact on air quality, which impacts adversely on human health, especially in urban areas. In India, road and rail have been the preferred modes of transport for passengers as well as freight.

3.3.1 PASSENGER TRANSPORT

Passenger transport grew at a CAGR of 7.4 between 1990 and 2010. The share of passenger transport by road increased from 83.1 per cent in 2001-02 to 88 per cent in 2009-10 (Figure 19). The high growth in road transport occurred both for intercity transport (including transport from rural areas to cities) and within cities. As buses and personal modes of transport like cars and two-wheelers provide point-to-point connectivity and have shorter waiting times, they are preferred to rail. The share of cars in intercity road transport has increased due to higher incomes and improvements to selected highways in the country.

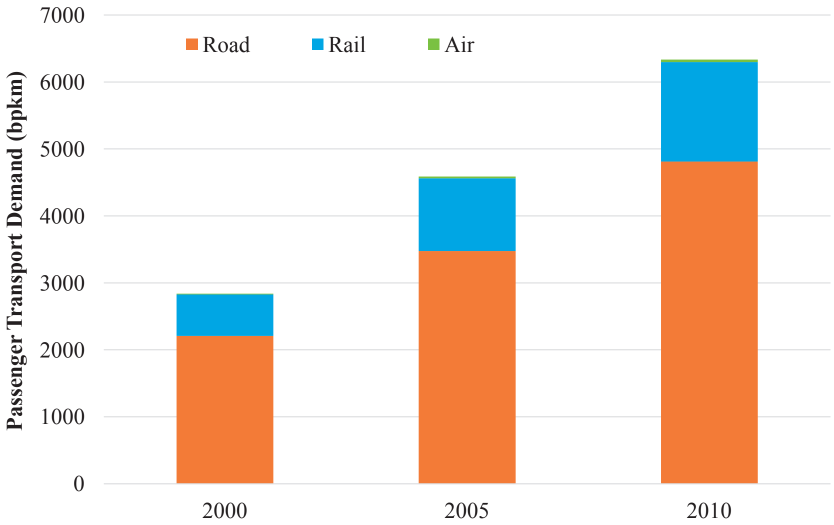
The demand for passenger transport is dependent on a variety of factors, including travel demand in terms of time and distance, in addition to changes in lifestyle due to increasing levels of income and types of vehicle at the individual level, as well as the policy environment (for example, the odd and even rule) and traffic management, which are exogenous but equally important. Passenger traffic in 2011-12 was about 10,375 billion passenger kilometres (bpkm), which is expected to grow by about 15 per cent until 2030. The share of public transport is expected to be overtaken by private transport by 2040. NMT is expected to grow in line with population growth.

Intercity passenger demand should increase at a much slower pace compared to the demand for urban trans-

TABLE 14: Household-wise ownership of assets in the future

	2030		2050	
	RURAL	URBAN	RURAL	URBAN
Number of HH (million)	157.6	122.7	178.9	232.7
Electric fan (per 1000 HH)	700	950	850	985
AC/Air cooler (per 1000 HH)	100	325	150	450
Washing machine (per 1000 HH)	75	285	110	390
Refrigerator (per 1000 HH)	145	560	250	710
Lighting-kerosene (per 1000 HH)	110	0	0	0
Lighting-electricity (per 1000 HH)	845	965	955	990
Other electric appliances (ICT etc.) (per 1000 HH)	100	450	500	750

FIGURE 19: Trends in passenger transport demand (billion passenger km)



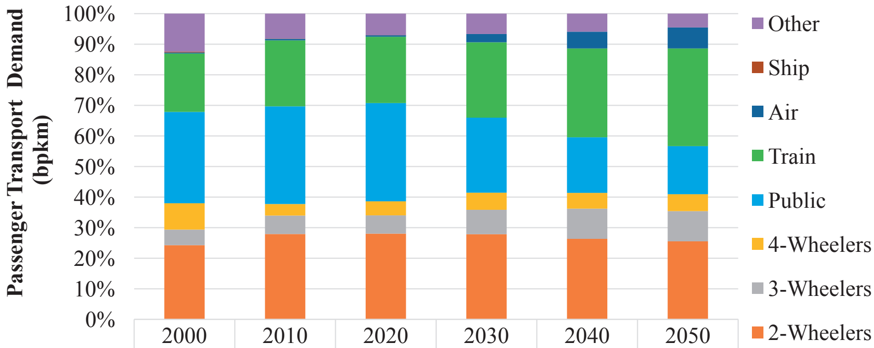
Source: Dhar, et al. (2015)

port, reaching 25,941 bpkm in 2050 (Dhar et.al, 2015). The demand for transport is mainly met by road-based modes, and the decreasing role of rail will not see a major turnaround. The growth in road and rail traffic will be around 15.4 and 9 per cent respectively by 2030.[20] Demand for air transport is gradually increasing, and air traffic is estimated to grow at the rate of 12 per cent for domestic and 8 per cent for international travel.[21] An increase has been observed in individual vehicle ownership over the past few decades. A combination of poor traffic management due to overcrowded roads, energy security (oil dependency) and environment concerns (local and global emissions) have encouraged the government to enhance public transport and non-motorized transport, in addi-

20 *Planning Commission Transport (2012-17). [http://planningcommission.nic.in/reports/genrep/NTDPC_Vol_01.pdf]*

21 *DGCA*

FIGURE 20: Passenger transport demand (in bpkm)



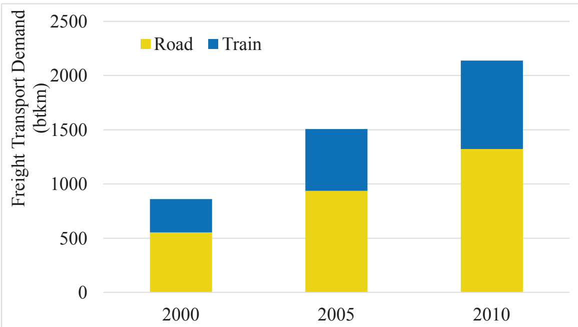
	2000	2010	2020	2030	2040	2050
Other	405	564	730	867	1163	1500
Ship	7	2	0	0	0	0
Air	11	37	56	349	1092	2287
Train	621	1487	2261	3203	5747	10619
Public	972	2208	3358	3184	3596	5228
4-Wheelers	281	261	475	725	1019	1859
3-Wheelers	166	417	623	1039	1954	3267
2-Wheelers	788	1925	2927	3618	5206	8495

tion to establishing vehicle efficiency standards. Figure 20 shows the share of demand for passenger transport till 2050 assumed in the model.

3.3.2 FREIGHT TRANSPORT

Road and rail are the two major modes of freight transport. Rail freight increased from 127 billion tkm in 1970 to 626 billion tkm in 2010 at a CAGR of 4.06 per cent, whereas road freight increased from 67 billion tkm to 1,128 billion tkm during the same period at a CAGR of 7.3% (Dhar et al., 2015). There was a significant shift in the share of freight transport from rail to road; however, since 2000, the share of rail has remained at around 40 per cent (Figure 21). Freight transport also includes a small share from coastal shipping, barges on inland waterways and pipelines. In 2010, the share of freight taken by coastal shipping accounted for less than 6 per cent of overall demand.

FIGURE 21: Trends in freight transport demand (billion tkm)



Source: Dhar, et al. (2016)

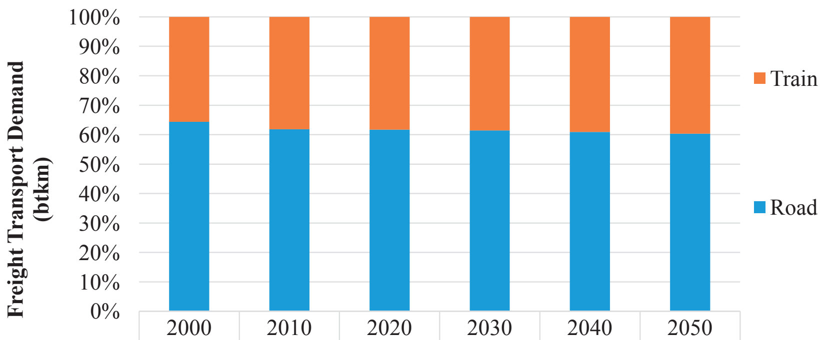
Freight traffic was estimated to be around 2000 billion transport kilometres (btkm) in 2011-12 and is expected to grow at 9.7 per cent per year. In the BAU scenario, per capita demand is expected to increase to 5,941 tkm in 2050, and consequently the overall demand for freight transport is expected to be 10,052 billion tkm in 2050, with a growth rate of 4.4 per cent. Figure 21 represents the trends in freight transport from 2000-10 and figure 22 illustrates the projection of freight transport till 2050..

3.4 AGRICULTURE

India used to be primarily an agrarian economy, but since liberalization the share of GDP from agriculture and allied sectors has steadily declined. Despite a decline in its share of GDP, however, it still remains as the main source of livelihood for more than half the population. This sector is critical to the Indian economy, as it ensures the country's food security. It also provides raw materials for major industries such as food-processing, sugar, textiles, jute and paper. It is also the driver of many industries, including fertilizers, pesticides, automobiles, farm equipment and irrigation machinery. The demand from agriculture is dependent on the increase in per capita food consumption and the growth in non-food industrial consumption.

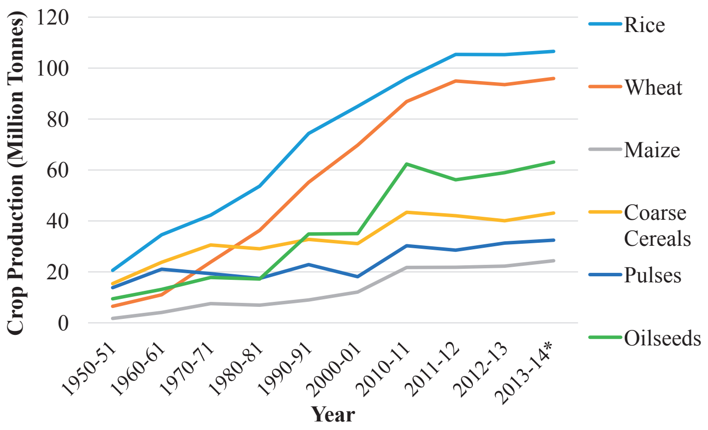
Figure 23 presents crop-wise production trends from 1951-2014. It can be observed that production of rice and wheat increased since 1970s as a result of the Green Revolution.

FIGURE 22: Freight transport demand (in btkm)



	2000	2010	2020	2030	2040	2050
Train	307	815	1720	2708	3796	4314
Road	554	1322	2769	4316	5916	6557

FIGURE 23: Crop production in million tonnes (1951-2014)



Source: Ministry of Agriculture (2016)

The production of crops is dependent on a combination of factors, including size of landholding, cropping intensities, nutrient intake, weather patterns and irrigation mechanisms. There has been a substantial increase in agricultural productivity and irrigated land, though total land area has remained the same in the past few decades. Agricultural land accounts for 43 per cent of total land, of which about 50 per cent is under some form of irrigation and about 8 per cent is under micro-irrigation. The yield for every crop has increased in the past seven decades, though it is yet to reach global levels. After the Green Revolution a marked increase in yields was observed, which has been maintained over time. Figure 24 shows the increase in irrigated land, along with production and yield per hectare from 1951-2012. The yield of various crops grown in India differs according to irrigation techniques, along with location and weather patterns.

