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Energy Efficiency Potential in India

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Foreword

With the growth of India's economy, the demand for energy has grown substantially and high levels of energy intensity in some of the sectors became a matter of concern. Therefore, efficient use of energy resources and their conservation assume tremendous significance and are essential for curtailment of wasteful consumption and sustainable development in India. Recognizing the fact that efficient use of energy and its conservation is the least-cost option to meet the increasing energy demand, Government of India has enacted the Energy Conservation Act, 2001 and established the Bureau of Energy Efficiency in March, 2002.

Bureau of Energy Efficiency under the Ministry of Power has implemented energy efficiency schemes which cover major areas such as Standards and Labelling programme for appliances and equipment, Perform, Achieve and Trade (PAT) under National Mission for Enhanced Energy Efficiency (NMEEE) and Demand Side Management initiatives in Agriculture, Municipalities, Buildings etc. These measures are taken with the aim to bring market transformation, improve energy efficiency, decrease India's emissions intensity and thereby mitigate climate change.

Against this backdrop, it is imperative to estimate the energy efficiency potential for the entire country in a realistic manner. In the present report a scenario-based approach is used to conduct a modelling-based study delineating the scope of energy efficiency and its contribution to reduce emission intensity in India. The analysis presented in the report is an outcome of TERI's energy system model (MARKet Allocation model) together with a series of structured interviews with domain experts and shall act as a comprehensive reference for stakeholders.

I would like to commend & congratulate all participating experts for putting together this analysis and report in a timebound and professional manner.

I am convinced this publication is helpful to the policy makers, academia, private sector and other stakeholders.

Abhay Bakre

DG BEE

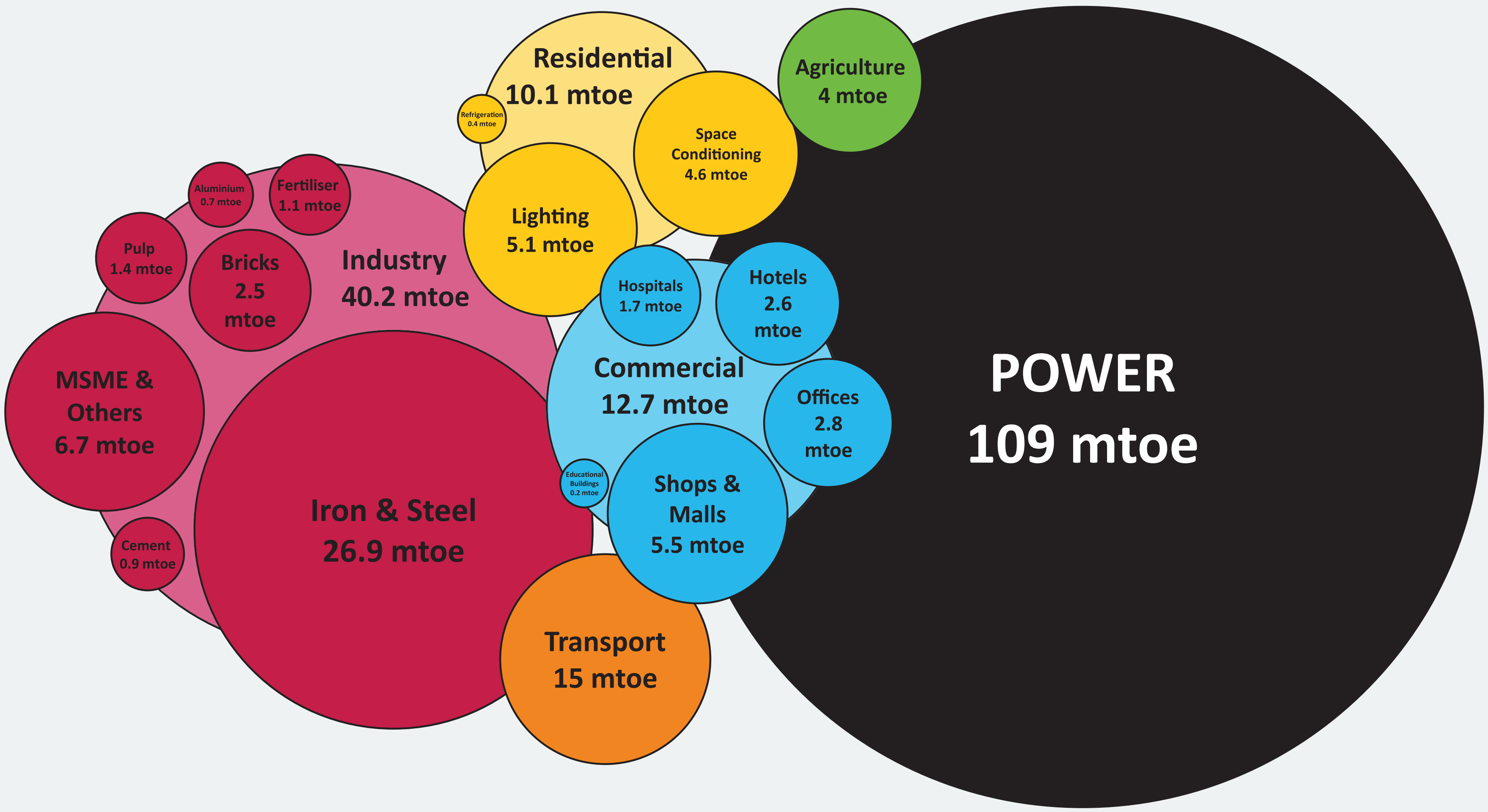
Key Findings

1	**Energy efficiency in industry has the highest savings potential for India, therefore the PAT schemes must be continued, strengthened and widened.**
2	**Energy efficiency in the SME sector is increasingly important with new support schemes to be designed.**
3	**Through energy efficiency more than 100 GW additional coal capacity can be avoided until 2047 already taking into account the future capacity mix with renewable energies.**
4	**After the iron & steel sector other sectors such as transport, bricks, space cooling and hospitals will become significantly important.**
5	**Need for a roadmap for energy efficiency until 2047 identified.**

Energy saving by end use based on scenarios (mtoe)

SECTOR	END USE	2021		2031		2041	
		SAVINGS	% SAVINGS	SAVINGS	% SAVINGS	SAVINGS	% SAVINGS
Agriculture	Irrigation	1.18	6%	3.5	16%	6.4	25%
Residential	Space Conditioning	0.20	2%	4.6	13%	17.9	28%
	Lighting	1.11	6%	5.1	17%	10.7	30%
	Refrigeration	0.03	1%	0.4	2%	1.9	5%
Commercial	Educational Buildings	0.02	3%	0.2	12%	0.6	17%
	Hospitals	0.53	34%	1.7	39%	4.1	40%
	Hotels	0.48	15%	2.6	33%	6.6	41%
	Shops & Malls	1.18	18%	5.5	34%	15.0	40%
	Offices	0.46	15%	2.8	37%	7.8	47%
Industry	Iron & Steel	0.74	1%	26.9	18%	45.3	19%
	Bricks	0.88	3%	2.5	7%	4.3	10%
	Cement	0.03	0%	0.9	2%	1.9	3%
	Aluminium	0.14	2%	0.7	7%	1.7	12%
	Fertiliser	0.07	1%	1.1	6%	3.3	14%
	Paper & Pulp	0.78	14%	1.4	18%	2.0	22%
	MSME & Other Industries	1.21	1%	6.7	2%	15.2	3%
Transport		2.65	2%	15.0	5%	36.6	6%
Power	Thermal Power Plants	42	15%	109	17%	163	20%

Energy Saving Protential in India by 2031



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Executive Summary

India's energy sector is poised at a juncture wherein it still needs to increase both the total and per capita levels of energy provisioning in order to improve the level of services, infrastructure and total economic output. At the same time, the country faces the challenge of achieving this growth while maximising resource efficiency and thereby containing the environmental implications to the maximum level possible.

The multiple dimensions of energy security, global emission reductions and local air pollution among other reasons suggest the need for a significant and rapid transformation in India's energy production and consumption levels and patterns towards these ends. Energy efficiency is seen to be one of the key elements that can contribute towards reducing the energy requirements and the associated environmental implications. India's Nationally Determined Contributions also emphasize on energy efficiency as a key measure to manage energy demand.

The Government has already undertaken several measures to improve efficiency in the energy sector, accelerate the introduction of renewables and clean energy and improve the infrastructure and services in the country. However, it is important to delineate the role that energy efficiency can play in the next couple of decades, and discern the key areas where this potential rests, so that efforts could be targeted at the most relevant end-uses and processes. Accordingly, using a scenario based approach, this study conducts a broad assessment of the key focus areas that can play a role in reducing energy and emissions intensities across each of the main energy consuming sectors.

The study indicates that the most relevant end-uses and sub-sectors with significant potential for energy efficiency in India include:

- Iron & Steel, Cement, Bricks, and other industries including MSMEs
- Energy efficiency in transport through improvements in the aviation sector, switch towards rail based movement and electric vehicles and improvement in vehicle efficiencies
- Efficient buildings for shops/malls, hotels and offices as well as hospitals.
- Improvement in irrigation efficiencies in agriculture sector
- Lighting and space conditioning appliances in the residential sector.

Further, the study clearly indicates that the role of energy efficiency is instrumental in dampening the rate of increase in final energy use even as the country seeks to enhance the provisioning of useful energy demands. The energy efficiency potential as envisaged through the scenarios also indicates that it would play a positive role in contributing towards India's NDC target. While the REF scenario indicates a possibility of achieving only the lower end of the NDC target of 33% emission intensity reduction, pursuing the EFF scenario could achieve an emission intensity of around 41%. India's NDC target related to emission intensity reduction is for all GHGs and would accordingly depend on how the profiles of growth and mitigation across various sectors and various GHG gases pan out over time. However, given that both CO_2 emissions and the energy sector are major contributors to overall GHG emissions [the share of energy related GHG emissions in total GHG emissions is 71% and the share of CO_2 from energy in total GHG emissions is 67%], in a partial analysis of only efficiency improvements related to the energy sector (as in case of this study), some tracking in magnitude terms does help to visualize the effect of the mitigation options considered and to examine their relative contribution. Therefore, while the study clearly indicates that energy efficiency has a key role to play in moving towards India's NDC objectives, it must be noted, that this does not imply that energy efficiency alone can meet India's NDC targets. Also, since the study considers full achievement of energy efficiency possibilities across some of the end-uses, in a sense it presents the maximum CO_2 emission intensity reduction by 2030 due to energy efficiency in these sectors.

Different end-use sectors face different kinds of challenges, policy environment and availability of technological alternatives. Accordingly, there are opportunities in some sub-sectors such as irrigation in the agriculture sector and efficient lighting and space conditioning in the residential and commercial sectors wherein changes could possibly be brought in fairly quickly.

Given that the uptake of efficient technological options is often limited by the high upfront costs of alternative technologies and processes, the study also points to the need for a stronger policy push and for envisaging appropriate business models to scale up the uptake of the more efficient options.

Given that rapid growth in building infrastructure is expected (in particular, for commercial buildings), it is critical that energy efficiency in the building sector is pursued through a policy and regulatory regime to harness the potential of energy savings. Energy benchmarking of buildings (differentiated by varying profile of buildings), strengthening of institutional capacities at various levels to implement ECBC developing technical expertise and compiling credible databases are some of the important steps that should be undertaken to trigger in efficiency improvements quickly in the buildings sector.

Energy efficiency in the industry has the highest savings potential for India. Through the PAT mechanism, Government of India is mandating large industries to reduce their current energy consumption levels. Encouraged by the achievements of PAT-1 cycle, Government is widening its ambit in terms of expanding the scope by including other large energy consuming industrial sub-sectors. Efforts in this direction must be continued, strengthened and widened. In addition, as has been pointed out in the report, there are many sub-sectors including MSMEs, which are energy intensive but presently outside the purview of PAT mechanism. Although a few initiatives have been undertaken by Government/bilateral/multilateral organisations to help MSMEs improve their energy performance, there is a lot more that can be done to improve their energy performance. Hence, efforts need to be directed towards developing programs for this sector, which is a very important contributor of Indian economy.

In other sub-sectors such as irrigation, again the larger benefits of savings of water resources as well would be applicable and need to be given importance. The results of this study indicate the need for a roadmap for energy efficiency until 2047.

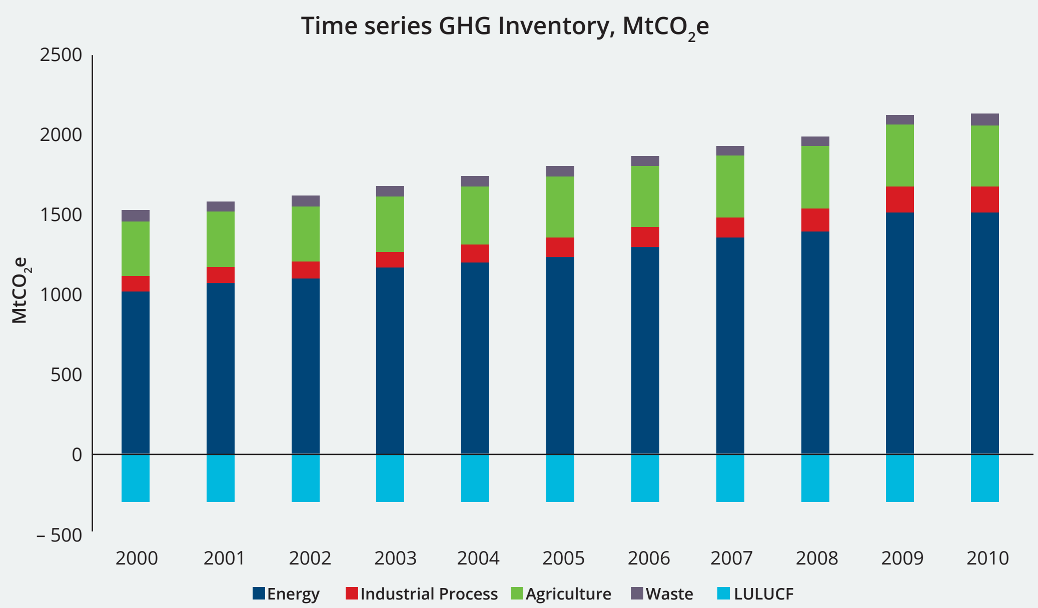
1. Introduction

1.1 Background

Energy efficiency is undoubtedly an important element for a country like India, which is confronted with the challenge of enhancing energy access to a large and growing population and simultaneously limiting the environmental implications of growing energy use. Energy efficient options provide the unique advantage of providing the ability to manage and even reduce final energy demands even if the demands for end-use services increase. Moreover, as compared to many of the low-carbon technologies that may be important from a mitigation perspective, energy efficiency can sometimes play a role in reducing energy and emissions intensity at fairly low incremental costs.

Increase in energy efficiency can also lead to lowered growth in total electricity demand, reduce peak demand and help manage the electricity load curve. With low penetration of consumer electronics and rising demand for appliances such as air conditioners, India's energy needs can increase multi-fold, with higher urbanization, changing consumption patterns and increasing access to clean and modern energy fuels and electricity. Further, programs like "Make in India" that aim at high manufacturing sector growth, could also stimulate final energy demands to higher levels. It is in this regard that energy efficiency as a lever that can play a key role in decoupling energy and economic growth assumes relevance. Energy efficiency can also often come about at fairly low costs especially when considered over the life cycle of alternative competing options. In the transport sector, multiple benefits such as lowering of air pollution and congestion can come about simultaneously with energy efficiency benefits that can be gained by shifting away from private vehicles to buses and trains, or from road based transport to rail based freight movement. Therefore, in some sense, energy efficiency is a complex measure that may often

Figure 1-1: GHG inventory (2001-2010) in $MtCO_2e$



Source: MoEF (BUR 1)

require a combination of technological and policy interventions. At the same time, given the problem of resource scarcity, the scope to reduce total energy demands can go a long way in addressing the problems of energy security and climate change mitigation. Further, in an economy like India, where finances are limited, prioritizing of policy measures is critical for efficient allocation of scarce finances.

India is placed in a unique position in that it is at a stage of development where it still needs to focus on maintaining high economic growth, retaining a significant share for manufacturing in terms of structural share in the economy, and at the same time needs to fuel this growth and infrastructure development increasingly through a non-fossil fuel supply base. Energy efficiency measures therefore are likely to be able to bring in positive benefits in terms of being able to contain the growth trajectory of final energy demands at least to a certain extent.

India's gross GHG emissions were 2.136 billion tonnes CO_2 equivalent in 2010. Of this, the Energy sector contributed about 71%, IPPU 8%, Agriculture 18% and waste sector 3%. About 12% emissions were offset by carbon sink action of forests and croplands, such that net emissions were 1.884 billion tonnes CO_2 equivalent. (MoEF, India First Biennial Update Report to the UNFCCC, 2015).

Figure 1-1 clearly depicts that the energy sector accounts for the largest share of GHG emissions (around 77%). Making it important to examine the potential to improve energy efficiencies and to identify the main areas where these improvements can be achieved.

The Indian Government has been proactive in promoting measures such as star labelling and adopting other market mechanisms for improving energy efficiency in order to work towards greater energy security and for achieving its carbon mitigation goals. India's Nationally Determined Contributions submitted to the UNFCCC on October 2, 2015 emphasizes on energy efficiency as a key measure to manage the power sector demand. Growth in capacity in the power sector would be dependent on the requirements in each end use sector and energy efficiency could help curtail this demand at lower costs. However, no recent analysis has been undertaken specifically towards this end to study the potential and cost of energy efficiency related reduction for India.

It is against this background that this study has been undertaken. A scenario based approach is used to conduct a modeling based study to delineate the scope of energy efficiency and its contribution to reduction in emission intensity in India.

1.2 Objective & Scope

The objective of this study is to assess:

a) the potential of energy efficiency improvement in India across various sectors & end-uses and identify the sectors with higher potential for energy efficiency
b) Identify the technological and policy options that would facilitate in achieving energy efficiency across sectors and
c) provide a broad understanding of the costs and challenges associated with the adoption of the alternative energy efficient technological options until 2021/22 and 2031/32

The study looks at energy efficiency prospects across the 5 end-use sectors, namely – Residential, Agricultural, Commercial, Transport, and Industry. Apart from this, we include the power sector as a supply side sector. The scope would be analyzed in each of these sectors using a scenarios based approach to prioritize the key areas that indicate energy efficiency potential.

2. Methodology

2.1 Approach & Methodology

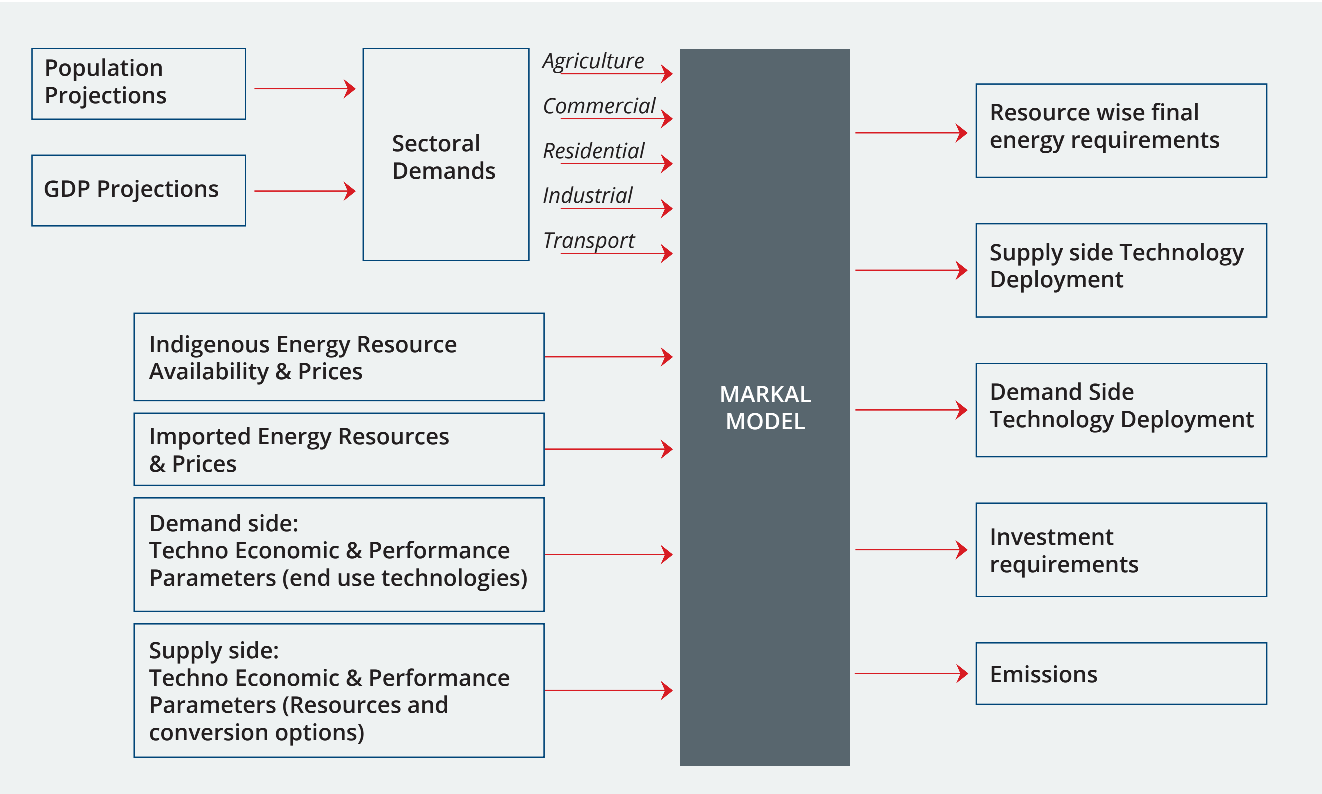
For this study, we have used TERI's existing energy system model - the MARKAL (MARket Allocation) model, which has been developed over the years to represent India's national level energy system in detail. This modeling framework (a dynamic linear programming optimisation model) has been set up at the national level for India in order to examine the patterns of energy use and related environmental impacts under various techno-economic scenarios.

A schematic of the MARKAL model is given in Figure 2.1.

For this study in particular, the model database extending from 2001-2051 has been updated to a limited extent, mainly to better validate and align the energy consumption across sectors especially for the recent past years given the short time-frame of this study. However, cost and technology data have not been re-visited for this study. A GDP growth rate of around 8.3% is assumed till 2030, and 7% thereafter across the scenarios, keeping in line with the Government's aspiration of doubling per capita incomes every decade.

Additionally, we have sought expert opinion & judgement on the levels of efficiency improvement potential and options across sectors in order to delineate which end-use options lend themselves to efficiency improvements and to incorporate insights regarding the levels of improvements that can be envisaged across technologies, processes and end-use equipment over the next few decades. Secondary data and information supplemented with discussions with experts has helped to align and validate the model results with realistic trends.

Figure 2-1: Schematic for working of the MARKAL model



The envisaged potential is incorporated via 2 scenarios that are developed to reflect an Efficiency scenario (EFF) vis-à-vis a Reference scenario (REF). The Reference scenario (REF) considers energy efficient technologies and processes to continue being adopted based on past trends and/or at constrained levels on account of higher upfront costs, consumer choices etc. The Efficient scenario (EFF) considers a higher level of penetration of efficient options based on discussions with various sector experts regarding plausible enhanced penetration levels of these alternatives.

Additionally, in order to reflect the more recent situation wherein India seems to have moved to a situation of excess power generation capacity, we have also conducted a sensitivity analysis to envisage a situation wherein no new investment is envisaged for coal based generation beyond 2021, and any additional generation is based on renewable sources only.

Accordingly, the report provides an understanding of the energy use in each of the consuming end-use sectors and the power generation sector under these 2 scenarios, thereby providing a glimpse of the scope for energy efficiency improvements in these sectors.

The results are examined to provide insights into the main end-use options that are most relevant from the Energy Efficiency (EE) perspective across sectors, and are also tabulated to a broad appreciation of where the savings due to EE are expected to be large and significant across the energy sector as a whole.