FIGURE 24: Land under cultivation and irrigation: total production and yield (1951-2012)

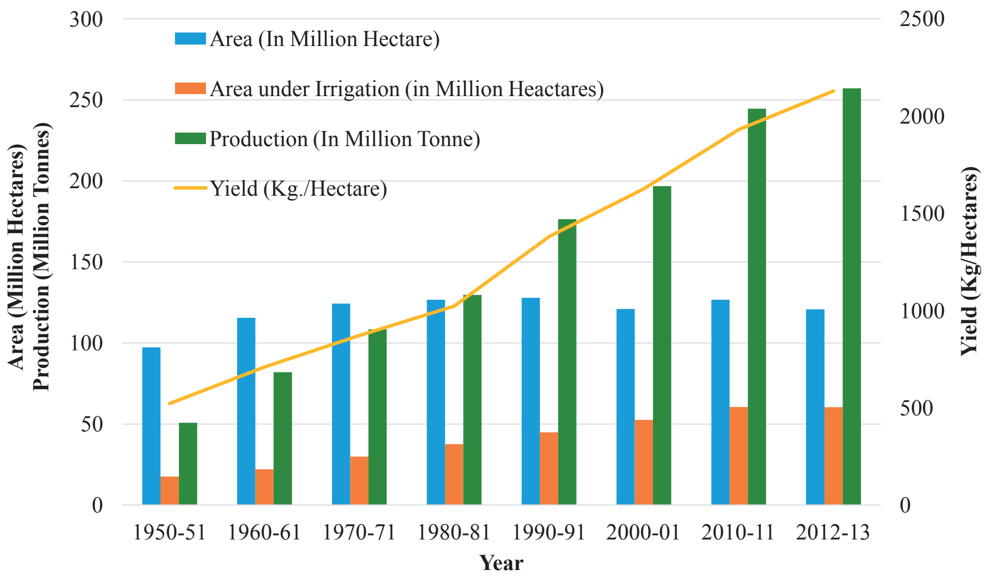
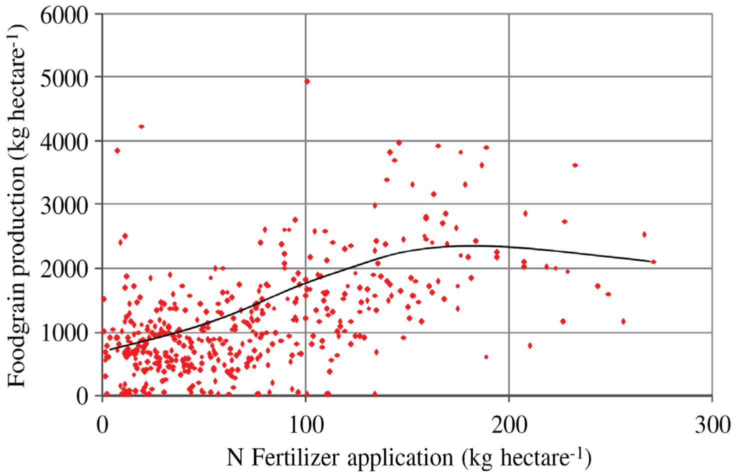


FIGURE 25: Fertilizer use efficiency of Indian districts



Source: Garg et al. (2012)

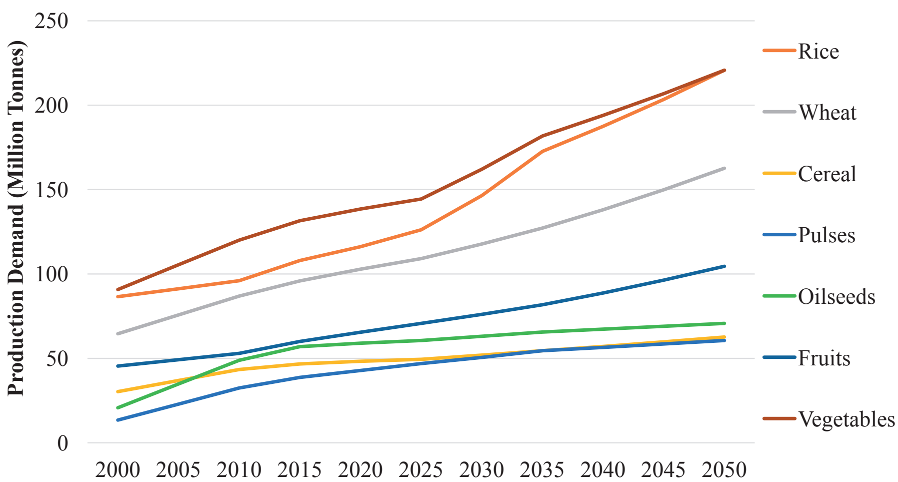
Garg (et. al., 2012) found that the N-fertilizer applied per unit of cropped area and crop yield shows wide differences across the Indian states and districts (Figure 25). Such differences and high fertilizer use in several regions are mainly due to unsustainable practices such as excessive use of water, along with imbalanced use of chemical fertilizers, decreased use of organic fertilizer, decreasing carbon/organic matter content, deficiency of micro-nutrients etc. Such impacts are found very strongly in the 'Green Revolution' areas of northern and north-western India, where fertilizer consumption is comparatively high, and the response ratio of grain output to fertilizer input has declined over recent years.

Demand projections in general are estimated on the basis of assumptions about the base year demand, population, expenditure elasticity and economic growth. Household food demand has been driven primarily by the growth in population and incomes. Figure 26 presents the domestic demand projections for various crops, which are arrived at by adding up the direct human demand.

The energy required for one unit of GDP from agriculture is comparatively less than in other sectors. However, with the Green Revolution, the building of dams and canals and the sinking of tube wells, in addition to the mechanization of the larger farms, the demand for energy in agriculture has increased in the past four decades. Energy is required at three stages: 1) to prepare the land, 2) to procure water, and 3) after the harvest. For purposes of the current study, energy demand in end-uses is based on:

1. Tillers and tractors
2. Pumps

FIGURE 26: Crop production demand (million tonnes)



CHAPTER 4

POLICIES FOR ENHANCING ENERGY EFFICIENCY IN KEY SECTORS

In the current study, energy efficiency pertains to the use of more efficient technologies in each of the selected sectors. This includes technological improvements in the power and industry sectors, efficient pumps in the agricultural sector and vehicle efficiency in the transport sector. Energy efficiency is also expressed through changes in the energy intensity of the technology and/or the sector over a given period. The following section explains the policy interventions and relevant technology improvements selected for the current study in the electricity, industry, residential, transport and agricultural sectors.

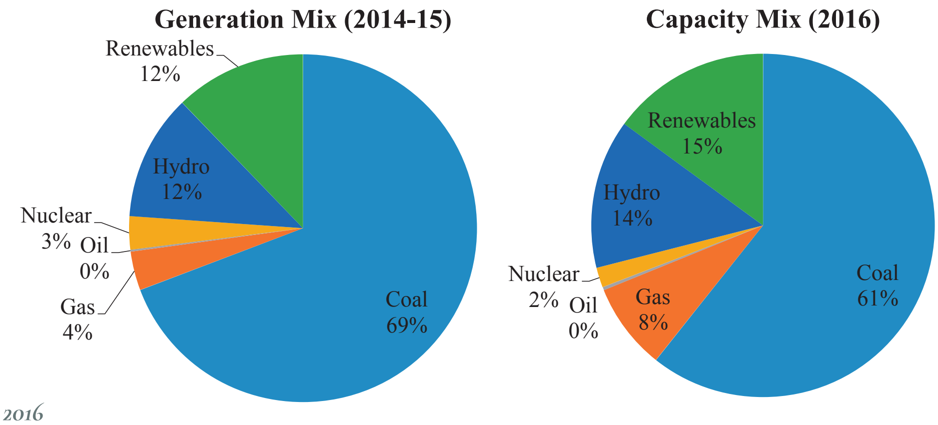
4.1 ELECTRICITY

Electricity generating capacity in India is growing at a fast rate. Total installed capacity as of October 2016 was 307.3 GW (MoP, 2016). The detailed breakdown of India's installed generating capacity is provided in Appendix B. Electricity generation in the country was 1107 billion units (BU) in 2015-16.

Figure 27/28 show that coal has remained the mainstay of India's electricity generation. However, there has been an increase in power generation from renewable energy sources (RES) in the past decade. The resources for electricity generation in India are unevenly dispersed and concentrated in a few pockets. Hydro resources are located in the Himalayan foothills and North Eastern Region (NER), whereas coal reserves are concentrated in Jharkhand, Odisha, West Bengal, Chhattisgarh and parts of Madhya Pradesh, and lignite in Tamil Nadu and Gujarat. Also, a number of power stations generating power from gas and renewable energy sources like solar, wind etc. have been installed in various parts of the country.

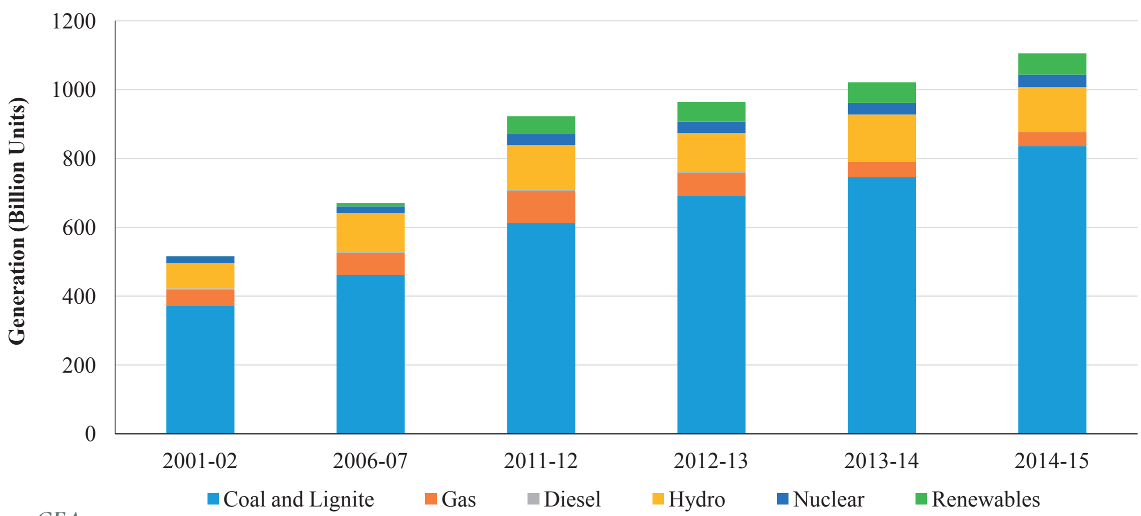
In India, the domestic and industrial sectors are the main consumers of electricity, accounting for almost 70% of total consumption (Figure 29).

FIGURE 27: Fuel-wise share of electricity capacity and generation mix in India



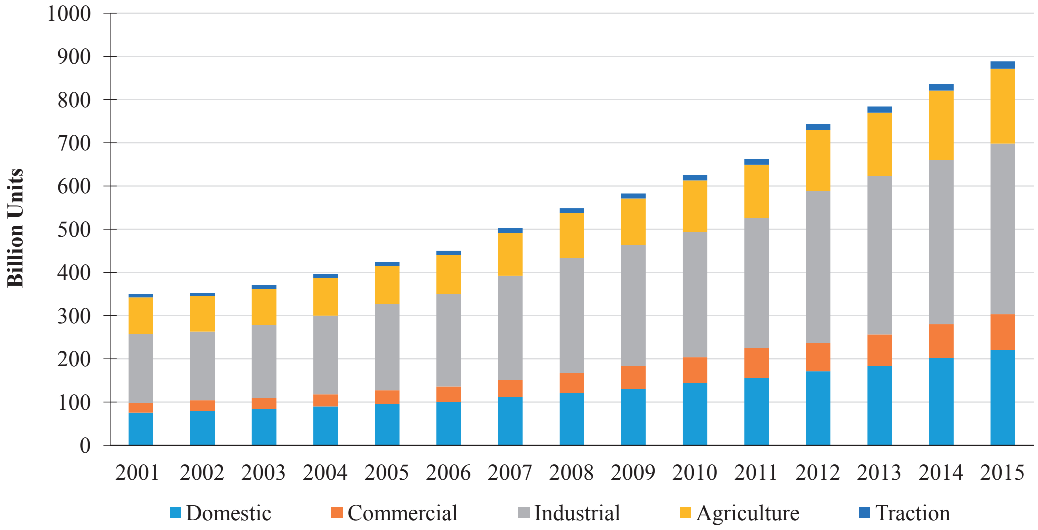
Source: CEA, 2016

FIGURE 28: Trends in electricity generation in India



Source: CEA, 2015

FIGURE 29: Category-wise electricity consumption in India



The demand for electricity has increased considerably in all sectors at an annual growth rate of 6-7%. The energy supply and fuel mix is still heavily dependent on fossils fuels such as coal and oil. Efforts to shift towards cleaner sources of fossil fuels like natural gas have started in the past decade, though this transition will only support energy demand for the next twenty to thirty years. Hence, a strong push towards new and renewable sources of energy has been recommended in the NAPCC, which is further strengthened through INDCs. The strategies under the BAU and INDC scenarios for coal and renewable sources are listed in Table 15.

The Government of India places special emphasis on reducing T&D losses and on demand-side management to optimally utilize the limited resources. Concerted efforts are continuing to bridge the gap between demand and supply through policy initiatives such as tariff-based competitive bidding, the New Hydro Policy, Private Sector Participation in the Transmission Sector, the National Mission on Enhanced Energy Efficiency, the Focus on

TABLE 15: Power sector policies and measures covered in the BAU and INDC Scenarios

SCENARIO	POLICY INTERVENTIONS	STRATEGY	MISSION	INSTRUMENT	MEASURES TAKEN/TO BE TAKEN
BAU	NAPCC	Increase non-fossil fuel, renewable energy capacity	National Solar Mission, NMEEE		Solar: 20 GW by 2022 Wind: 38.5 GW by 2022 Small hydro: 6.5 GW by 2022 Biomass: 10 GW by 2022
		Improve thermal efficiency		PAT 1	Assigning mandatory targets to improve EE in 144 old thermal power stations
					Stringent emission standards
INDC	INDC	Improve thermal efficiency	NMEEE	PAT 1 and 2	Installation of forty units of supercritical thermal power stations with capacity of 27485 MW
		Promote clean coal technology	National Mission for clean coal (Carbon) technologies		Development of ultra-super critical technology to reduce emissions by twenty per cent
	INDC	Reduce power transmission and distribution losses	NMEEE	PAT 2	Smart grid projects sanctioned in 1412 towns

the Development of Renewable Energy Sources (RES) and development of Ultra Mega Power Plants (UMPP).

Transmission and distribution (T&D) losses were more than 20 per cent in 2014-15. India's T&D losses are high when compared with the world average, being at around 9 per cent (Table 16).