While the model is set up to provide an indication of the incremental investment costs and the overall system-wide costs, we do not provide an indication of the cost in this report as some of the cost result were not meaningful when randomly checked with expert. This was firstly because all of the technological profiles have not been updated for this exercise and second because the costs are only a technology to technology comparison and therefore often discounts several transaction costs that may actually need to be accounted for to achieve the efficiency benefits.

The report analyses each of the 5 energy consuming sectors and the power sector in terms of discussing the following for the periods 2021/22, 2031/32 and 2041/42[1]. Overview of growth trends in each sector along with a description of end-uses in the sector & their final energy demands

- An overview of energy efficiency related policies and plans in India
- Technological options available for energy efficiency improvement in each end-use sector
- Energy efficiency potential across each sector and end-use along with prioritization of major options
- Scenarios of energy consumption based on different penetration of energy efficiency options based on policy or expected technological progress

The implications of the Green India Mission and of land use, land use change and forestry (LULUCF) related changes are beyond the scope of the current study, since the aim of this project was restricted to examining the potential of energy efficiency related options only. Accordingly, the MARKAL model framework used in the study also captures the energy sector only.

Chapters 1 & 2 of the report provide the Introduction & Broad Approach, Scope & Methodology adopted. Chapter 3 provides a discussion of the end-uses/ subsectors within each of the energy consuming sectors as considered in the model. It describes the kinds of technologies and processes adopted in the country. Chapter 4 lays out the assumptions taken across the 2 scenarios and provides an idea of the broad trends that various technologies are likely to follow. Chapter 5 provides the results of the model from the 2 scenarios. Chapter 6 lays out the main conclusion and broad recommendations of the study. The policies and plans that have implications for energy efficiency are included as an Appendix to the report.

[1]We have also provided results for 2041 as experts provided indication for change in share of alternatives over a longer time frame.

3. India's Sector-wise Energy & Technology Profile

3.1 An Overview of India's energy demand and supply

This section provides an overview of energy use across the various energy consuming sectors over the past decade to provide a background of the existing patterns of consumption and growth. The analysis is based on secondary data compiled from various volumes of TEDDY (TERI Energy & Environment Data Diary and Yearbook) to bring together a profile of overall commercial energy use over the decade 2002-2012 (Figure 3-1).

An analysis of energy use during this period indicates that total energy consumption in India doubled during 2002-2012. The industry sector continued to account for the largest shares (largely fuelled by coal and lignite). The energy consumption in the agriculture sector stayed more or less constant, while energy consumption in all the other sectors has seen more or less a steady growth.

In terms of supply of fuels, while renewable energy forms are increasingly being adopted, coal, oil and gas continue to account for the major share of the country's primary energy supply as indicated in Figure 3-2.

Figure 3-1: Total Energy Consumption by sectors

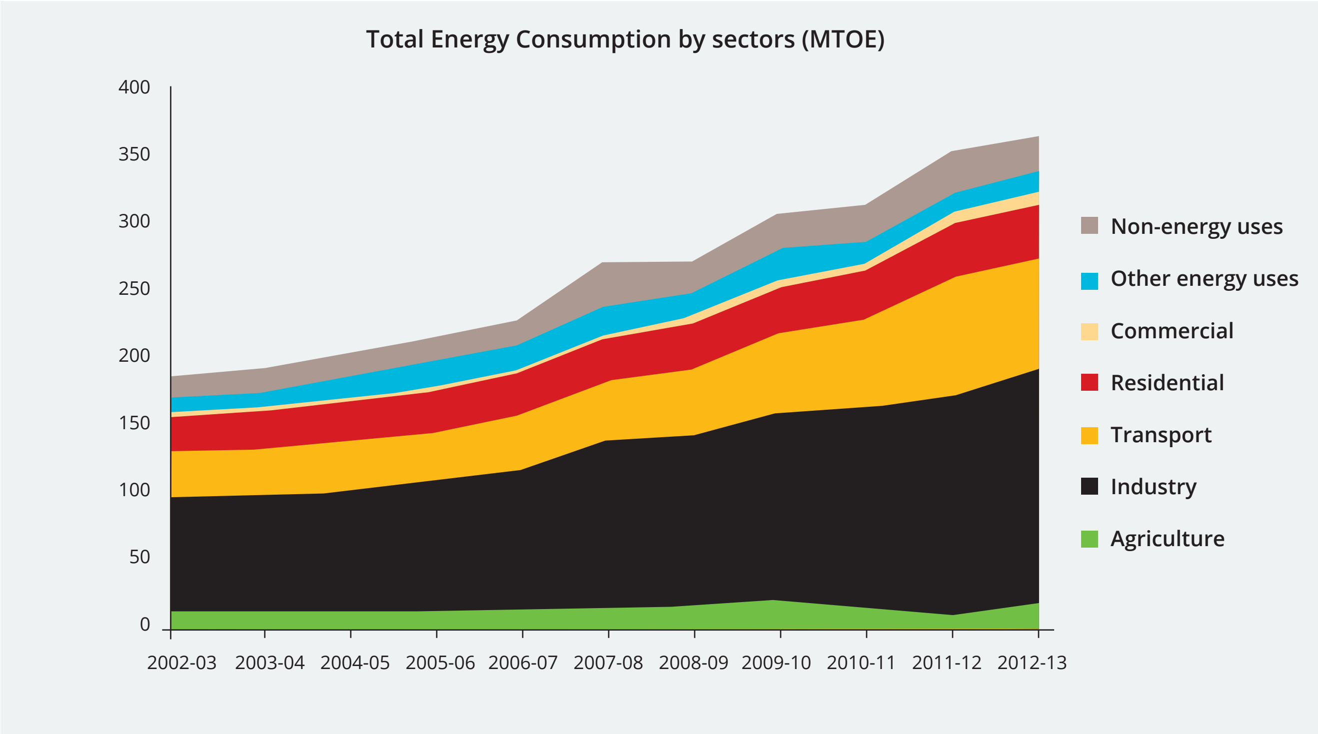
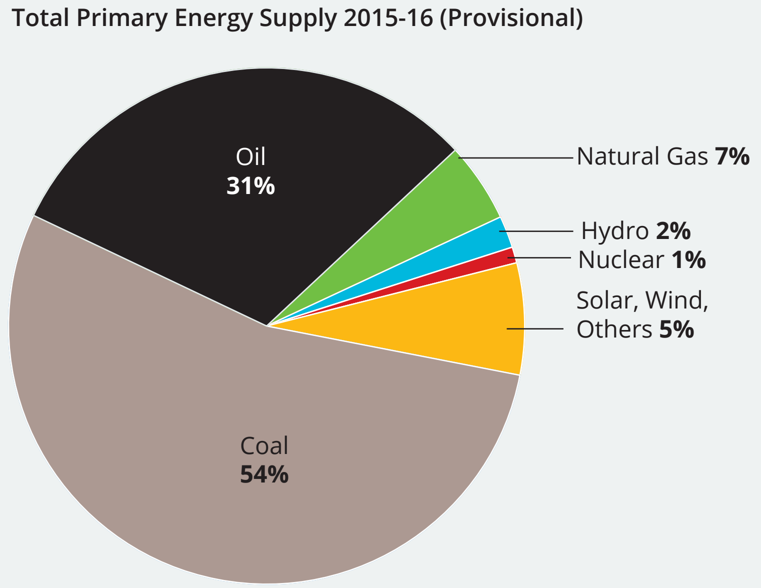


Figure 3-2: Primary Energy Supply



Source: Ministry of Statistics and Programme Implementation

3.2 Agriculture sector

3.2.1 Overview of the Agriculture Sector

The agriculture sector holds an important position in India's economy. It provides employment to about 54% of the population and contributes around 13.9% to the GDP (MoA, 2015). According to the new series of the National Income released by the CSO, at 2011/12 prices, the share of agriculture in total GDP was 18% in 2013/14 (MoF, 2015). Of the total geographical area of India of 328.7 million hectares, 140.8 mha was net sown area and 195.2 mha was the gross cropped area in 2011/12 (Land Use Statistics, MoA).

Food security is an important aspect for India, and despite the large area of the country, land area under food grains has remained more or less stable being 124.7 Mha in 2011/12, 120.7 Mha in 2012/13, and 126.0 Mha in 2013/14 (MoA, 2015). Over the years, the foodgrain production has increased significantly from around 51 MT in 1950, to 257.13 MT in 2012/13 although it fell marginally to 252.68 MT in 2014/15 due to erratic rainfall. This indicates the dependence of food production on rainfall, and the need for enhanced access to irrigation sources. India's gross and net irrigated area were 91.5 Mha and 65.3 Mha respectively with a cropping intensity of 138.7% in the year 2011-12 (Land Use Statistics, MoA).

3.2.2 Energy end-use & technological profile in the Agriculture Sector

The main fuels consumed in the agriculture sector are diesel and electricity. While overall fuel use has not increased very significantly in this sector, there is a trend of higher replacement of diesel by electricity in the later years of the decade considered as reflected in Figure 3-3. There are also some irregularities in the energy use in this sector in certain years which may partly be due to pure performance of the sector in that year and /or some data irregularities. Minor amounts of natural gas, light diesel oil and fuel oil are also reported as used in the sector, but these are insignificant.

Energy demands in the agriculture sector are largely those for land preparation and irrigation. Diesel is largely used by land preparation machines like tractors and power tillers and by diesel pumps used for irrigation, while electricity is consumed by electric pumps that are increasingly being used for irrigation.

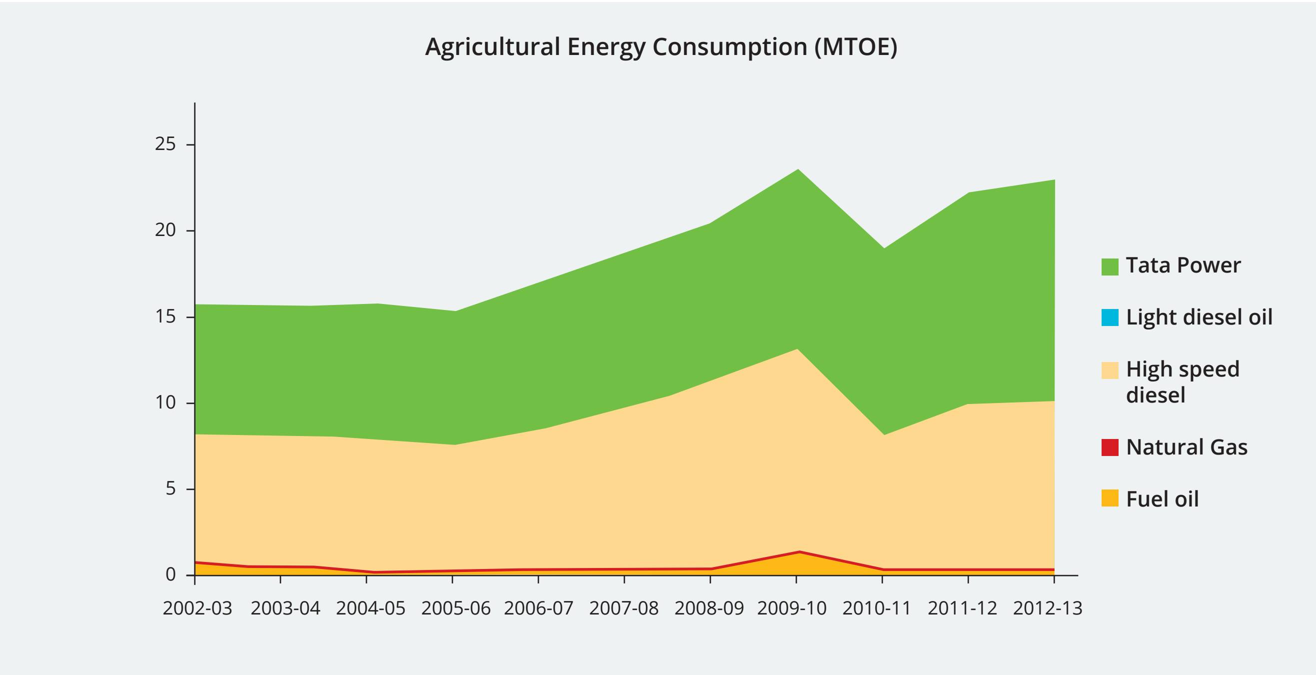
Power tillers and tractors are used for land preparation and the choice is largely based on their economic capacity determined by land holding and access to adequate credit. Power tillers are becoming popular in lowland flooded rice fields and hilly terrains. Tractors with a horse power ranging between 21 and 50 are generally used in land preparation; higher horse power tractors are more conducive for construction and transportation purposes. The sales of tractors with engine power below 20 HP have been very small in the past, and their share of the total sales is currently insignificant.