TABLE 16: T&D (%) losses of various countries

SR. NO.	COUNTRY	2011	2012
1.	Korea	3.57	3.47
2.	Japan	4.98	4.79
3.	Germany	4.70	4.46
4.	Italy	6.46	6.61
5.	Australia	5.94	5.68
6.	South Africa	9.61	10.19
7.	France	6.47	7.99
8.	China	6.45	6.56
9.	USA	6.41	6.73
10.	Canada	6.27	8.19
11.	UK	8.06	8.26
12.	Russia	12.59	12.59
13.	Brazil	16.08	16.63
14.	India #	23.97	23.65
15.	World	8.90	8.89

 # includes commercial losses

Sources: Ministry of Power (2016)[22]

Electricity generation from renewable energy is also achieving prominence in India. Currently, almost 14% of the country's electricity generation comes from non-conventional renewable sources. Installed capacity of grid-interactive power through renewable sources was 45 GW by the end of September 2016 (Table 17).

4.2 INDUSTRY

The industry sector is one of the major consumers of energy. Its energy intensities are higher than the global average (Table 9). The introduction of PAT represents an attempt to reduce energy intensities along with overall energy consumption by targeting the large point sources that have been identified as energy-intensive designated consumers. Table 18 lists the strategies used in the model for reductions in specific energy consumption (SEC) targeted under the BAU and INDC scenarios for the selected industries.

22 *Ministry of Power (2016). Source: http://powermin.nic.in/sites/default/files/uploads/RS_02052016_Eng.pdf*

4.3 RESIDENTIAL

Energy is used in the residential sector for various purposes, including cooking, lighting, cooling (space and otherwise) and heating water. In the current model, the policies considered include those programs that fall under BEE for energy efficiency, the National Habitat Mission, the National Building Code (NBC) and the Energy Conservation Building Code (ECBC), which aim to reduce overall energy intensity in the residential sector. The emphasis has been placed on electrical appliances in the current study. Lighting and cooling appliances for commercial spaces have also been included in this sector for the current study. Table 19 lists the strategies used in the model for the selected categories under the different scenarios.

4.4 TRANSPORT

All modes of transport are clearly under severe pressure to meet both the current objectives and the demand for passenger and freight traffic by reducing overall carbon emissions in the sector and lowering its dependence on oil. The study considers the strategies provided by the National Transport Development Policy Committee for the 12th Plan along with the plan given in the NAPCC to build a safe, smart and sustainable transportation network. This study looks into the impact of metro transit on passenger transit in the coming decade. Table 20 lists the strategies used in the model for the BAU and INDC scenarios in the transport sector

4.5 AGRICULTURE

Given the proliferation of canal and groundwater irrigation and mechanization in farming, the demand for pump sets and tractors has increased over the past few decades. Diesel pump sets constituted about 70 per cent of total pump sets in 2011 (Agricultural Census, 2011). Under the NSM, there has been push to replace the existing diesel pumps with solar pump sets, while the NMEEE promotes the use of energy-efficient electric pump sets. Efficient use of water through micro-irrigation systems has been observed to increase production while reducing energy consumption. The National Water Mission (NWM), along with the Pradhan Mantri Krishi Sinchayeen Yojana (PMKSY) and the National Mission on Micro-Irrigation (NMMI), are encouraging experiments and financing micro-irrigation methods in certain states, especially in Maharashtra, Gujarat and Karnataka. The diesel pumps used in tractors have been assumed to improve efficiency in the INDC scenario. Table 21 lists the interventions under the BAU and INDC scenarios.

TABLE 17: Programme/scheme-wise physical progress in 2016-17

SECTOR	FY- 2016-17		CUMULATIVE ACHIEVEMENTS
	TARGET	ACHIEVEMENT (APRIL TO SEPTEMBER, 2016)	(AS OF 30.09.2016)
I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)			
Wind power	4000	1306	28083
Solar power	12000	1750	8513
Small hydro power	250	49	4323
BioPower (biomass and gasification and bagasse cogeneration)	400	51	4882
Waste to power	10	8	115
Total	16660	3164	45917
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MW)			
Waste to energy	15	2.2	162
Biomass (non-bagasse) cogeneration	60		652
Biomass gasifiers			
-Rural	2		18
-Industrial	8	2.4	167
Aero-generators/hybrid systems	1	0.2	3
SPV systems	100	48.1	362
Water mills/micro-hydel	1 MW + 500 Water Mills	0.10 MW + 100 Water Mills	19
Total	187	53.1	1383
III. OTHER RENEWABLE ENERGY SYSTEMS			
Family biogas plants (in lakhs)	1	0.17	48.72

Source: MNRE, 2016

TABLE 18: Industry Sector- strategies used in BAU and INDC scenarios

SCENARIOS	POLICY INTERVENTIONS	SECTOR	STRATEGY	MISSION	INSTRUMENT	MEASURES TAKEN/TO BE TAKEN
BAU	NAPCC	Energy-intensive industries	Energy Saving Potential: 5-15%	NMEEE	PAT 1	Reducing specific energy consumption (SEC) in 478 plants (designated consumers) through PAT
INDC	INDC	Energy-intensive industries	Improve SEC through PAT in eight intensive industries for first PAT cycle. Addition of railways, electricity distribution and refineries in Second cycle	NMEEE	PAT 1 and 2	4-5 per cent decline in SEC in the selected industries in 2015 as compared to 2012
INDC		Energy-intensive industry	Process improvement			Aluminium: switch to safe baking nodes; steel: move to DRI, shift to COREX process; chlor-alkali: switch to zero gap membrane and oxygen depolarized cathode
		Energy-intensive industry	Recycling and waste heat recovery			Aluminium: recycling of RM; steel: use of scrap metal and waste heat recovery; chlor alkali: recycling brine

TABLE 19: Residential sector- strategies used in BAU and INDC scenarios

SCENARIO	POLICY INTERVENTIONS	SUB-SECTOR	STRATEGY	MISSION	INSTRUMENT	MEASURES TAKEN/TO BE TAKEN
BAU	NAPCC	Residential	Labelling and equipment and appliances	NMEEE	Standards and Labelling Programme	21 appliances and equipment (lighting, cook stoves, refrigerator, AC) are labelled
INDC	INDC	Cooking	Reducing carbon emissions in addition to harmful local pollutants	NMSH, NSM	Subsidies	Replacing firewood chulhas with smokeless chulhas and LPG in rural areas; moving to city gas pipelines instead of cylinders.
		Lighting		NMEEE	Market Transformation for Energy Efficiency	Shift to LEDs by phasing out of incandescent lights, and kerosene lamps; scaling up solar street lighting
	INDC	Building appliances		NMEEE	Information – Standard and Labelling, ECBC	Focus on energy-efficient building envelopes by moving to super-efficient fans and ACs along with energy efficient design and construction Shift to more EE residential appliances (refrigerators, ICTs)
		Water heating appliances	Shift to solar heating systems	National Solar Mission	Subsidies, Information – Standard and Labelling	Complete shift to solar water heating systems from electric and conventional sources

TABLE 20: Transport sector- strategies used in BAU and INDC scenarios

SCENARIO	POLICY INTER-VENTIONS	SUB-SECTOR	MISSION	INSTRUMENT	TYPE OF TRANSPORT	MEASURES TAKEN/TO BE TAKEN
BAU	National Urban Transport Policy (NUTP)	Passenger	National Mission on Sustainable Habitats		Road	Share of private modes continue to increase
					Rail	Slow pace in implementation of metro and high speed rail corridors
		Freight		Dedicated Freight Corridor (DFC)		Slower pace of adaptation of Dedicated Freight Corridor (DFC)
		Other				Electric vehicles - buses and BRT in BAU; 2 % blending of biofuels to reach 10 % in 2050
INDC	INDC, NUTP	Passenger	National Mission on Sustainable Habitat	Infrastructure Investment in NMT	Walking and Cycling	Increase in non-motorized transport
	INDC, NUTP			Infrastructure Investment in Metro	Road	Increase in public transport, 30 % of private transport shift to public transport, Scaling up Metro transport
	INDC			Infrastructure Investment in rail	Rail	Increase rail-based transport by 10% from 36 to 45%
		Freight		Infrastructure investment in Dedicated Freight Corridors	Rail	Reduce emissions by about 457 MT of CO_2
		Other				Electric vehicles – buses, 2W and 4Win BAU; 2% blending of biofuels to reach 20% in 2050

TABLE 21: Agricultural Sector- strategies used in BAU and INDC scenarios

SCENARIO	POLICY INTERVENTIONS	STRATEGY	MISSION	INSTRUMENT	MEASURE TAKEN/ TO BE TAKEN
BAU	NAPCC	Use energy-efficient pumps; replace diesel pumps with solar pumps	NSM and NMEEE	Subsidies, Information – Standard and Labelling	
INDC	INDC	Use energy-efficient pumps	NMEEE	Subsidies, Information – Standard and Labelling	10-15% improvement in diesel and electric pumps
	INDC	Replace diesel pumps with solar pumps	NSM	Subsidies	Install 90,000 solar pumps (2012-17) (1 per cent of diesel pumps)
		Tractor efficiency improvements	NMEEE		7% fuel efficiency over 2000
	INDC	Other farm mechanization improvements	NMEEE		7% fuel efficiency over 2000
	INDC, PMKSY	Increase micro-irrigation systems	NWM, NMMI	Subsidies	Increase area covered under micro-irrigation (drip and sprinkler) from 6 to 15 per cent

CHAPTER 5

RESULTS

The following section describes in detail energy consumption under the BAU and INDC scenarios by technology and fuel type in selected sectors for 2020, 2030 and 2050.

5.1 NATIONAL LEVEL

5.1.1. ENERGY

The growth in energy consumption was observed to be higher in the industry and residential sectors, followed by transport. The main fuels involved differ across the sectors: for example, coal is used primarily in the industry and power sectors, while oil is used in the transport sector. Figure 30 presents the total primary energy demand in the economy in the BAU and INDC scenarios. Reductions in the demand for energy are predicted in the INDC scenario by 6 per cent in 2030 and by 10.4 per cent in 2050. Technology improvements through better efficiencies, fuel replacement through policies in the power, industry, residential and transport sectors, and the switch to cleaner and renewable sources of energy, primarily in the power sector, will contribute to the decrease in the overall final energy demand.

Figure 31 gives a sector-wise break-down of final energy consumption. It was observed that the industrial and residential sectors accounted for about 85 per cent of final energy consumption in 2000. In future, in both the BAU and INDC scenarios, the share of the residential sector would fall and the share of the transport sector increase. The share of the agricultural sector is expected to remain constant. In the INDC scenario, overall final energy consumption (FEC) falls by 7% in 2030 and 14% in 2050 as compared to BAU scenario.

Figure 32 presents the total FEC fuel mix for 2020, 2030 and 2050. It can be observed that coal and oil continue to remain the dominant fuels in the mix, though their shares fall from 58 per cent to 55 per cent in 2050 under the INDC scenario as compared to the BAU scenario. Similarly, there is a decrease in the share of biomass from 34 per cent in 2000 to 7 per cent in 2050. There is also an increase in the share of solar from 1 per cent in 2000 to 4 per cent in 2030 and to 9 per cent in 2050 in both scenarios. Electricity's share increases by 6 per cent in the BAU scenario and 8 per cent in the INDC scenario by 2050 as compared to 2000.

Imports of coal, oil and gas play a crucial role in the BAU scenario, with increases in demand in the end-use sectors. The demand for coal increases in the industry sector to meet the increased demand for power and heating. Rapid growth in the transport sector increases the demand for petroleum products, though the transition to electricity after 2030 in the transport sector shifts, allowing fuel diversification. Gas is seen to be the fuel that will allow a transition towards a cleaner society, with increasing demand for it in the industry, residential and transport sectors. Nevertheless, even with an appropriate energy infrastructure, the price and availability of these fuels in the international market after 2030 will play a crucial role in their usage.