With the increasing shift towards modern farming methods, sale of tractors is increasing. However, a number of factors such as cost, size of land holding and soil type influence the choice of the size of tractors. Since 2003, there has been a shift away from the 21-30 HP segment towards the higher segments as higher the HP, better the overall fuel efficiency. However, high cost of the larger tractors and the low average size of landholdings in India constrain the utility of the larger tractors.

In case of land preparation, the Reference and Efficient scenario, therefore consider similar trends in terms of the usage of land preparation equipment and their efficiencies based on secondary data. The model accordingly accounts for the total diesel consumption from tractors and tillers based on these parameters.

Water required for irrigation is a function of the major crops grown, water requirement per crop, and total area irrigated by tube wells and open wells, and the energy used for pumping depends on the share of diesel and electric pumps in use and their operational parameters. Diesel pumps are most suitable in shallow aquifers and are used in deeper aquifers only to substitute for erratic electricity supply. Over time, the number of diesel pumps has been reducing and they are increasingly getting substituted by electric pumps. Solar pumps have also been introduced in some areas but are a very small number as of now and have currently not been included in the analysis.

Figure 3-3: Agricultural Energy Consumption



3.3 Residential Sector

In the residential sector, while rural areas continue to use a fair amount of traditional fuels like firewood, crop residue and dung (mainly for cooking), in the latter half of the decade, LPG and electricity have seen an increase in their share replacing kerosene and some part of the traditional fuel use. Also, with improvement in living standards and higher urbanization, shifts both in terms of fuels and appliances used in the residential sector have augmented the consumption of LPG and electricity.

The main end-uses in the residential sector include lighting, space conditioning, and refrigeration in terms of electricity related use, and cooking which accounts for LPG, electricity, kerosene and traditional fuels such as firewood, crop residue and dung in rural areas.

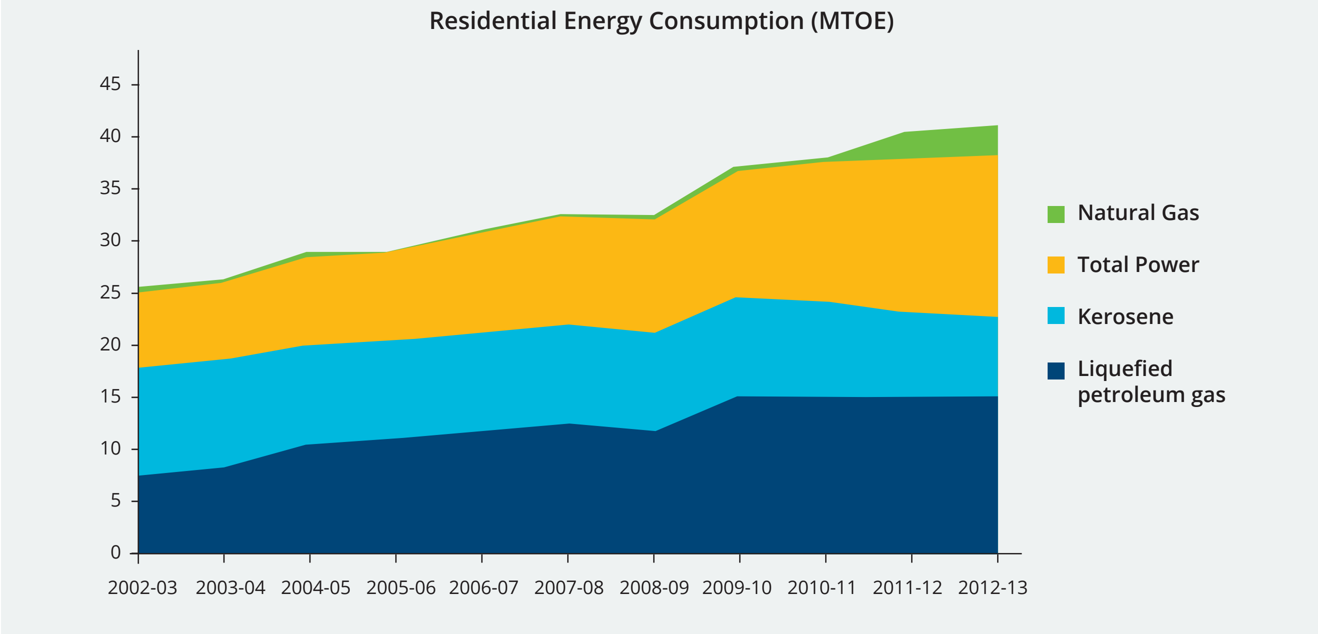
In case of lighting, while the GLS light bulbs and tube-lights were the only electrical lighting appliances in earlier periods, CFLs and more recently LEDs have penetrated to a significant extent and are following a rapid pace of replacing the conventional bulbs. Moreover, as a larger share of the un-electrified population is getting access to electricity, it is envisaged that there would be a shift away from kerosene based lighting to electricity through efficient LEDs.

Space conditioning considers the use of fans, water coolers and air-conditioners. While there is an increasing ownership of these appliances, the efficiencies have also been improving as a result of which the rate of increase in final energy consumption has not been very sharp. Technology progress as well as the supportive policy environment is conducive to enabling large efficiency gains in this particular end-use within the residential sector.

While the efficiencies of other appliances such as water heating geysers, room heaters etc. has also been improving, the total energy consumption by these end-uses is comparatively smaller and therefore may not hold a large scope for energy savings.

With regard to cooking as an end-use in the residential sector, while the focus is on providing access to clean cooking fuels and to that extent, the use of LPG is expected to increase as it replaces traditional fuels, there may be potential for efficiency enhancement not only in terms of improved LPG cook-stoves but also in terms of moving to electricity based induction cook-stoves in a big way.

Figure 3-4: Residential Energy Consumption



3.4 Commercial Sector

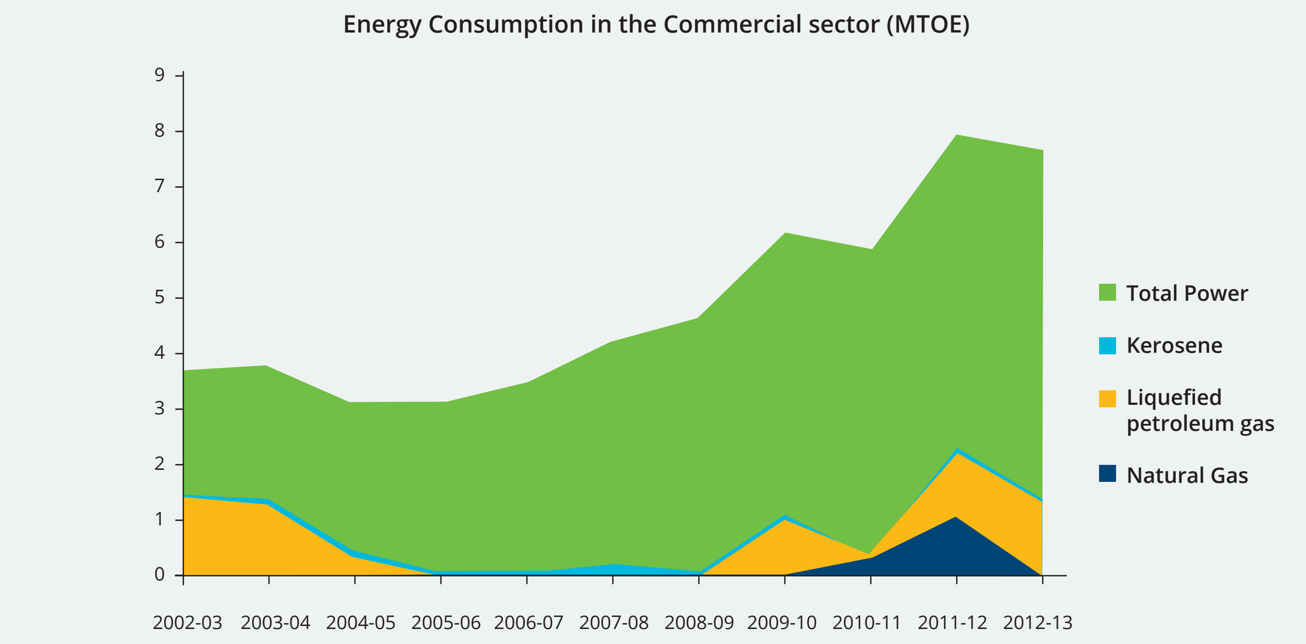
The commercial sector includes energy consumption in shops, hotels, public and private institutions like hospitals, schools etc. and public lighting and water works. Accordingly, this sector largely consumes electricity for most of the end-uses in this sector apart from some liquid fuels such as LPG and kerosene for cooking purposes.

The end-uses considered in the model for the commercial sector include lighting, space-conditioning and other electricity use apart from LPG based cooking.

Since the data on technological details of lighting equipment, space-conditioning etc. for commercial establishments is fairly varied and not well documented, we account for the energy usage and the potential for energy efficiency across various segments of the commercial sector based on discussions with sector experts, and using estimates of floor space under different kinds of commercial establishments.

Energy consumption in the commercial sector is largely dominated by electricity, with some extent of LPG, kerosene and natural gas that are used for cooking purposes by hotels, dhabas etc. With growth of offices, malls, hotels, hospitals, schools etc. the commercial sector has seen a surge in electricity demand over the period 2002-2012. Even though it had a relatively small share in the past, kerosene has gradually been replaced by LPG and while some amount of natural gas has been reported in the later periods, largely the cooking energy in the sector continues to be based on LPG with other end-uses relying on electricity as indicated in Figure 3-5. It must be noted that some part of energy consumption by the commercial sector (as defined in our study), is often reflected as "other energy" consumption in national energy balances, but is not differentiated by fuel type. Therefore, energy consumption as reflected in Figure 3-5 may provide an underestimate of the commercial sector energy consumption.

Figure 3-5: Energy Consumption in the Commercial sector



3.5 Industry Sector

3.5.1 Current status & Overview of the Industry sector

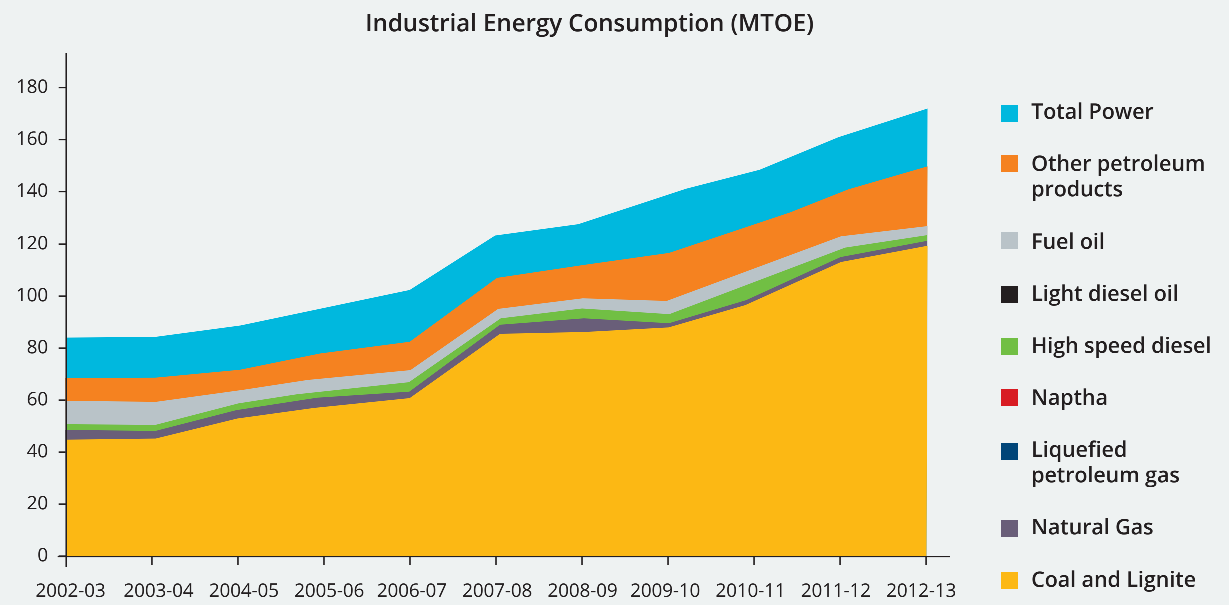
The industry sector plays a vital role in the Indian economy due to its close linkage with the country's overall development. The industry sector is the largest energy consumer, and the only end-use consumer of coal and lignite other than the power generating sector. While natural gas and fuel oil have had a small and declining share of energy consumption in the industry sector during 2002-2012, the consumption of coal, electricity, diesel and other petroleum products has consistently increased in magnitude terms as indicated in Figure 3-6. The total energy consumption has increased from around 81 mtoe in 2002/03 to around 170 mtoe in 2012/13.

The industry sector in India is highly diversified in terms of the industrial sub-sectors, and consists of a mix of large industries as well as several MSME (Micro, Small and Medium Enterprises) sub-sectors.

The Iron & steel, cement, fertilizer, petrochemicals, aluminium, chlor-alkali, pulp & paper, and textile sectors are among the high energy consuming large industrial sub-sectors. However, in addition to the large industries, the MSME sub-sector is an important component of the industry sector due to noticeable contribution to the country's manufacturing output, exports and employment opportunity it provides to large number of people.

Recognising that increasing energy efficiency is one of the best options to contain the rising energy demand without affecting growth, this has been given priority by the policy makers in the country. The Energy conservation Act, 2001 provides a legal mandate for the implementation of the energy efficiency initiatives through the institutional mechanism of the Bureau of Energy Efficiency (BEE) and State Designated Agencies (SDAs). The National Mission on Enhanced Energy Efficiency (NMEEE), launched in 2008 as one of the eight missions in the National Action Plan for Climate Change, encompasses many initiatives for enhancing energy efficiency. One of the initiatives focusing on large industrial units is the Perform, Achieve and Trade (PAT) mechanism. This is a market based mechanism that mandates the Specific Energy Consumption (SEC) reduction targets to Designated Consumers (DCs) to achieve mandatory reduction in energy consumption during a period of three years or the first PAT cycle. The PAT

Figure 3-6: Industrial Energy Consumption



scheme mandates the award of SEC (specific energy consumption) reduction targets to DCs to achieve mandatory reduction in energy use in the range of 2% - 10% during a period of three years or the first PAT cycle (BEE, 2012). The scheme is estimated to have saved about 8 mtoe of energy by the end of its first cycle (2012-2015). The second cycle of the scheme has already begun.

Increased competition following liberalization, higher energy prices and policy initiatives such as National Manufacturing policy and Energy Conservation Act etc. have also contributed in increasing the energy efficiency of the Indian industrial sector. In fact, since the late 1980s, the industry sector has recorded greater energy efficiency improvements as compared to any of the other sectors in India (World Bank 2011). Some of the units in the energy intensive industrial sub-sector like the fertiliser and cement sub-sectors have adopted state-of-the- art technologies and are competing with the world's best plants in terms of their energy performance. Most of the new capacity additions in the industrial sector are already adopting best available technologies and the existing units are reinventing themselves to improve their energy efficiency. In spite of this, there is a vast potential that needs to be tapped to improve the performance of industry sector in terms of energy consumption. Moreover, compared to the large industry sub-sector, which is organized, majority of the units in the MSME sub-sector are unorganized and still use conventional technologies and operating practices that are inefficient and results in higher energy consumption.

A brief highlight of the some of the energy-intensive industrial sub-sectors is provided in the following sections.

3.5.2 Iron and Steel

The steel sector contributes nearly 2% to the country's GDP and employs over 0.6 million people. India is the third largest producer of crude steel and largest producer of direct reduced iron (DRI) or sponge iron in the world. The annual production of iron and steel in India is around 90 million tonnes and it consumes over 52 mtoe of energy contributing about 6 percent of the National Greenhouse Gas emission.

Crude steel is primarily made by two routes. The primary producers use blast furnace and basic oxygen furnace (BF-BOF) route. The BF-BOF route uses raw materials such as iron ore, coal and limestone. The process of steel making involves sinter plant, blast furnace and BOF. Iron ore fines along with blast furnace dust and fuel are sintered to specified size in sinter plant. The sinter along with fluxing agent and lump ore is fed into the blast furnace as a feed material. The iron ore is reduced to iron in BF to produce hot metal or pig iron. The iron is then converted to steel in the BOF. The secondary producers use DRI to make steel using electric arc furnace (EAF) route or recycle steel in induction furnaces. The molten metal from both the routes is cast and/or rolled to produce coil, plate, sections or bars.

Crude steel production has shown a sustained rise since 2010-11 along with capacity. Accordingly, crude steel production grew at a cumulative average growth rate (CAGR) of 6.2% during the last five completed years ending 2014-15.

The share of different processes adopted in crude steel production in the country is given in Table 3-1. The share of electric route of steel making, particularly the induction furnace route, which accounted for 32 percent of total crude steel production in the country during 2014-15 and 31 percent during April-December 2015-16, has emerged as a key driver of crude steel production.

Energy consumption in the steel industry depends on the process route adopted for steel production. The specific energy consumption (SEC) of steel industries in India is in the range of 6.0 to 8.0 Gcal/ tcs as compared to 4.5 to 5.0 Gcal/ tcs of world average. The typical SEC for DRI–EAF based steel plants is in the range of 4.5–5.50 Gcal/ tcs. The SECs have been estimated assuming EAF/ induction furnace has a charge-mix of 70% DRI and 30% steel scrap. DRI may be from captive unit or purchased from market.

3.5.3 Cement

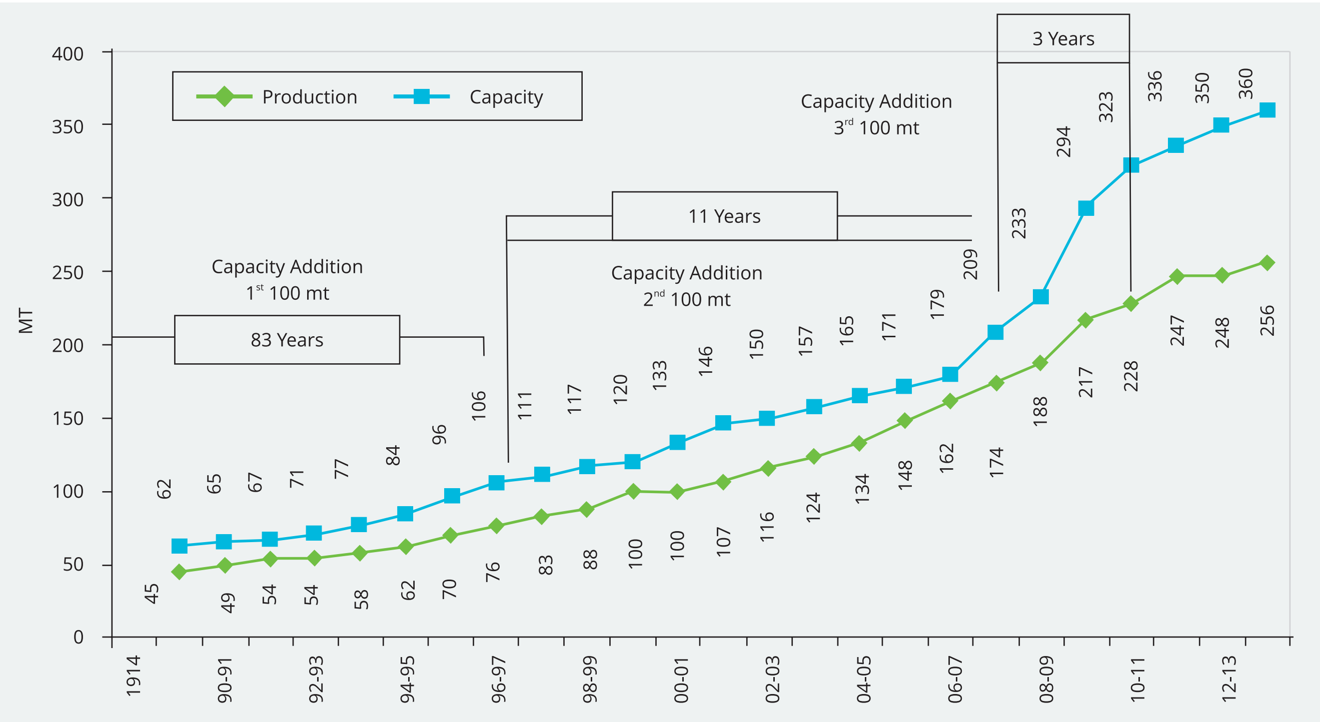
The cement industry occupies an important place in the Indian economy because of its strong linkages to other sectors such as construction, infrastructure,

Table 3-1 Percentage share of different process routes in crude steel production

PROCESS ROUTE	PERCENTAGE SHARE		
	2010-11	2014-15	2015-16 (APR-DEC)*
Basic Oxygen Furnace (BOF)	43	42	44
Electric Arc Furnace (EAF)	24	26	25
Induction Furnace (IF)	33	32	31
Total	100		100

* Provisional
Source: JPC, Annual Report, Ministry of Steel 2015-16

Figure 3-7: Capacity and production trends in Indian cement industry



Source: NCCBM, 2014

coal and power. Cement is one of the most technologically advanced industries in the country. The modern Indian Cement plants are state-of- the art plants and are comparable to the best in the world. The cement industry comprises of 210 large cement plants with an installed capacity of 350.00 million tonnes and more than 350 mini cement plants with an estimated capacity of 11.10 million tonnes per annum (DIPP 2016). There are a few large cement plants owned by the Central and State Governments. Large cement plants contribute about 97% to the total installed capacity. About 98% of the installed capacity is in the private sector and balance 2% is in public sector. As the basic raw material for cement production is limestone, the industry is concentrated around the abundant limestone reserves in the country.

Different types of cements produced by Indian cement industry are:

- Ordinary Portland Cement (OPC)
- Portland Pozzolana Cement (PPC)
- Portland Slag Cement (PSC)
- Oil Well Cement
- Rapid Hardening Portland Cement
- Sulphate Resisting Portland Cement
- White Cement

The share of blended cements has been increasing and about 70% of cement production was accounted by blended cement in 2012. The share of other types of special cements is negligible and normally counted in OPC. The production of flyash based cement had gone up from about 19% of the total cement production in 1999 to over 67% by 2009. Presently, the cement industry has been utilizing the maximum share of flyash generated in the country.

Figure 3-7 indicates the trend in production and capacity of the Indian cement industry.

The major manufacturing processes, technology profile and specific energy consumption trends in Indian cement sector are discussed in this section. Cement manufacturing is generally done through one of the four processes:

i. Wet process
ii. Semi-dry process
iii. Semi-wet process
iv. Dry process

Wet process technology accounted for 94% of total installed capacity in the year 1960 and came down to about 61% by 1980, and has been reduced to just about 1% today. The total share of cement production capacities by modern efficient dry process technology accounts for about 99%.

Indian cement plants are characterized by wide variations in terms of vintage, capacity, product-mix, technology adoption and level of technology up-gradation. This has resulted in wide variations in SEC level of various cement plants. The dry process technology with 6-stage preheater and pre-calciner is highly energy efficient having an average specific thermal energy consumption of 726 kcal/kg clinker and specific electrical energy consumption of 78 kWh/tonne cement. The average SECs of Indian cement industries adopting different processes are given in Table 3-2.