FIGURE 30: Total primary energy demand under BAU and INDC scenarios (in PJ)

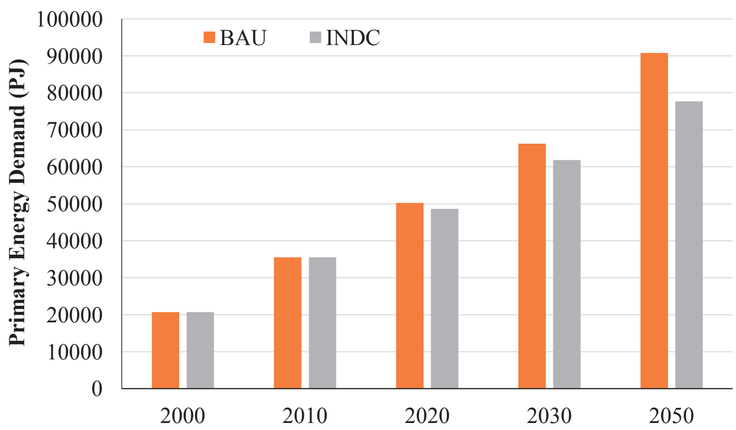


FIGURE 31: Sector-wise final energy consumption in BAU and INDC (in PJ)

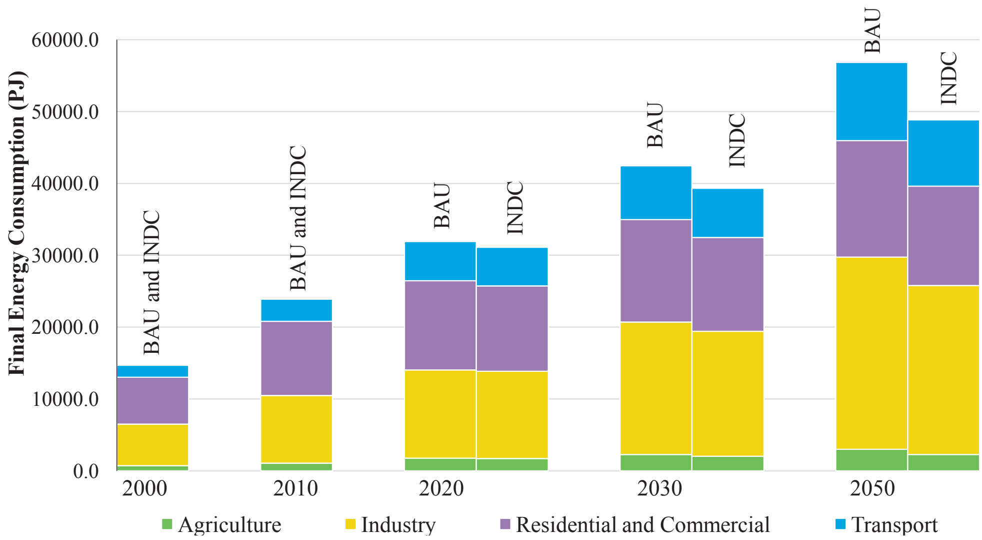
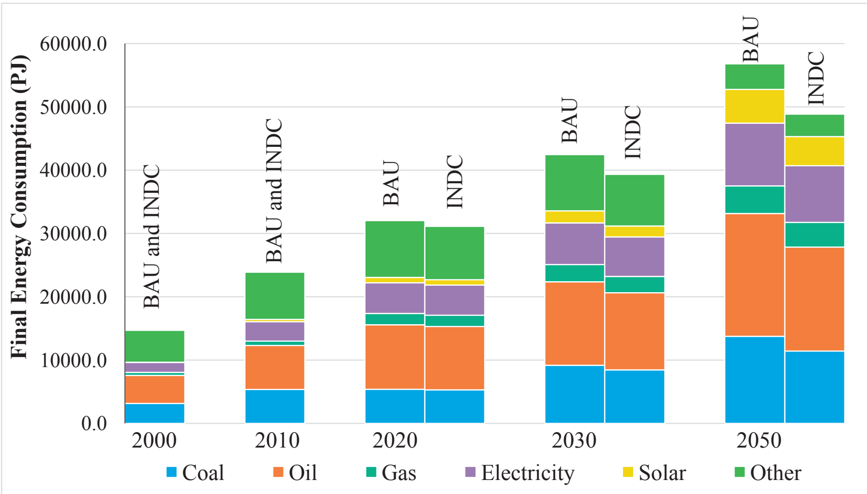


FIGURE 32: Final energy consumption: fuel mix under BAU and INDC (in PJ)



5.1.2. CO_2 EMISSIONS

India's per capita emissions are considerably smaller than those of China and other developed countries, though it is among the most vulnerable countries to be hit by the impact of climate change in the form of uncertain weather conditions and increasing water scarcity. In the past decade, policy interventions through regulatory (emission standards), economic (like subsidies, taxes, tariffs) and information-related (like labelling) instruments, together with the changes in economic structure and the electricity regulatory framework through a combination of ongoing policies in addition to INDCs have shown a reduction in the Indian economy's overall emissions intensity. Overall carbon dioxide emissions will reduce by about 11 per cent and 19 per cent in 2030 and 2050 respectively (Figure 33). In 2030, carbon emissions will be reduced mainly in the industrial sector (by 16 per cent), followed by power (by 13 per cent) and the agricultural sector (by 7 per cent). In 2050, reductions will be observed mainly in industry (by 23 per cent) and the power sector (by 22 per cent), as shown in Table 22.

FIGURE 33: Total carbon dioxide emissions

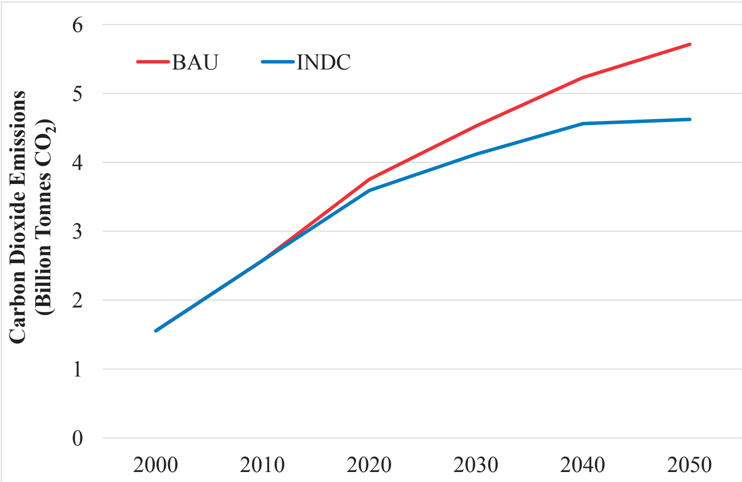


TABLE 22: Carbon dioxide emissions in the BAU and INDC scenarios

SECTOR	2000	2010	2030		2050	
			BAU	INDC	BAU	INDC
Industry	471.6	777.9	1401.5	1307.8	2013.9	1714.2
Power	429.0	809.8	1370.0	1044.5	2120.6	1185.2
Other	337.3	523.1	995.0	960.7	1297.3	1228.5

5.1.3 ENERGY AND CO_2 INTENSITY

India's INDC has a CO_2 intensity target, whereas SEforALL has a target of doubling the global rate of energy efficiency. Table 23 present energy and carbon intensities in the BAU and INDC scenarios. The carbon intensity of GDP declines by more than 35% in 2030, the estimated target for the INDC, in both scenarios. The energy intensity of GDP improves at a rate of 1.4% between 2010 and 2020 and of 1.9% between 2020 and 2030 in the BAU scenario, which is lower than the global rate of 2.6% proposed by SEforALL. However, the improvement in energy intensity is faster in the INDC scenario: 1.6% between 2010 and 2020, and 2.1% between 2020 and 2030.

The INDC scenario exceeds its emission intensity target for 2030 and, due to the massive penetration of renewables expected after 2030, there will be a noticeable decline in CO_2 emissions per unit of energy consumption compared to the reference scenario.

5.2 ELECTRICITY SECTOR

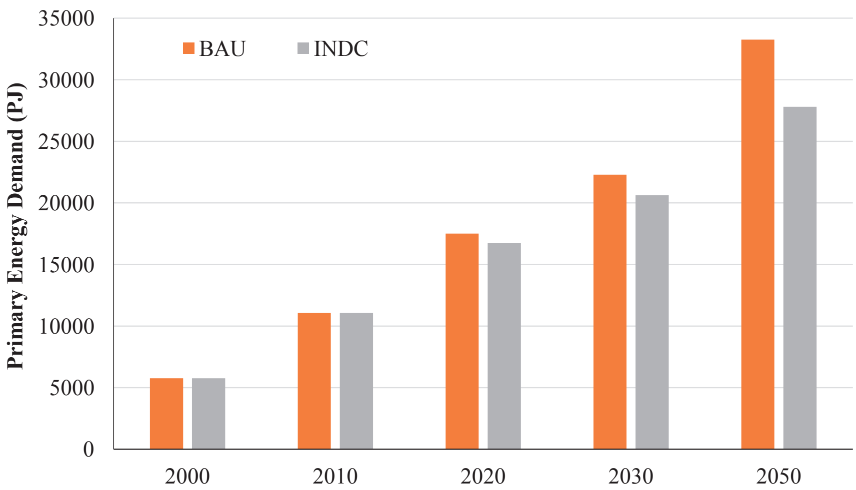
Sustainable energy in the form of electricity is considered an important indicator of both economic and social development. Figure 34 presents the primary energy demand required for the production of electricity under the BAU and INDC scenarios, while Figure 35 shows the fuel mix and Figure 36 presents sector-wise electricity consumption for both scenarios. There will be falls in energy demand between the BAU and INDC scenarios of 4.4, 7.5 and 16 per cent in 2020, 2030 and 2050 respectively. Coal remains the major fuel, constituting 69 per cent of the total fuel mix for power in 2000 and 45 per cent in 2050 under BAU conditions. The share of oil remains constant, while the share of gas increases from 10% in 2000 to about 26% in 2050.

The share of renewables (solar, wind, biomass) increased from 2 per cent in 2000 to 12 per cent in 2050 under the

TABLE 23: Energy and carbon intensity indicators in the BAU and INDC scenarios

	2000	2010	2020	2030	2040	2050
CO_2 (MT CO_2)						
Reference	1554.0	2575.3	3753.4	4529.2	5230.3	5713.4
INDC	1554.0	2575.3	3591.4	4118.9	4562.0	4622.5
CO_2/GDP (MT CO_2/billion US$ 2005)						
Reference	2.9	2.3	1.8	1.1	0.7	0.5
INDC	2.9	2.3	1.7	1.0	0.6	0.4
CO_2/capita (t CO_2/capita)						
Reference	1.5	1.4	1.3	1.1	1.0	1.0
INDC	1.5	1.4	1.2	1.0	0.9	0.8
Energy/GDP (PJ/billion US$ 2005)						
Reference	38.9	31.8	23.9	16.3	11.1	7.6
INDC	38.9	31.8	23.1	15.2	10.0	6.5
CO_2/energy (MT CO_2/EJ)						
Reference	75.0	72.5	74.5	68.2	64.9	62.9
INDC	75.0	72.5	73.7	66.5	63.3	59.5

FIGURE 34: Primary energy demand in power sector (in PJ)



BAU scenario, whereas in the INDC scenario the share increases to 24 per cent. The shares of hydropower and nuclear remain constant at 14-16 per cent in the fuel mix respectively. Even as the share of renewables increases in the fuel mix over the next few decades, the amount of electricity generated, especially from solar and wind, is about 11 per cent in the BAU scenario for 2050. The share of traditional biomass falls, though there will be an increase in the use of bio-fuels and waste to energy in these years.

The supply of electricity increases in all sectors to meet the increased demand from them. Switching to electricity will lead to reductions in GHG emissions, as it is a cleaner fuel with increased efficiency and use of renewables in its generation. There has been a push towards new and renewable forms of energy, encouraging the distributed and decentralized generation of electricity. The demand for electricity is observed to increase threefold in the agricultural sector, about fourfold in industry and the residential sector, and eightfold in the transport sector in 2030 over 2000. The increase in transport is the highest in 2050 due to the shift to electric vehicles for both public and private transport.

FIGURE 35: Electricity consumption fuel mix under both scenarios (in PJ)

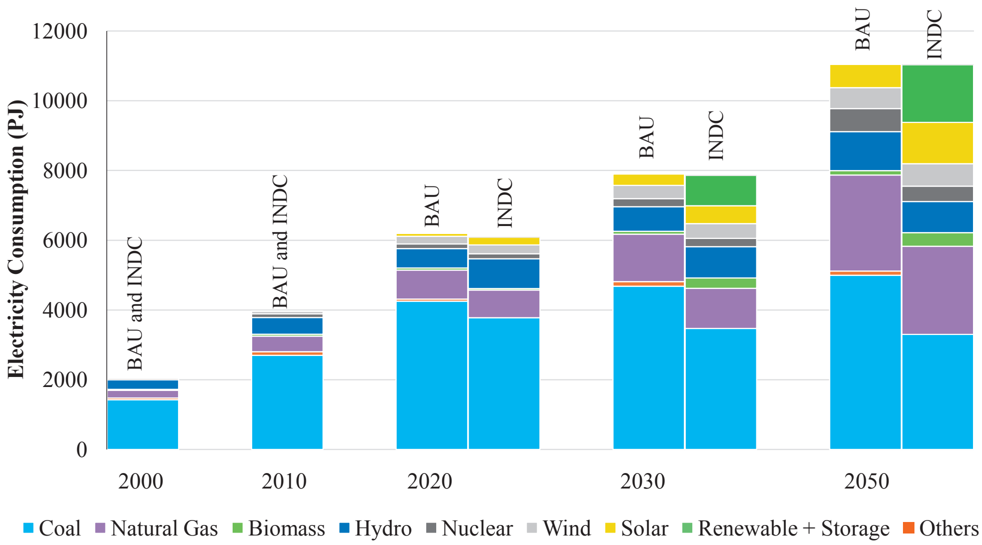
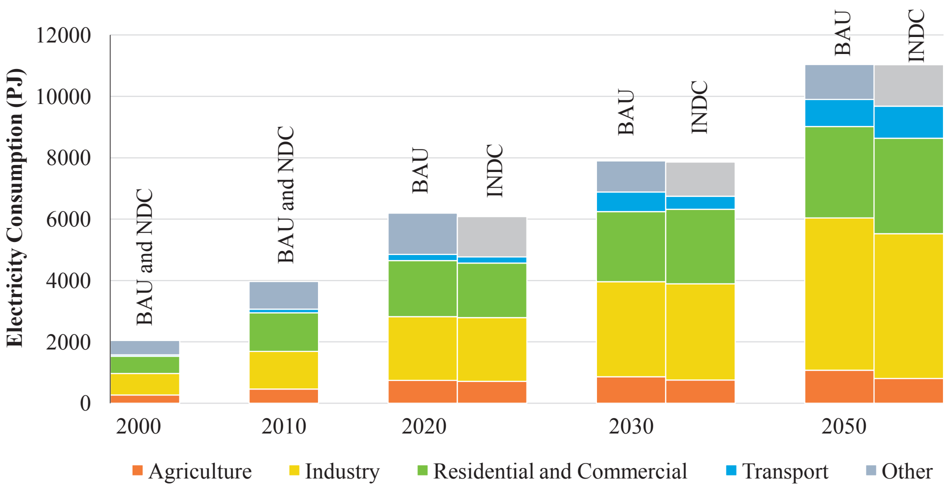


FIGURE 36: Electricity consumption across various sectors under both scenarios



5.3. INDUSTRY SECTOR

Energy consumption is estimated to increase by 4.3 percent annually due to a huge increase in the energy demand for cement, brick manufacturing and iron and steel. This is due to the heavy investments in infrastructure that are needed to meet the developmental needs of the country in the next few decades. Figures 37 and 38 present the total primary energy consumed in the two scenarios and by fuel type respectively.