3.5.4 Fertiliser

The chemical fertilizers provide essential plant nutrients for higher crop yields. They are the major sources of primary and secondary nutrients. The sources of nitrogen are straight nitrogen fertilizers and complex fertilizers. Urea contains 46% Nitrogen (N) and accounts for almost 84% of the total nitrogen application in the country. India is the 3rd largest producer and 2nd largest consumer of fertilizers in the World. There are 156 fertilizer plants in operation in the country. This includes 30 urea plants, 19 complex fertilizers plants, 95 single super phosphate (SSP) plants, 10 ammonium sulphate plants, 1 calcium ammonium nitrate plant and 1 ammonium chloride plant.

The total installed capacity of fertilizers in the country was 48.5 million tonne in the year 2014, with urea accounting for 48% of total installed capacity of fertilizer plants.

Natural gas and Naphtha are used as fuel and feedstock in Indian fertilizer industries. Fertilizer units using heavy oil have generally switched over to NG and coal based units have been shut down. In case of NG based ammonia plants, about 70% of the energy is used as feedstock and 30% is used as fuel.

As a result of the energy conservation efforts of the industry over the years and addition of capacity through more efficient plants, the weighted average energy consumption of ammonia plants in the country was reduced from 12.48 Gcal/ t of ammonia in 1987-88 to 8.49 Gcal/ t of ammonia in 2013-14,

Table 3-2 Average SECs of different technologies in Indian cement industries

PROCESS	SEC-THERMAL (KCAL/KG CLINKER)	SEC-ELECTRICAL (KWH/ TONNE CEMENT)
Wet process	1300	115
Semi-dry process	900	110
Dry process	670-900	67-102

Source: Data analysis by NCCBM, 2014

Table 3-3	Feedstock-wise SEC of ammonia plants		
FEEDSTOCK	PRODUCTION (MILLION TONNES)	SHARE IN PRODUCTION (%)	WEIGHTED AVERAGE SEC (GCAL/T AMMONIA)
Natural gas	13.42	95.4	8.42
Naphtha	0.65	4.6	9.80
Overall	14.07	100	8.49

Source: Database, FAI - New Delhi

showing an improvement of about 32% in energy efficiency of ammonia production. The feedstock pattern of the ammonia plants has undergone tremendous change since last one decade and most of the ammonia capacity has converted to energy efficient NG feedstock based process. Table 3-3 gives feedstock-wise SEC of ammonia plants during 2013-14.

3.5.5 Pulp and Paper

Paper industry in India is one of the oldest industries having bearing on socio-economic development of the country. There are 813 number of paper mills in India producing nearly 14.99 million tonnes paper, paper board and newsprint per annum. This accounts for about 3.7% of the world's production of paper. The industry provides employment to more than 0.5 million people directly and 1.5 million people indirectly.

The paper industry is diverse due to a variety of raw materials, products and technologies used. The industry can be categorized based on its use of raw material as it determines the basic structure and layout of fibre line & major processes by type of raw material. The paper industry is highly fragmented with varying sizes ranging from 10 tons per day (tpd) to 1500 tpd. There are 31 large mills based on woody raw materials (Eucalyptus, Casurina, Subabul etc.) having capacities ranging from 300 to 1500 tpd contributing to 26% of the total production. The remaining 74% of the production comes from recycled waste paper and agro residue based mills.

Most of the paper mills in the country are in existence for a long time and hence present technologies that fall in wide spectrum ranging from rather obsolete to the most modern technologies. The pulp and paper industry is highly energy intensive. Energy cost accounts for about 16-25 per cent of the cost of production of paper. Pulp production and paper drying consume the maximum amount of energy.

Depending on consumption level, the variability among the paper mill and the comparison with best India / international mills is presented in Table 3-4.

3.5.6 Aluminium industry

The per capita[2] consumption of aluminium in India is 1.4 kg which is very low as against a world average of 8 kg. The consumption pattern of aluminium shows electricity sector accounts for about 48% of total energy consumption in the country in 2012 (Table 3-5).

Table 3-4	Energy consumption of wood based industry		
		RANGE	INDIAN BEST / INTERNATIONAL
Wood based	Energy, GJ/t	25 – 45	18
	Capacity, t/d	<250 to >500	>500
Agro based	Energy, GJ/t	35 – 50	25
	Capacity, t/d	100 – 300	400
RCF based	Energy, GJ/t	18 – 25	10 – 15
	Capacity, t/d	27 – 100	>1000

[2] http://mines.nic.in/writereaddata/UploadFile/NALCO_PDAC_2014.pdf

Table 3-5	Aluminum consumption pattern in India
CATEGORY	SHARE (%)
Electricity	48
Transport	15
Construction	13
Consumer durables	7
Machinery & equipment	7
Packaging	4
Others	7

Source: http://mines.nic.in/writereaddata/UploadFile/NALCO_PDAC_2014.pdf

Table 3-7	Specific energy consumption for 2014
LOCATION	SEC (KWHAC/TONNE)
North America	14,870
South America	15,038
Europe	15,513
Asia (ex. China)	14,714
China	13,596
GCC	14,889
Africa	14,569
Oceania	14,770
World average	14,289

Source: http://www.world-aluminium.org/statistics/primary-aluminium-smelting-energy-intensity/

Production of primary aluminium

Bauxite is the raw material used for producing aluminium metal. The basic production processes involves (1) refining of bauxite to produce alumina using Bayer process for alumina refining and (2) smelting to produce aluminium metal using Hall-Heroult process. On an average, about one tonne of alumina is produced from three tonne of bauxite; about one tonne of aluminium is produced from two tonnes of alumina. The total estimated reserves[3] of bauxite in India is 593 million tonne (mt) of which Odisha and Andhra Pradesh account for more than 90% of metallurgical grade resources. There are four major producers of primary aluminium in the country. The production of aluminium by primary aluminium producers from 2012/13 to 2015/16 is provided in Table 3-6.

Table 3-6	Production of aluminum by primary aluminum producers			
NAME OF THE COMPANY	ALUMINIUM PRODUCTION (IN TONNES)			
	2012/13	2013/14	2014/15	2015/16 (April–December)
NALCO	403 384	316 492	327 070	275 771
Hindalco	547 416	618 286	835 896	827 777
Vedanta Group	773 946	795 355	883 590	698 623
Total	1 724 746	1 730 133	2 046 556	1 802 171

Source: MoM (2016)

Aluminium smelter and alumina refinery are the two major energy consuming centres in primary aluminium manufacturing. The "specific energy consumption" (SEC) of Jharsuguda smelter of Vedanta group was reported to be 14,858 kWh/tonne during 2014-15. The SEC of aluminium smelters for different countries shows it is lowest for China (13,596 kWhAC/tonne) against a world average of 14,289 kWhAC/tonne (Table 3-7).

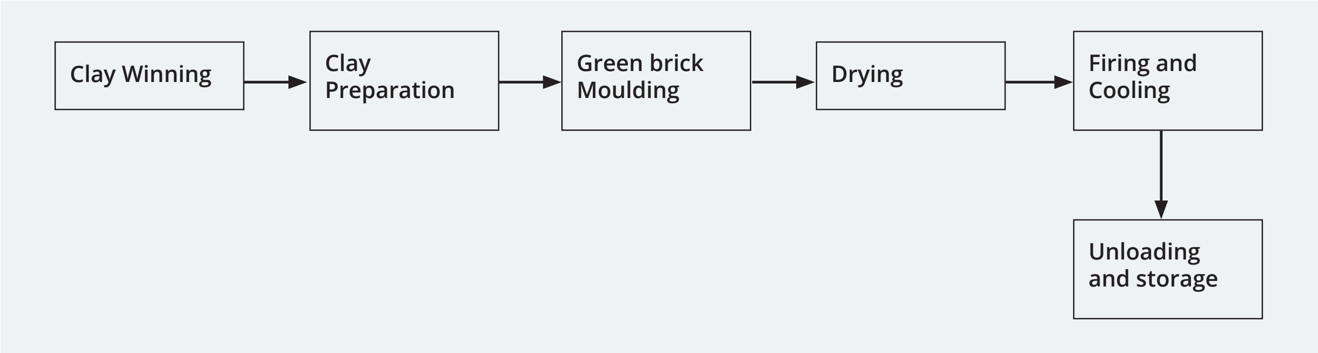
Aluminium is highly recyclable and it has been estimated that over 70% of total aluminium produced till date is still being used. Aluminium recycling process consumes about 5% of energy required to produce primary aluminium. Apart from primary producers, there are a large number of industries in the unorganised sector involved in aluminium recycling. There is only one large-scale aluminium recycling unit of Hindalco located in Taloja with a capacity of 25,000 tonne per annum (tpa).

3.5.7 Brick industry

Brick making is one of the prominent industry sub sectors accounting for significant energy consumption. Brick kilns are generally located in

[3]Indian Minerals Yearbook 2014 (Part-II: Metals & Alloys), Ministry of Mines / Annual Report Ministry of Mines, 2014-15

Figure 3-8: Schematic of brick manufacturing process



clusters that are spread throughout the country. The industry is seasonal and generally operates during November to June during the year (avoiding rainy season). It is also labour intensive and typically characterised by use of inefficient manufacturing methods /technologies and so far the industry has witnessed limited level of mechanisation.

Brick manufacturing being an un-organised activity, the industry specific parameters like size, production, energy consumption, turnover etc. are not readily available for the sector. A national level study undertaken by TERI during 2000-01 had estimated about 90,000 brick kilns in the country producing 144 billion bricks annually using 24 million tonnes of coal and 3 million tonnes of biomass. A similar study was undertaken by TERI during 2013-15 and the estimated that 220 – 280 billion bricks were produced annually by 190,000-280,000 brick kilns using 29 – 35 million tonnes of coal and 12 – 16 million tonnes of biomass.

The basic raw material for brick making is clay and the fuel used is coal and Biomass. Bull's Trench Kilns (BTKs) and clamp kiln are the main brick firing technologies used for firing of bricks in the country. Use of BTK is more common in northern and eastern part apart from small pockets in central, western and southern India. The clamp kiln technology is prevalent in southern, central and western part of the country. Almost entire brick production in the country is in the form of solid bricks using top soil from the nearby agricultural fields. Figure 3-8 shows a schematic of the manufacturing process for bricks.

Table 3-8 shows the specific energy consumption of different brick firing technologies.

Table 3-8 Specific Energy Consumption of different brick firing technologies

TYPE OF BRICK FIRING TECHNOLOGY	SEC (MJ/ KG-FIRED BRICK)
Clamp kiln	1.5 – 3.5*
Fixed chimney BTK	0.95 – 1.82*
VSBK	0.8 – 1.2#
Zig-zag kiln	0.91 – 1.15@
Down-draft	1.78 – 3.14*

* Field monitoring by TERI and PSCST
# Field monitoring by TERI
@ Field monitoring by PSCST