Coal contributes as a fuel in most cases, but it is also as a raw material in some cases (like non-coking coal in iron and steel, or non-coking coal in cement). It constitutes to more than fifty per cent of the fuel mix in the industry sector, followed by diesel, natural gas and electricity. This is because the iron and steel, paper and textile industries are moving towards electrification, while the fertilizer industry is shifting towards natural gas.

FIGURE 37: Primary energy demand in the industry sector under BAU and INDC scenarios

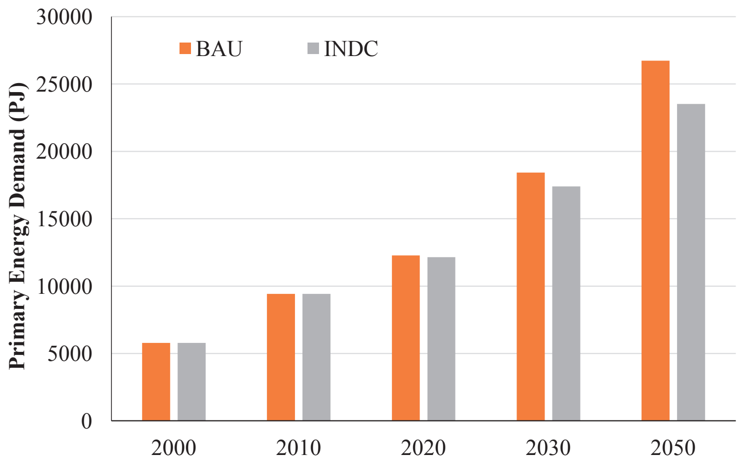
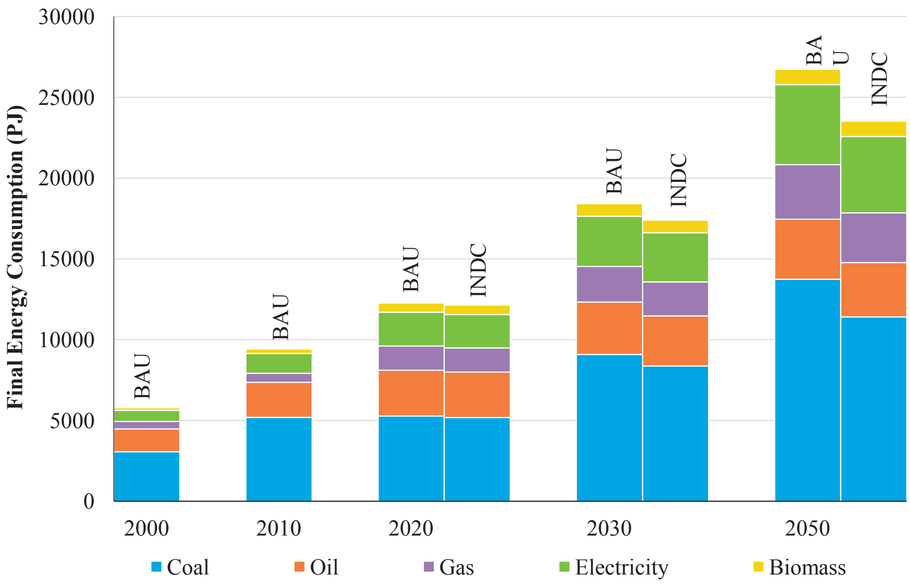


FIGURE 38: Industry sector fuel mix under both scenarios



5.4. RESIDENTIAL SECTOR

Energy consumption in the residential and commercial sector, as shown in Figures 39 and 40, depends on the type of fuel and technology used for the various services. Cooking accounts for more than fifty per cent of the energy consumption in BAU (not in INDC in 2050), most of which is met by biomass in the form of plant residue and firewood.

Switching fuel to LPG and solar energy, which commenced in the late 2000s, picks up after 2020 at the rate of 3-9 per cent, depending on the type of technology. This is due to current policy interventions through regulations, as well as the economic instruments needed to shift towards cleaner fuels to meet the demand for cooking. The rate of adoption of cleaner technologies has turned out to be slower than expected, and the rate of use of biomass is found to decline only after 2040. Solar is found to increase due to increased demand for rooftop water heaters. An increase in electricity is observed due to the electrification of residential and commercial building, especially for space cooling.

FIGURE 39: Energy consumption in the residential and commercial sector

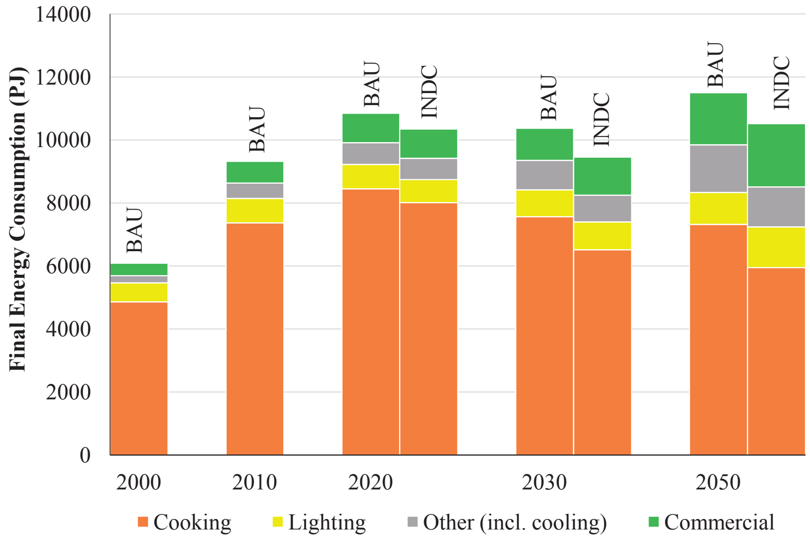
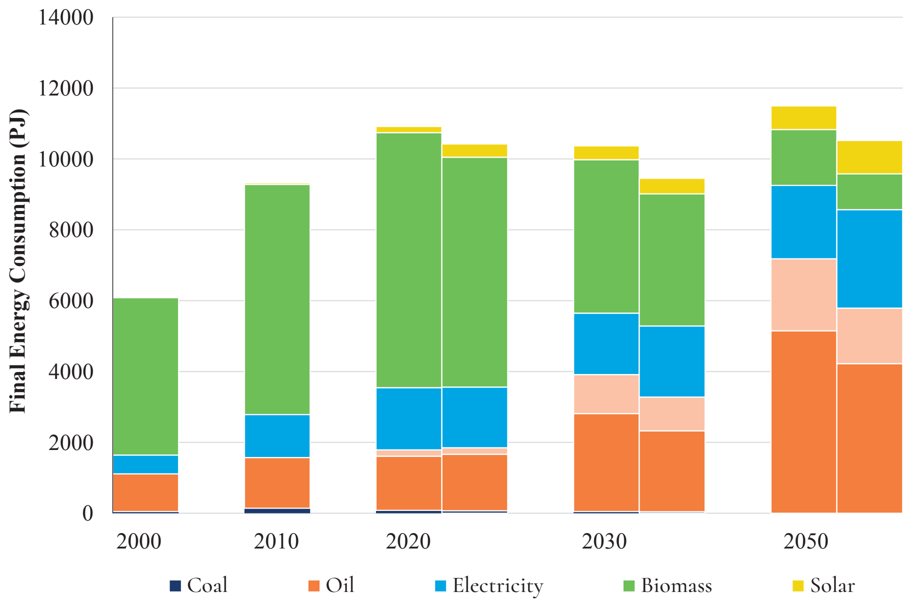


FIGURE 40: Final energy consumption by fuel type in the both scenarios for residential sector



5.5 TRANSPORT SECTOR

The transport sector accounted for about 11 per cent of total energy demand in 2000, and its share is expected to increase to 17 per cent in 2030 and about 19 per cent in 2050.

Figure 41 shows energy consumption by type of fuel, while Figures 42 and 43 present mode-wise consumption. There is a decline in the consumption of oil after 2030, due to the shift towards hybrid and electric vehicles, along with the increased share of public transport by road and rail. In passenger traffic, bus use is expected to increase, though due to the shift towards CNG the energy intensity is improved, thereby reducing overall energy consumption. There is a marked increase in the demand for two-wheelers and three wheelers. With increasing public transport in cities, the share of four wheelers decreases. This is due

FIGURE 41: Transport: energy consumption by fuel type

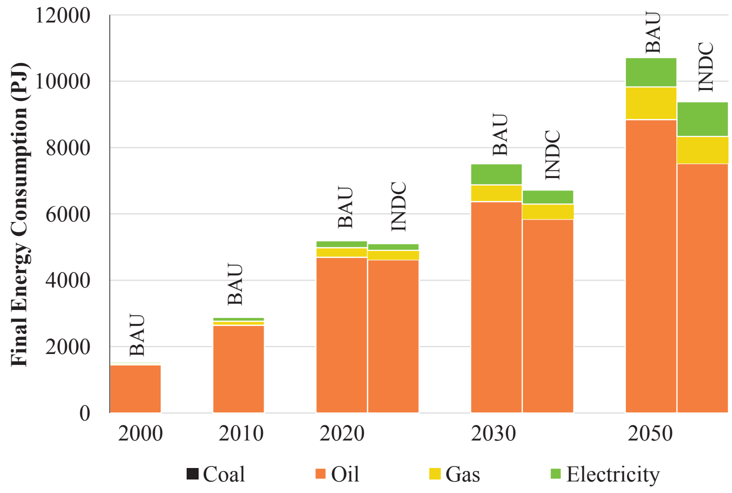


FIGURE 42: Primary energy consumption: passenger transport

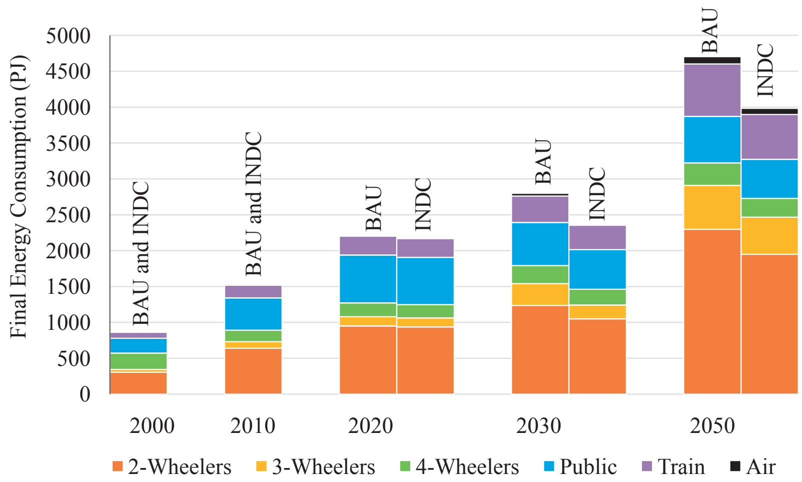


FIGURE 43: Energy consumption- freight transport

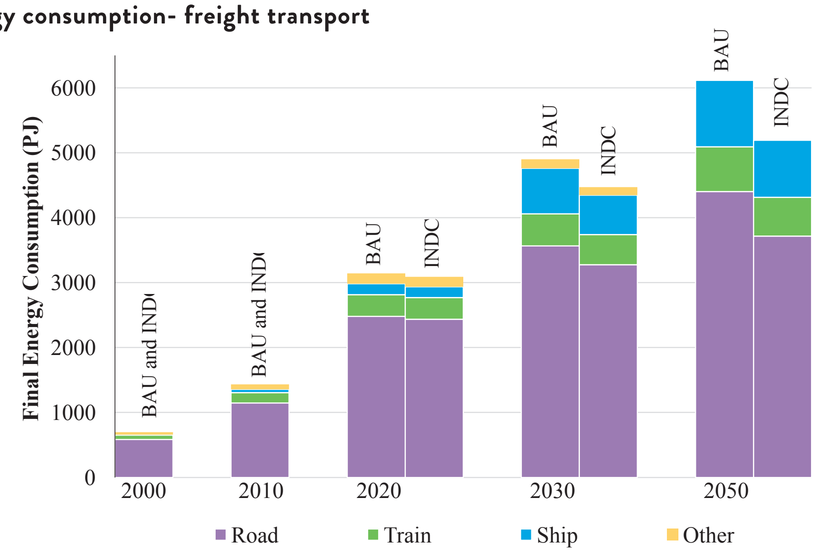
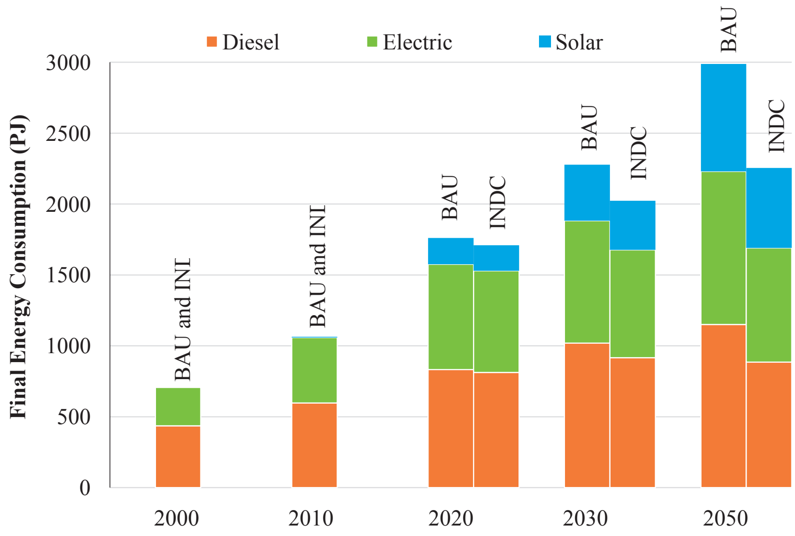


FIGURE 44: Fuel mix in the agricultural sector in the BAU and INDC scenarios



to a significant push to move towards the use of electricity and bio-fuels in the transport sector, especially in rail and road (for two-, three- and four--wheelers and buses), in addition to the introduction of metro-rail. The freight sector shows a decrease in the share of rail traffic, with a significant increase in waterways traffic (Figure 44).

5.6 AGRICULTURE SECTOR

Agriculture's share of GDP has been declining in the past two decades, though it still continues to employ about fifty per cent of the population both directly and indirectly. The demand for food is expected to increase, and the sector faces various challenges to meet the growing energy demand. This is compounded due to the use of inefficient pumps, tractors and other implements, coupled with increased mechanization in farming and the inefficient use of water and fertilizers. The sector's overall consumption of energy is low when compared to industry and power, though it is responsible for about 50-60 per cent of diesel and 10-14 per cent consumption of electricity.

Figure 44 presents the fuel mix in the agricultural sector under the BAU and INDC scenarios. It can be observed that electricity consumption by pumps increases in line with the increased need for irrigation. India is implementing policies to improve energy efficiency and shifting towards cleaner forms of energy. Hence, there is a decrease in the share of diesel consumption and a shift in the direction of energy-efficient electric pumps and cleaner solar pumps. However, diesel consumption is due to increase after 2020 because of its increased use in tractors. Chapter 6 further discusses the type of technology mix in the sector and why energy-efficient pumps are one of the high-impact opportunities that needs to be encouraged.

CHAPTER 6

HIGH-IMPACT OPPORTUNITIES

This section evaluates the energy savings potential of the selected HIOs in each major sector in the short (2015-20), medium (2020-30) and long terms (2030-50). The indicated saving potentials are dynamic in reality and will be impacted by various factors – technological (innovation, design), economic (price of the technology, energy usage), social (adaptation and use) and environmental. This chapter only covers the technologies that are currently cost-effective. The following section presents HIOs in electricity, industry and other sectors. The last section of the chapter summarizes the HIOs from the residential, transport and agriculture sectors.

6.1. HIOs REPRESENT A DYNAMIC CONCEPT

High Impact Opportunities (HIOs) in the current study are represented as a dynamic concept in the sense that a current HIO may not remain an HIO in the future. This can happen when a technology has been widely diffused, for example, LEDs is an HIO in India currently, or is being diffused widely through programs in residential establishments.[23] Commercial establishments are also adopting this technology from cost-efficiency considerations. However, in the longer term the focus may shift to solar lanterns or LED tube lights after most of the incandescent lamps have been replaced with LED bulbs. Even though LED lights may see technological improvements in the next decade, the relative energy efficiency gains may be minuscule compared to those being achieved at present from replacing inefficient lighting by LEDs. Similarly, transmission, distribution and commercial losses (T&D losses) are around 23 per cent currently in India. The Government of India has a target to bring them down to 15% by 2022. The relative importance of this HIO may decline in the medium and longer terms when the T&D losses have come down to single digits.

6.2 HIOs IN THE ELECTRICITY SECTOR

In the electricity sector, the energy efficiency options related to electricity generation are accompanied with other options included in the INDC scenario from an emissions reduction perspective, such as reducing T&D losses and increasing the share of new and renewable forms of energy. Energy efficiency in generation is being achieved by switching to super-critical and ultra-super-critical power plants (with higher technical efficiencies) along with cleaner fossil fuels. Additionally, the demand for electricity is also met through renewables, especially in areas outside the grid.

Under the BAU scenario, the reliance on coal remains. However, the shifts from sub-critical to super-critical and ultra-super-critical power plants predominate, as there is no constraint on carbon through policies or prices. Figure 45 shows the difference between the BAU and INDC scenarios in the energy intensities of coal and lignite thermal power plants. Under the INDC scenario, the fuel mix has lower share of coal, the assumption being that the existing technologies will be phased out completely with advanced, efficient technologies in coal power plants. The shares of nuclear and hydro power in the energy mix increase along with solar and wind. Figure 46 presents the proportion of energy savings between 2015-50 due to energy efficient technologies, and addition of renewables.

Table 24 estimates energy savings between 2015-50 due to energy-efficient technologies, the addition of renewables, reductions in ATC losses and the introduction of a smart grid. It can be observed that super-critical power plants and reductions in ATC losses save energy during the period 2015-20. The smart grid and renewables (especially solar) are only picked up in the late 2030s. With a strong push from government through energy conservation and clean energy programs and a more environmentally aware society, the penetration of these technologies may improve further.

6.3. HIOs IN INDUSTRY

The industry sector accounts for 38-40 percent of final energy consumption, making it one of the major end-users along with the electricity sector. Industrial energy demand has been growing since 2000 and is expected to increase further in the future due to the government's promotion of its 'Make in India' policy. PAT was introduced in 2011 as part of improving the energy efficiency of the sector. The first cycle of the PAT (PAT 1) has resulted in substantial energy savings under a frozen technology scenario[24] (Table 25).

23 India has replaced 34 million LEDs in residential areas in the last two years.

24 A scenario assuming no improvement in the efficiency of technology.

FIGURE 45: SEC for coal power plants in BAU and INDC scenarios

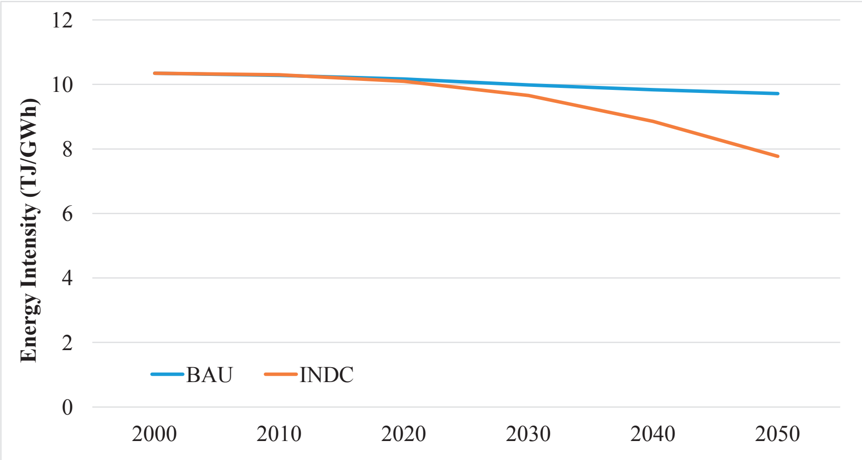


FIGURE 46: Energy savings in the power sector

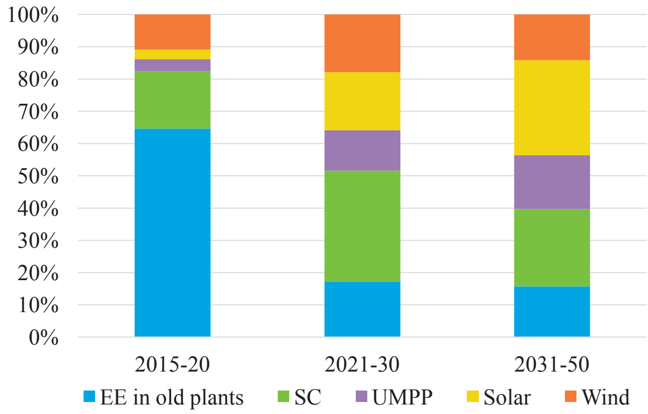


TABLE 24: Energy savings with respect to sub-critical coal technologies

	HIOS	ENERGY SAVINGS (PJ)	INSTALLED CAPACITY SAVED (GW)
2015-20	Super-critical power plants w.r.t. sub-critical	1004	32
	ATC losses	540	17
	Renewables (solar, wind) w.r.t. Coal - sub-critical	1292	41
2021-30	Super-critical / ultra-super-critical w.r.t. sub-critical	9722	311
	ATC losses	720	23
	Renewables (solar, wind) w.r.t. Coal - Sub critical	6171	197
	Smart grid	105	3.3
2031-50	Super-critical power plants w.r.t. sub-critical	28858	922
	ATC losses	1200	38
	Renewables (solar, wind) w.r.t. coal – sub-critical	30928	988
	Smart grid	2070	66

TABLE 25: Energy savings under PAT cycle I (2012-15) (in PJ)

	ACTUAL PAT SAVINGS
Thermal power plants	128.12
Iron and steel	87.92
Cement	60.29
Aluminium	30.56
Pulp and paper	10.89
Fertilizer	34.75
Textiles	5.02
Chlor alkali	4.19
TOTAL	361.7

The energy intensities of energy-intensive industries were observed to decrease by between 10 and 20 per cent from the base year for designated consumers during PAT cycle I. PAT II is being extended to more sectors beyond industry, namely the railways, electricity and refineries, though it will continue to play a crucial role within the industry sector. PAT cycle II is planned to reduce these energy losses, which, however, have not been considered in the present study.

The importance of PAT can be estimated from the difference between the BAU and INDC scenarios, since BAU reflects improvements to energy efficiency due to ongoing measures, whereas INDC reflects the additional efficiency that a mechanism like PAT can help to realize. Figure 47 illustrates the improvement in energy intensity measured in terms of a decrease in specific energy consumption per unit output under the BAU and INDC scenarios for the seven major industries.

These improvements in SEC are taking place due to the diffusion of more efficient technologies (Table 26). It is observed that the energy intensities of the cement, fertilizer, pulp and paper and textile sectors are considerably reduced in the INDC scenario as compared to other industries. The intensities in the aluminum and iron & steel sectors are found to decrease even in the baseline scenarios, as these industries are assumed to increase their use of recycled materials and switching to electricity.

TABLE 26: Selected technology options to improve energy efficiency

SELECTED INDUSTRY	SELECTED TECHNOLOGIES
Aluminium	Improved Bayer process Improved Soderberg process Improved pre-baked process
Iron and steel	Scrap –EAF DRI –EAF (coal-based) DRI –EAF (gas-based)
Cement	Dry process Semi-dry process
Fertilizer	Natural gas Naptha
Paper and pulp	Co-generation Blow heat recovery
Textile	New spinning process Drying process

Table 27 presents the energy savings in the selected energy-intensive industries, indicating the installed power capacity saved. It can be observed that about 236 GW and 1193 GW of capacity can be saved during 2015-30 and 2031-50 respectively by shifting to the best available, most energy-efficient technologies.

Thus, through the implementation of PAT with currently available technology measures over the next 35 years, installed capacity of up to 40 GW per year can be saved over the BAU scenario, in the INDC scenario. It can be observed that maximum energy can be saved in cement, followed by fertilizers, iron and steel, and paper and pulp.