3.6 Transport sector

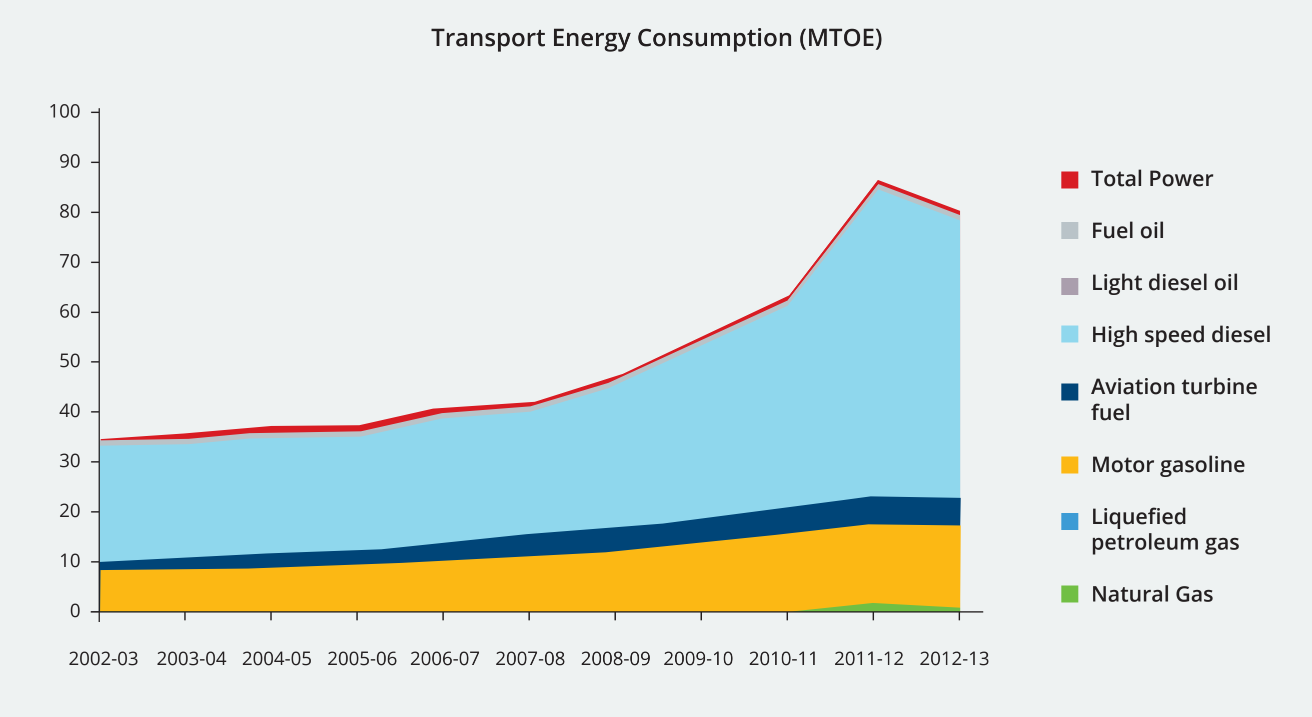
The transport sector is the second largest and the fastest growing sector in terms of energy consumption after industry. The sector has seen a three-fold increase in energy consumption in the last one decade from about 34 mtoe in 2001 (TERI, 2006) to about 86 mtoe in 2011 (TERI, 2015). Rate of growth of energy consumption, 18% annually, in the last decade has been higher than in any of the previous decades, with the largest increase coming from road based mobility.

The transport sector accounts for the second largest share of the sector in country's energy consumption and the rapid increase in energy demand, it is imminent that any set of measures identified to reduce the rate of growth of energy demand in the country, will have to include and target transport sector. The objectives of improved energy efficiency in the country cannot be realised without significant contribution from the transport sector. This is all the more important given that nearly 98% of the energy needs of transportation sector are met through petroleum products, and almost half of the total consumption of petroleum products in India occurs on account of transport activities. Given that India has been importing almost 80% of its petroleum requirement, improved energy efficiency in transport sector will also have an important role in terms of addressing the energy security issues and reducing the import bill for the country. Also, given the heavy dependence of the sector on fossil energy, transport is critical from the perspective of reduction of GHG emissions.

The sector was the second largest contributor to CO_2 equivalent emission (CO_2e) in 2007 and generated 142 $MtCO_2e$ (MOEF, 2010). The Government of India recognizes the critical role of transport in the climate mitigation strategies for the economy; the National Action Plan on Climate Change lays down several strategies to reduce CO_2 emissions, both from the intra and inter-city passenger and freight transport. The Government of India also constituted a dedicated Working Group/Technical Committee to chart out ways for low carbon growth of the sector, the inputs of which were fed into the 12th Five Year Plan outlay for transport sector.

The transport sector is largely dependent on petroleum products, with high speed diesel accounting for the largest share followed by motor gasoline (petrol). Aviation turbine fuel (ATF) consumption by the aviation industry has also been increasing over the years with growth in air based traffic. Natural gas and electricity consumption is relatively minor thus far as reflected in Figure 3-9, but given that one of the most important levers for decarbonisation of the transport sector necessitates shifting away from petroleum products to electricity based movement, technology and policy developments in this sector may need to bring in significant changes in future.

Figure 3-9: Transport Energy Consumption

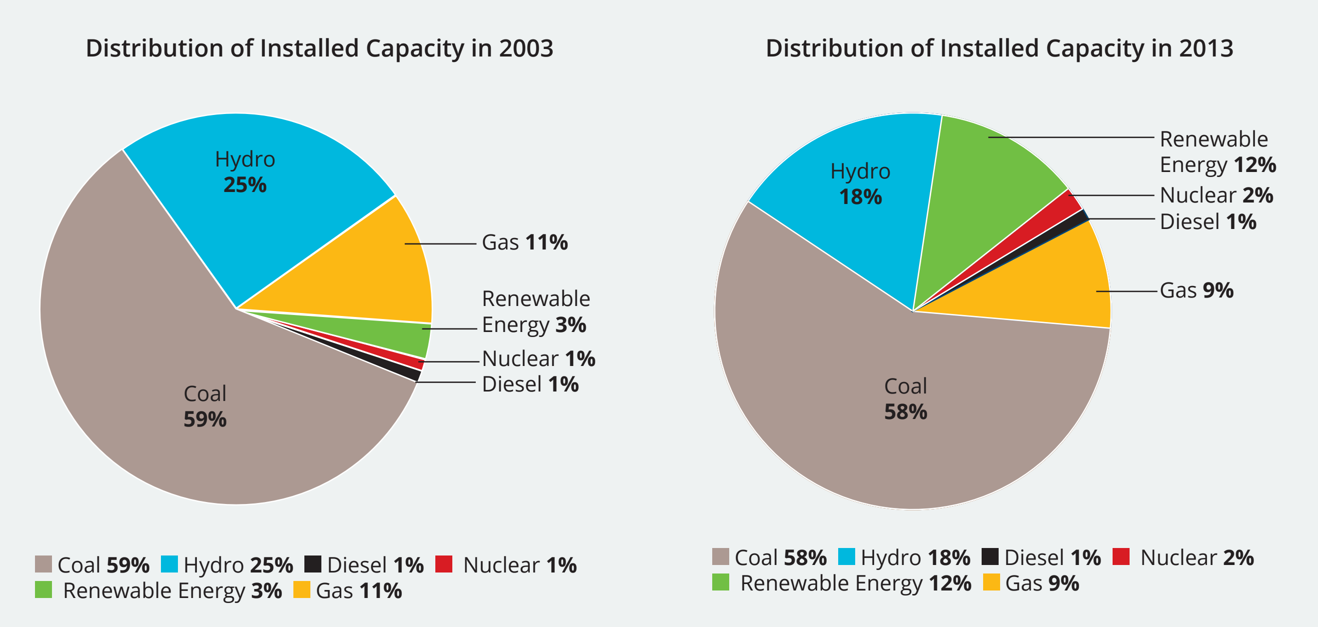


3.7 Power Sector

The installed power generation capacity in India has increased by one-half in the period 2003-13. The largest growth was observed in renewables followed by coal by a fairly large margin. In 2003, the share of renewables in total capacity was only 3%, which increased to around 12% by 2013. Accordingly, while the share of coal based capacity did not decrease significantly (since coal based capacity also increased in magnitude terms during this period), shares of gas and hydro based capacities reflected a decline in 2013 as compared to 2003 (Figure 3-10).

Coal based power generation has been largely based on the sub critical generation technology in the past, but now all new coal based power plant are being based on super critical technology with higher efficiency. Simultaneously, R&M of coal based power plant and retirement of inefficient plant is likely to increase the overall efficiency of this stock of power plants. On the T&D side, plans to decrease the losses are also under way.

Figure 3-10: Installed power generation capacity in 2003 & 2013



4. Scenario-based Analysis of Scope of Energy Efficiency

This chapter discusses energy use across 2 scenarios developed for purposes of this study in particular. The Reference scenario (REF) considers energy efficient technologies and processes to continue being adopted based on past trends and/or at constrained levels on account of higher upfront costs, consumer choices etc. The Efficient scenario (EFF) considers a higher level of penetration of efficient options based on discussions with various sector experts regarding plausible enhanced penetration levels of these alternatives.

Additionally, in order to reflect the current situation of over-capacity in the power sector, we conduct a sensitivity analysis for the power sector to envisage the renewable capacity requirements if no new additional coal based capacity were to be envisaged.

4.1 Agriculture Sector

Energy consumption in the agriculture sector is on account of diesel use in land preparation equipment and both diesel and electricity use in pumps used for irrigation. The energy consumption in the agriculture sector is expected to increase from around 22.92 mtoe to 33.88 mtoe during 2011 to 2041 in the REF scenario. In the EFF scenario, it increases to 27.48 mtoe during the same time period. Irrigation accounts for around 70% of the energy use in this sector.

While tractors and land tillers are the energy consuming technologies used for land preparation and efficiencies of these equipment have been improving in general, there is large variation in the size and capacity of the equipment used which is contingent on a number of factors such as land holding sizes, renting of tractors etc. For this reason we have not accounted for energy efficiency separately for this end use.

In case of irrigation, there seems to be significant potential for end-use efficiency improvement both by technological change and better management practices. Accordingly we consider existing and efficient diesel and electric pumpsets across the two scenarios to establish the energy saving potential in this end use.

It is assumed that in the efficient scenario the diesel pumps will be increasingly replaced by electric pumps. Furthermore, in each of the two pumps, it is assumed that the more efficient pumps will dominate the market. It is expected that the efficient variants will have a share of around 18% in 2021, 31% in 2031 and 51% in 2041.

The efficiency of a standard diesel pump is assumed at around 1.11bcm/PJ, while for the efficient diesel pumpset it is around 2.17bcm/PJ. The same for the standard electric pumpset is 1.21bcm/PJ and for its efficient counterpart is 2.84bcm/PJ.

4.2 Residential Sector

It is assumed that the households will move to the more efficient variants of the technologies for space conditioning. Air conditioners, coolers and ceiling fans are expected to increase efficiency by 71%, 22% and 17% respectively. In the REF scenario penetration of efficient appliances is assumed to be 19% by 2021, 29% by 2031 and 40% by 2041 where as in the EFF scenario the same are assumed to be 25%, 49% and 73% respectively.

In the lighting end-use, it is assumed that the LEDs will have a higher penetration in both rural and urban areas. CFLs will decline gradually while the FTLs will die out by 2020-21. LEDs are expected to have a penetration of around 60% in both rural and urban areas by 2041 in the EFF scenario. The efficiency improvement of refrigerators is assumed to increase by 17% while an average increase of around 6% is assumed for efficiency of other appliances. For purposes of this study we have not made any distinction in the cooking technologies across the two scenarios. However, there may be potential for some efficiency gains in this end-use as well.

Given the short duration of the project, while the study does not detail out initiatives like the ECBC in buildings explicitly due to the complexity in capturing the varied and disaggregated data, we assume an aggressive improvement in space conditioning efficiencies to partly reflect efficiency gains due to passive building design improvements over time.

4.3 Commercial Sector

The energy consumption in the commercial sector reflects an increase from 18 mtoe in 2011 to 191 mtoe in 2041 in the REF scenario as against 156 mtoe for 2041 in the EFF scenario. Growth in energy requirement in the commercial sector is expected to increase dramatically as malls replace traditional shopping centres and offices and other commercial buildings become centrally air conditioned complexes. The commercial buildings are segregated into five subcategories in the model viz. educational buildings, hotels, hospitals, shopping malls, shops and offices. The energy consumption of the commercial buildings holds the largest share in this sector, ranging between 32% and 46% in this period.

In the REF scenario, it is assumed that mostly the commercial buildings will be conventionally constructed while in the efficient scenario, a higher penetration of energy efficient buildings is expected across all the buildings categories. A typical GRIHA rated building is more efficient in terms of the energy consumption than its conventional counterpart.

In the EFF scenario we assume that the penetration of efficient (GRIHA rated) buildings increases to around 70 – 80% share by 2041 in most categories as compared to shares of around 20% in the REF scenario.

4.4 Industry Sector

Demands across the industry sub-sectors are estimated based on expected economic growth in the future and following saturation curves that are in line with those in other countries that have followed similar development paths. Also, policies such as "Make in India" are expected to provide an impetus to the manufacturing sector. Accordingly, energy requirements in the industry sector continue to hold a large share of total energy requirements.