FIGURE 47: Energy intensities in energy-intensive industry in the BAU and INDC scenarios

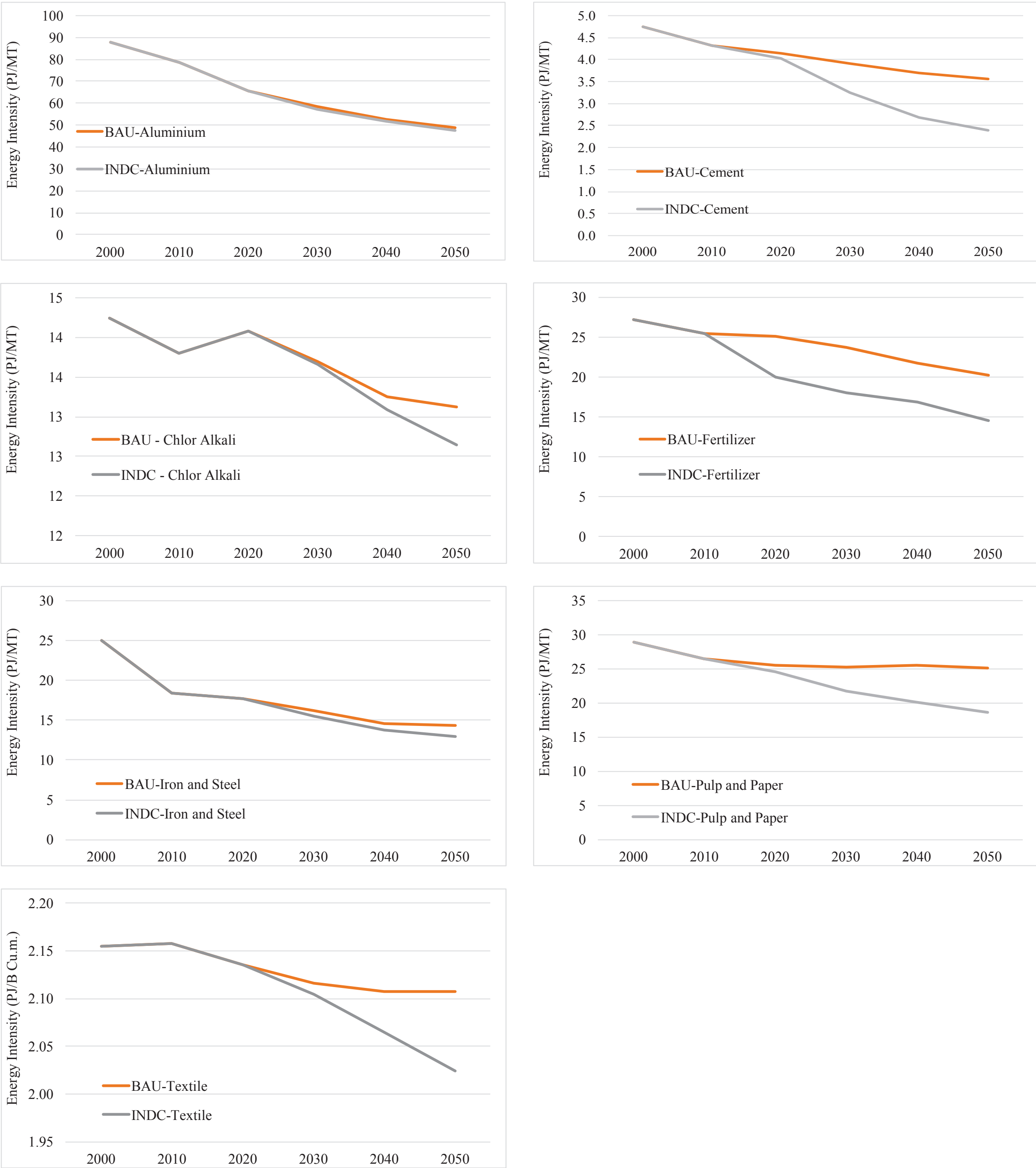


TABLE 27: Improvements in SEC, energy savings and installed capacity saved through PAT

	INDUSTRY	IMPROVEMENTS IN SEC (%)		ENERGY SAVINGS W.R.T. BAU (PJ)	INSTALLED POWER CAPACITY SAVED (GW)
		BAU	INDC		
2015-20	Aluminium	8	8	0	21.7
	Cement	3	7	86.2	
	Chlor alkali	1	1	0	
	Fertilizer	1	5	568.6	
	Iron and steel	1	1	0	
	Paper and pulp	2	5	29.6	
	Textiles	3	1	0	
2021-30	Aluminium	11	14	88.6	214.3
	Cement	6	21	2525.6	
	Chlor alkali	3	3.5	6	
	Fertilizer	6	23	2787.8	
	Iron and steel	9	10	798.7	
	Paper and pulp	0.9	13	548	
	Textiles	1	2	4.3	
2031-50	Aluminium	10	19	235.8	1193.4
	Cement	5.5	20	21506.7	
	Chlor alkali	3	6.5	122.1	
	Fertilizer	7.5	3	5437.1	
	Iron and steel	9	17	5420.2	
	Paper and pulp	1.2	12	4787.3	
	Textiles	1	6	124.9	

6.4 HIOs IN OTHER SECTORS

Figure 48 presents the energy demand in the agricultural sector by technology and fuel type from 2000 to 2050. There is a decline in the diesel pump sets, which are planned to be phased out by 2040. There is an increase in the efficient electric pumps along with micro- irrigation. Solar pumps, which are being used in the current experimental phase, are expected to pick up only after 2020.

Figures 49-51 present energy demand by technology type in the residential sector in cooking, lighting and space cooling respectively. The figures specifically show the transition of the technologies used in cooking, lighting and space cooling services due to both better efficiencies in equipment and fuel switching. For example, cooking energy demand in Figure 49 is estimated for both rural and urban areas. It is observed that biomass stoves dominate the category, followed by more efficient biomass stoves. Even as the government pushes electric stoves, LPG and solar cookers into the market through various interventions, the use of biomass is found to decline only after 2025. Transition in technologies is observed as model selects efficient biomass technologies over old biomass stoves in rural areas and shifts towards cleaner fuels such as LPG and solar cooking stoves after 2040.

Similarly, in Figure 50 energy demand for lighting is given for both residential (urban and rural) and commercial sectors. It shows the prominence of LEDs, which pick up after 2020, when other forms of technology such as incandescent lamps and CFLs are phased out. Solar lamps, which are currently used in villages and are being promoted for street lighting, also become prevalent after 2030.

The market in cooling appliances is dominated by fans, which account for more than 80 per cent of the energy demand. Figure 51 shows the energy demand for space cooling through technologies such as fans and ACs. It also shows conventional ACs and fans being replaced by newer and more efficient technologies such as super-efficient fans, advaced ACs, and ACs with cooled roofs after 2020.

FIGURE 48: Agriculture: energy demand by technology and fuel type in the INDC scenario

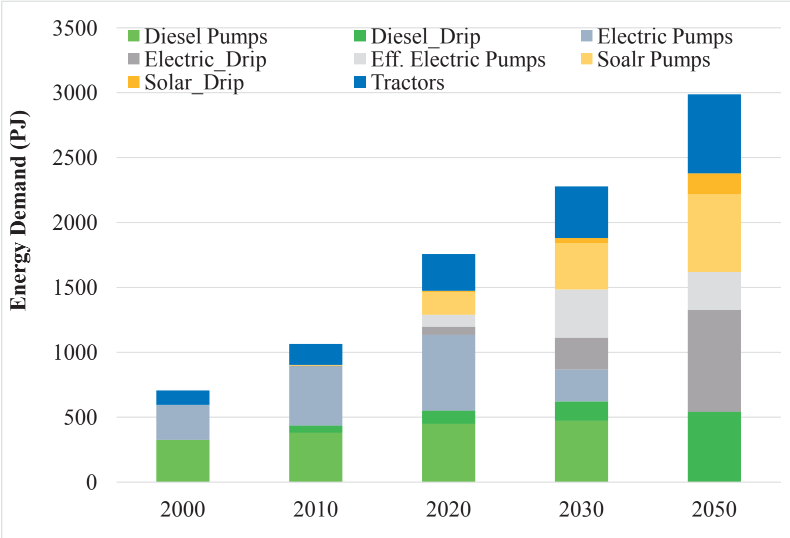


FIGURE 49: Cooking: energy demand by technology and fuel in the INDC scenario

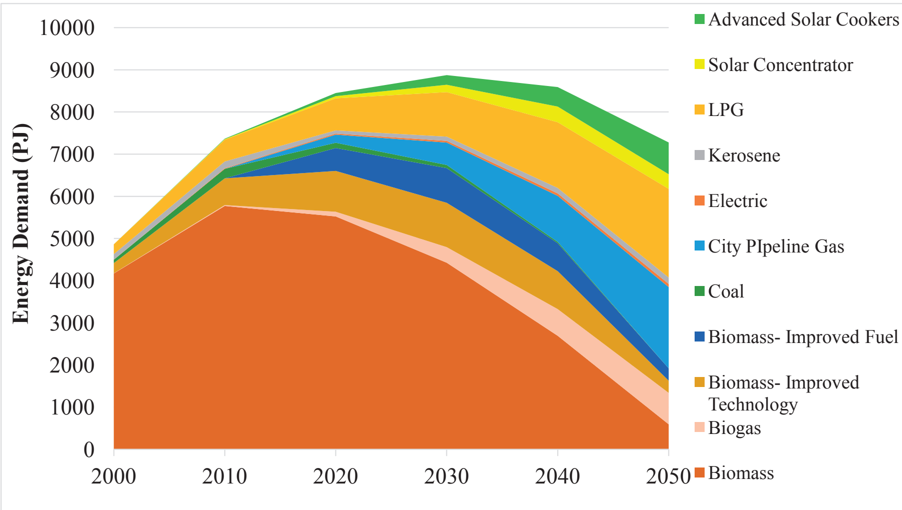


FIGURE 50: Lighting: energy demand by technology in the INDC scenario

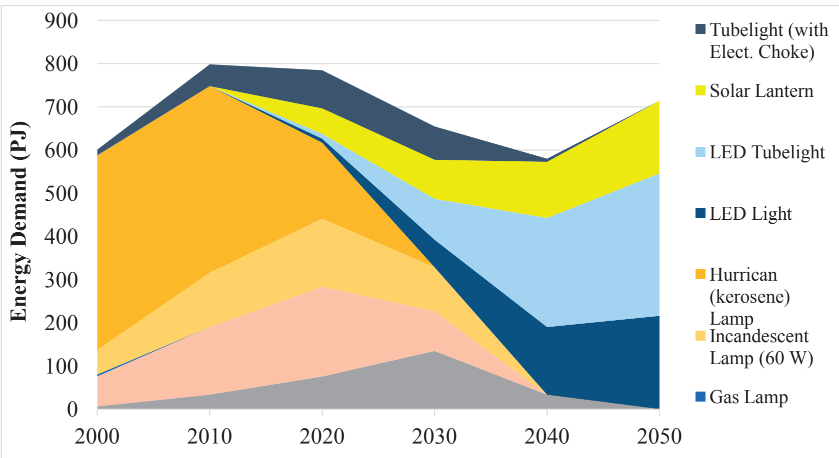


FIGURE 51: Cooling appliances: energy demand by technology in the INDC scenario

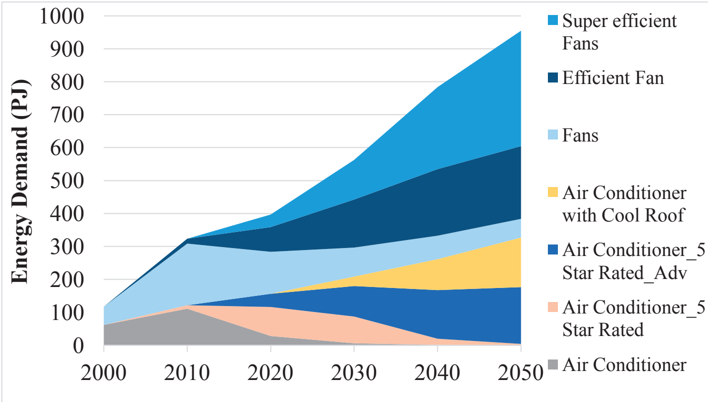


Table 28 shows the estimated improvements in specific energy consumption for various HIOs, energy savings and savings in installed capacity in the short, medium and long terms. It shows energy-efficient pumps in agriculture and LED lights, efficient fans and ACs and cleaner cooking stoves in the residential sector. The transport sector can be electrified by shifting to electric vehicles, electric trains and metro. The model presents metro-rail as an energy-efficient alternative to private vehicles in urban areas.

TABLE 28: Improvements in SEC and energy savings in the short, medium and long terms in the agricultural, residential and transport sectors

	HIOS	IMPROVEMENTS IN SEC (%)	ENERGY SAVINGS DUE TO REPLACEMENT (PJ)	INSTALLED POWER CAPACITY SAVED (GW)
2015-20	EE pumps w.r.t. Electric pumps	25%	110	3.5
	LED w.r.t. CFL LED w.r.t. incandescent bulb c. LED tubes w.r.t. Fl. tubes	45-80%	CFL: 75 Bulb: 126 Tube lights: 51	8
	AC (5 star) w.r.t. AC	15%	62	2
	Cleaner cooking stoves w.r.t. advanced biomass stoves	51%	139	4.5
	Metro w.r.t. 4 wheelers	97 %	75	2.5
2020-30	EE pumps w.r.t. Electric pumps	25%	592	18.8
	Super EE fans w.r.t. EE fans	31 %	1155	36.6
	AC (5 star) w.r.t. AC AC (Advanced) w.r.t. AC 5 star	AC: 15% AC Adv.: 29%	AC: 179 AC Adv.:128	9.7
	Cleaner cooking stoves w.r.t. LPG stoves	52 %	206	6.5
	Metro w.r.t. four-wheelers	97 %	235	7.5
2030-50	EE w.r.t. electric pumps	24%	453	14.4
	Super EE w.r.t. EE fans	30%	547	17.3
	2030: AC (advanced) w.r.t 5 star 2040: adv. AC with cool roof with adv. AC	2030: 16 % 2040: 30%	2030: 252 2040: 529	24.8
	Metro w.r.t. four-wheelers	94 %	3936	124.8

CHAPTER 7

CONCLUSION

Model outputs are used to formulate a robust policy response using a set of regulatory, economic and information instruments. Our study outlines the priorities for high-impact opportunities for energy efficiency while maintaining India's energy security and its alignment with global mitigations of CO_2 emissions. It has also identified present and future HIOs for each of the sectors that are represented in the model and their possible penetration rates and costs during the reported period. These policies have been selected on the basis of their potential to achieve energy efficiency through HIOs, thereby saving energy and reducing carbon dioxide emissions, in addition to associated co-benefits. Having conducted the scenario analysis in different competing situations, these policies are recommended in guiding the future course of action.

Table 29 lists not only the selected HIOs for the short and medium terms, but also potential HIOs in the longer term, based on the introduction of energy-efficient technologies and shifting to cleaner energy.

In the agricultural sector, the potential HIO is the energy-efficient pump set, with the increasing consumption of electricity in recent decades. There will be a shift to new, renewable and cleaner energy and improved grid distribution, though energy-efficient pump sets will be required to decrease energy demand for the same service. Hence, the technology will remain an HIO in the short and long terms. Under the Agriculture Demand-Side Management (AgDSM) program, pilot projects have already started in states like Gujarat and Maharashtra. In the residential sector, LED and cooking stoves are the selected HIOs for the short term, while energy-efficient fans and ACs were observed to be replacing current technologies due to existing policy interventions, in addition to the availability of better technology and improved economic conditions. Similarly, Metro, PAT, super-critical (SC) and ultra-super-critical (UMPP) power plants were the selected HIOs in their respective sectors.

In terms of energy savings, PAT, fuel efficiency on the energy supply side, **energy efficient pumps, LED, efficient fans and metro rail** are observed to be cost-effective HIOs in the short, medium and long terms that should be encouraged and enabled through policy initiatives, regulatory measures and economic instruments. Of these three, metro will need substantial upfront investment, which in turn will require a strong push by national and city governments to fast-track project implementation.

TABLE 29: HIOs in the short, medium and long terms

SECTOR	HIO – SHORT TERM 2015-2020	HIO – MEDIUM TERM 2020-2030	HIO – LONG TERM 2030-2050
Agriculture	Energy-efficient (EE) pumps	EE pumps	EE and solar pumps
Residential	LED, advanced space cooling systems, cleaner cooking	EE fans, advanced space-cooling systems, cleaner cooking (LPG, biofuels)	Advanced space-cooling systems (AC with cool roof), solar concentrators for cooking, city/housing complexes-based heating and cooling systems
Transport	Metro	Metro, electric vehicles	Metro, electric vehicles
Industry	PAT	PAT (enhanced sectoral and plant coverage)	PAT (enhanced specific energy consumption targets)
Power	Transmission and commercial (T&C) loss reductions, super-critical (SC) coal-based power plants	SC and ultra-mega power plants (UMPP), T&C loss reductions, solar and wind, smart grids	SC and UMPP, storage technologies, solar and wind, and other new and renewable sources, smart grids

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APPENDIX

APPENDIX A: KEY INDUSTRIES IN END-USE SECTORS

A.1 ALUMINIUM

There are three major players in this industry, which include National Aluminium Company Limited (NALCO), Hindustan Aluminium Company Limited (HINDALCO) and Sesa Sterlite Group. The remaining include Bharat Aluminium Company Limited (BALCO), a subsidiary of Vedanta group and Madras Aluminium Company Limited (MALCO). NALCO is the only company in the public sector with installed capacity of 460,000 tons per year. BALCO, earlier a public sector company, is now under private Spector with stake holdings apportioned between Sterlite Industries (India) Ltd (51%) and Government of India (49%). The remaining are in the private sector. Table A1 lists the aluminium plants in India along with their production capacities. It is projected that aluminium production capacity in India at the end of the 12th Plan Period viz, 2016-17 would be about 4.7 million tonnes (IMYB, 2014a).

TABLE A1: Aluminium plants in India

PRODUCER	PLANT	ANNUAL CAPACITY (KT)
Public Sector		
National Aluminium Co. Ltd	Angul (Odisha)	460
Private Sector		
Bharat Aluminium Co. Ltd	Korba (Chhattisgarh)	345
Hindalco Industries Ltd	Renukoot - 345 (Uttar Pradesh)	562
	Hirakud (Odisha) -217	
Madras Aluminium Co. Ltd	Mettur (Tamil Nadu)	40
Vedanta Aluminium Ltd	Jharsuguda (Odisha)	500
All India		1907

Source: IBoM, 2014

India imported 1.35 MT of aluminum & alloy and scrap, and exported 7.07 MT during 2013-14 (IMYB, 2014a). 16% of the import is from UAE, 12% from China, 7% from Saudi Arabia, 6% from UK, 5% each from Oman & South Africa and 4% from USA. The Exports were mainly to Korea (24%), Mexico (12%), USA (7%), China (6%), UAE (5%), Vietnam (3%) and Turkey (2%).

A.2 CEMENT

There are about 188 large cement plants and 365 small plants, with top 20 players accounting for 70 percent of the total cement production. Technologically, it can be observed that that 73 percent % of the plants in India are using dry process for production (Table A2).

TABLE A2: Technology wise distribution of cement plants in India (2011)

	DRY PROCESS	GRINDING UNIT	SEMI DRY PROCESS	WET PROCESS	TOTAL
No. of plants	109	57	4	11	182
Total Capacity (MT)	225	71	2	9	307
Percentage of total cement capacity	73%	23%	1%	3%	100%

Source: CMA (2012)

Table A3 shows the company wise plant capacity in India.

TABLE A3: Player wise plant capacity in India (2013)

COMPANY	CAPACITY (MT)
Public Sector	5.77
C.C.I. Ltd.	3.85
Malabar Cements	0.62
Tamil Nadu Cement	0.90
Others	0.40
Private Sector	338.10
ACC Ltd	29.00
Ambuja Cement Ltd	21.00
Andhra Cements	1.42
Binani Cement	6.25
Birla Corp. Ltd.	5.78
Cement Manu. Co. Ltd	1.26
Century Textiles and Industries Ltd	8.54
Chettinad Cement	14.20
Dalmia Cement (Bharat) Ltd	10.50
Heidelberg Cement (I) Ltd	3.10
J.K. Cement Ltd.	7.93
Jaiprakash Associates Ltd	32.05
JK Lakshmi Cement Ltd	5.83
Kesoram Industries	7.25
Lafarge India(P) Ltd	10.10

COMPANY	CAPACITY (MT)
Madras Cements Ltd	12.72
Mangalam Cement Ltd	2.00
Mehta Group	2.70
My Home Indus. Ltd	5.20
OCL India Ltd.	5.35
Orient Paper and Industries Ltd	5.00
Penna Cement Industries Ltd	6.50
Prism Cement Ltd	5.60
Rain Cements Ltd	4.00
Shree Cements	21.60
The India Cements Ltd	15.85
The K.C.P. Ltd.	2.35
UltraTech Cement Ltd	48.75
Zuari Cement Ltd	4.40
Others	31.87
ALL INDIA	343.87

Source: IMYB, 2014

The installed capacity and production are estimated at 479.3 MT tons and 407.4 MTtons respectively, (with a capacity utilisation of 85%) in 2016-17 (IMYB, 2014b). Cement import in 2013-14 was 0.78 MT. and main suppliers were Pakistan (63%), Bangladesh (23%) and Vietnam (8%). Cement exports were 5.14 MT in 2013-14, primarily to Sri Lanka (38%), Nepal (19%), Saudi Arabia (12%), Bangladesh (6%) and Bhutan (5%).

A.3 FERTILIZER

Tables A4 and A5 show the capacity and production trend of fertilizer in India, and company wise plant capacity respectively.

Increasing trend in consumption towards balanced application led to improvement in N:P:K use ratio. The ratio had been 6.8:2.6:1 at the end of 9th Plan improved to 5.9:2.4:1 at the end of 10th Plan which further improved to 5.0:2.4:1 during the fourth year of the 11th Plan (2010-11). Per hectare consumption of fertilizer nutrients improved from 92.2 kg at the end of 9th Plan improved to 112.1 kg at the end of 10th Plan which further improved to 145 kg during 2010-11.

TABLE A4: Capacity and Production of fertilizer in India

PRODUCT	NO. OF UNITS	TOTAL INSTALLED CAPACITY (MT)	PRODUCTION (MT)				
			2009-10	2010-11	2011-12	2012-13	2013-14
Urea	30	21.6	21.1	21.9	22.0	22.6	22.7
DAP	12	8.3	4.2	3.5	4.0	3.6	3.6
Complexes	21	6.1	8.0	8.7	7.8	6.2	6.9
TOTAL	63	36.0	33.4	34.1	33.7	32.4	33.2

Source: DoF, 2015

TABLE A5: Company wise fertilizers production capacity in India

COMPANY	INSTALLED CAPACITY (MT)	
	UREA	DAP
Brahmaputra Valley Fertilizer Corporation Limited	0.56	
Chambal Fertilisers and Chemicals Ltd	0.86	
Coromandel Fertilisers Limited	0.24	0.67
Deepak Fertilizers and Petrochemicals Corp		
Fertilisers & Chemicals Travancore Ltd.		
Gujarat Narmada Valley Fertilizers Co. Ltd.	0.64	
Gujarat State Fertilizers & Chemicals Ltd	0.37	1.15
Hindalco industries		0.40

COMPANY	INSTALLED CAPACITY (MT)	
	UREA	DAP
Indian Farmers Fertilizers Cooperation	3.69	2.70
Indo Gulf Fertilisers Ltd.	0.86	
KRIBHCO Shyam Fertilizers Limited	0.86	
Krishak Bharti Coperative Ltd	1.73	
Madras Fertilizers Ltd.	0.49	
Mangalore Chemicals & Fertilizers Ltd.	0.38	0.18
Nagarjuna Frtilizers & Chemicals Ltd.	1.19	
National Fertilizers Limited	3.23	
Paradeep Phosphates Limited		0.72
Rashtriya Chemicals & Fertilizers Limited	2.04	
Shriram Fertilisers & Chemicals	0.38	
Southern Petrochemicals Ind. Ltd.	0.62	0.48
Tata Chemicals Limited	0.86	0.68
Zuari Industries Ltd.	0.40	0.33
TOTAL	19.41	7.30

Source: FAI, 2011

A.4 IRON AND STEEL

Table A6 gives the overview of the steel production capacity in India in 2010?.

TABLE A6: Unit wise overview of Indian Steel Industry

TYPE OF UNIT	NUMBER	CAPACITY (MT)
Mini Blast Furnaces	42	19.5
Sponge Iron units	431	35.0
Electric Arc Furnace	49	19.3
Induction Furnace units	1307	30.3
Corex/MBF-BOF/EOF	4	8.2
Re-rolling units	1890	40.7
Hot Re-rolling Mills	14	15.7
Cold Rolling Mills	65	10.2
Coating Units: Galvanising Color Coating	20	5.6
TOTAL	3822	184.6

Source: JPC, 2010

APPENDIX B: ELECTRICITY GENERATION IN INDIA

TABLE B1: All India installed capacity (MW) of Power Stations (as on 31/10/2016)

REGION	OWNERSHIP/ SECTOR	MODEWISE BREAKUP							GRAND TOTAL
		THERMAL				NUCLEAR	HYDRO	RES* (MNRE)	
		COAL	GAS	DIESEL	TOTAL				
Northern	State	16598	2879	0	19477	0	7633	662	27772
	Private	17926	333	0	18259	0	2478	8314	29051
	Central	12001	2344	0	14345	1620	8266	0	24231
	Sub Total	46525	5556	0	52081	1620	18377	8976	81054
Western	State	22500	2994	0	25494	0	5481	311	31286
	Private	36725	4676	0	41401	0	447	15507	57355
	Central	12898	3534	0	16432	1840	1520	0	19792
	Sub Total	72123	11203	0	83326	1840	7448	15818	108432
Southern	State	16883	792	288	17962	0	11668	513	30143
	Private	8270	5322	555	14147	0	0	19765	33912
	Central	11890	360	0	12250	2320	0	0	14570
	Sub Total	37043	6474	843	44359	2320	11668	20278	78625
Eastern	State	7540	100	0	7640	0	3178	225	11043
	Private	8731	0	0	8731	0	195	339	9266
	Central	14221	0	0	14221	0	1005	0	15227
	Sub Total	30493	100	0	30593	0	4378	564	35535
North Eastern	State	60	446	36	542	0	382	259	1183
	Private	0	25	0	25	0	0	9	34
	Central	250	1254	0	1504	0	860	0	2364
	Sub Total	310	1724	36	2070	0	1242	269	3581
Islands	State	0	0	40	40	0	0	5	45
	Private	0	0	0	0	0	0	6	6
	Central	0	0	0	0	0	0	0	0
	Sub Total	0	0	40	40	0	0	11	51
ALL INDIA	State	63581	7211	364	71155	0	28341	1975	101472
	Private	71652	10356	555	82563	0	3120	43942	129624
	Central	51260	7491	0	58751	5780	11651	0	76182
	Total	**186493**	**25057**	**919**	**212469**	**5780**	**43112**	**45917**	**307278**

Source: CEA (2016)

** RES (Renewables) include small hydro, biomass, solar and wind Energy. Installed capacity in respect of RES (MNRE) as on 30.09.2016 (As per latest information available with MNRE)*

**Break up of RES all India as on 30.09.2016 is given below (in MW):*

SMALL HYDRO POWER	WIND POWER	BIO-POWER		SOLAR POWER	TOTAL CAPACITY
		BM POWER/ COGEN.	WASTE TO ENERGY		
4323	28082.95	4882.33	115.08	8513.23	45916.95

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This report on Enhancing Energy Efficiency in India: Assessment of Sectoral Potentials uses energy and economic model to assess the potential for further energy efficiency improvement in the agriculture, industry, transport, and power sectors. For each sector, the study identifies key high impact opportunities (HIOs) for energy efficiency improvement.

This publication forms part of China and India Energy Efficiency Series. Other titles in the series include:

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ISBN: 978-87-93458-13-0

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