The industry sector however has significant potential for energy efficiency distributed across various sub-sectors. Accordingly we have tried to detail the important sub-sectors to the extent possible given the limited time. The assumptions considered in each sub-sectors are discussed in the following sections:

Iron & Steel:
The iron & steel industry is one of the largest energy consuming industries, its share ranging from 22% to 27%. In 2011, it consumed 40 mtoe of energy which increased to 80 mtoe in 2021 149 mtoe in 2031 and 232 mtoe in 2041 in the REF scenario while in the EFF scenario it consumed 79 mtoe, 122 mtoe and 187 mtoe in 2021, 2031 and 2041 respectively. The major processes of steel production include BF-BOF route, Scrap based route and DRI-EAF route. Of these, scrap based process is the most efficient. The assumed SEC for the standard BF-BOF route is 6.53Gcal/tonne. The efficient process however improves its SEC to 5Gcal/tonnes post 2031. The standard DRI based processes have SEC of 5.9Gcal/tonne while their efficient counterparts have SEC of 4.9Gcal/tonne post 2031.

It is further assumed that the BF-BOF process will be the major steel producing technology. The share of scrap based steel production is assumed to be constant at 24.2%.

Cement:
Cement consumes 8% to 10% of the total industrial energy. In 2011 it consumed 14mtoe which increases to 52 mtoe and 75 mtoe in 2031 and 2041 respectively in REF scenario. In the EFF scenario however, it consumes 51 mtoe and 73 mtoe.

The cement production in India is done by dry processes only, with nearly all the wet and semi-wet plants having been closed down over the last couple of decades. The dry process can be 4-stage, 5-stage or 6-stage process to produce OPC, PPC and PSC. An average SEC of around 660 kcal/kg is assumed for the cement processes. It is assumed that a constant share of 24% will be maintained for OPC in the long run and that of PSC will be 11%.

Fertilisers:
The fertiliser industry consumes between 2% to 5% of the total industrial energy. In the REF scenario its consumption was 14.23 mtoe in 2021, 19 mtoe in 2031 and 24 mtoe in 2041 while in the EFF scenario, it is 14.16 mtoe, 18 mtoe and 21 mtoe respectively in the 3 years. The nitrogenous fertiliser plants use mainly three fuels viz. natural gas, naphtha and fuel oil of which the gas based plant is the most efficient.

In the REF scenario, the efficiency of the standard fertiliser plants remains constant across 2016 to 2041. Two more efficient variants of this plant are considered in the model as well whose efficiencies improve 1.13 and 1.2 times between 2016 and 2041. In the REF scenario, a bulk of the production of nitrogenous fertilisers comes from the standard plants run by natural gas, with a share of 64% in 2021 and 36% in 2041. However, in the EFF scenario, this process gives way to the most efficient natural gas fertiliser plants such that 69% of the output comes from it.

Paper & Pulp:
Paper and pulp industry is a small segment in the industrial sector with an energy consumption of around 1% to 2% of the total industrial energy. It is expected to consume 6 mtoe, 7 mtoe and 9 mtoe in 2021, 2031 and 2041 in REF scenarios and 5 mtoe, 6 mtoe and 7 mtoe in the EFF scenario.

Paper is produced mainly by three technologies - agro-based, forest-based and waste based. Waste based paper production technology is the most efficient technology of the three while agro based is the least efficient. Within each technology, there are standard processes and their efficient counterparts as well. In the REF scenario, the bulk of the production comes from non-efficient processes, in the EFF scenario, a larger output is catered by the more efficient processes.

The average efficiency of all the technologies considered in the model is 0.061Mt/PJ which ranges from a low of 0.0296 Mt/PJ to 0.1155 Mt/PJ. The efficient scenario (EFF) assumes a higher share of waste based paper. It increases from 47% in 2011 to 61.38% in 2041 while in the REF scenario it is assumed to remain constant at 47%. The share of agro-based paper is assumed to remain same across both the scenarios. This share falls down from 22% in 2011 to around 16% in 2041.

Aluminium:

The aluminium industry consumed 3 mtoe in 2011. In the REF scenario its consumption increases to 6 mtoe, 10 mtoe and 14 mtoe in 2021, 2031 and 2041 while in the EFF scenario it consumes 5 mtoe, 9 mtoe and 13 mtoe respectively for 2021, 2031 and 2041. Aluminium production constitutes of extraction of alumina from bauxite and final aluminium from alumina through Bayer's process and prebaked process respectively. Soderberg process is another process for aluminium extraction from alumina but this process is gradually dying out.

In the efficient scenario, the extraction process shifts to the more efficient technologies while in the reference scenario, the standard processes are assumed to continue. The SEC of the processes ranges from around 13.60kwh/kg to 14.86kwh/kg between 2016 and 2031.

Bricks:

The bricks industry consumes 5% to 15% of the total industrial energy and is largely dependent on coal and biomass for its energy requirements. It is expected to consume 31, 36 and 42 mtoe in 2021, 2031 and 2041 respectively in the REF scenario while in the EFF scenario these numbers decrease to 30, 34 and 38 mtoe.

The average SEC of the brick technologies is 1.6MJ/kg. However, the range of efficiency can vary from 2.5MJ/kg – 1.10MJ/kg based on discussions with experts. Therefore, significant scope for improving efficiencies further exists in this sub sector.

SME & Other Industries:

This set of industries include apart from small and medium enterprises, all the other industries not covered in the above subsections. As per the Report of the 4th All India Census of MSMEs, these enterprises employed about 9.31 million people in the registered sector and 40.9 million people in the unregistered sector in 2006-07. Among the registered sector units, around 67% of the MSMEs were involved in manufacturing, 16% in repair and maintenance and 17% in providing services. In the unregistered units, 53% were involved in manufacturing, 6% in repair and maintenance and 41% in providing services. Among the sources of fuel, electricity is the largest energy source used by this group of industries. The sector accounts for roughly 40% of total energy consumption.

In the REF scenario, this group consumed 60 mtoe in 2011 which steadily rises to 183 mtoe, 355 mtoe and 516 mtoe in 2021, 2031 and 2041 respectively. In the EFF scenario, the same consumptions fell to 182 mtoe, 348 mtoe and 500 mtoe. In the REF scenario the efficiency of the process is assumed to linearly increase from 2011 to 2041 by around 1.11 times whereas in EFF scenario it increases 1.24 times over the given period.

4.5 Transport Sector

In the transport sector, efficiency improvements are expected on account of shift of freight movement from roadways to railways, increased penetration of electric locomotives, increased share of electric two-wheelers in road transportation, etc. in the EFF scenario.

It is assumed that while in the REF scenario the share of EVs in road bpkms will increase from 0.9% in 2011 to 35% in 2041, the same will increase to 47% in the EFF scenario in 2041. The assumed efficiency for the EVs is around 18bpkm/PJ in the REF scenario and around 24bpkm/PJ in the EFF scenario.

Since the intent of this study was to focus on energy efficiency options rather than fuel switching, the report considers an uptake of EVs only to a limited extent to account for past trends in the REF scenario and undertake a very moderate increase in the EFF scenario.

In the EFF scenario, the vehicular efficiencies of various other modes are also assumed to improve more rapidly than in the REF scenario.

It is expected that share of railways in freight movement will decrease from 39% in 2011 to around 27% in 2041 in the REF scenario and to around 30% in EFF scenario. The share of electric traction in rail freight movement is assumed to increase from around 65% in 2011 to 72.0% in 2041 in the EFF scenario while it is assumed to go up to only 70% in the REF scenario. Similarly, in case of passenger traction, the share of electric locomotives is assumed to increase to around 58% in REF scenario and 60% in EFF scenario from 50% in 2011.

4.6 Power Sector

In the power sector, the EFF scenario considers 2 major changes vis-à-vis the REF scenario. The level of improvements in T&D efficiency is considered to be higher in the EFF scenario over time. T&D losses are assumed to decrease to about 18% in the REF scenario, while the EFF scenario considers this to decrease to 15% by the end of the period.

Secondly, the improvements in coal based power generation technologies is more rapid and much higher in the EFF scenario as compared to that in the REF scenario.

5. Results

The overall results of this study indicate that energy efficiency can play a significant role in India's energy transition story. The total primary energy requirement in the Reference scenario and the Efficiency scenario are shown in Figure 5-1. As indicated, energy savings of around 5%-12% are possible over the period 2021-2041. In energy terms, the EFF scenario can achieve a reduction of around 49 mtoe in 2021, 174 mtoe in 2031 and 338 mtoe in 2041 respectively.

Figure 5-2 shows the total sectoral energy consumption from 2006 to 2041. The energy saving potential for each of the sectors is discussed subsequently in the report.

The corresponding CO_2 emission levels in the 2 scenarios are indicated in Figure 5-3. By 2021, energy efficiency as envisaged in the EFF scenario can bring in a CO_2 emission saving of about 187 MT in 2021, 626 MT in 2031 and 1029 MT in 2041 respectively.

Based on the analysis of the 2 scenarios, we also observe that by 2021, the emissions intensity as compared to 2006 levels, decreases by 21% in the REF scenario and 26% in the EFF scenario. By 2031, the REF scenario is able to achieve only the lower end of the NDC target of 33% emission intensity reduction, but the EFF scenario is able to achieve around 41% reduction, clearly indicating the

Figure 5-1: Total Primary Energy Requirement

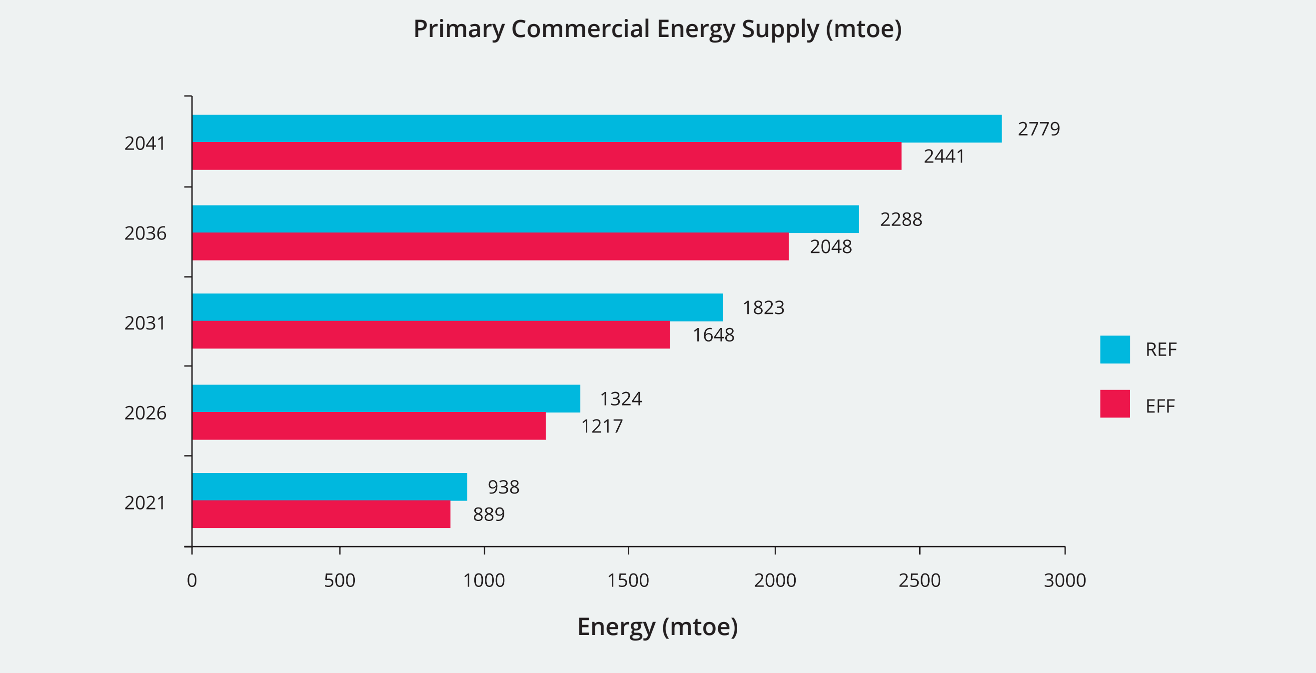


Figure 5-2: Total Energy Consumption by sectors (mtoe)

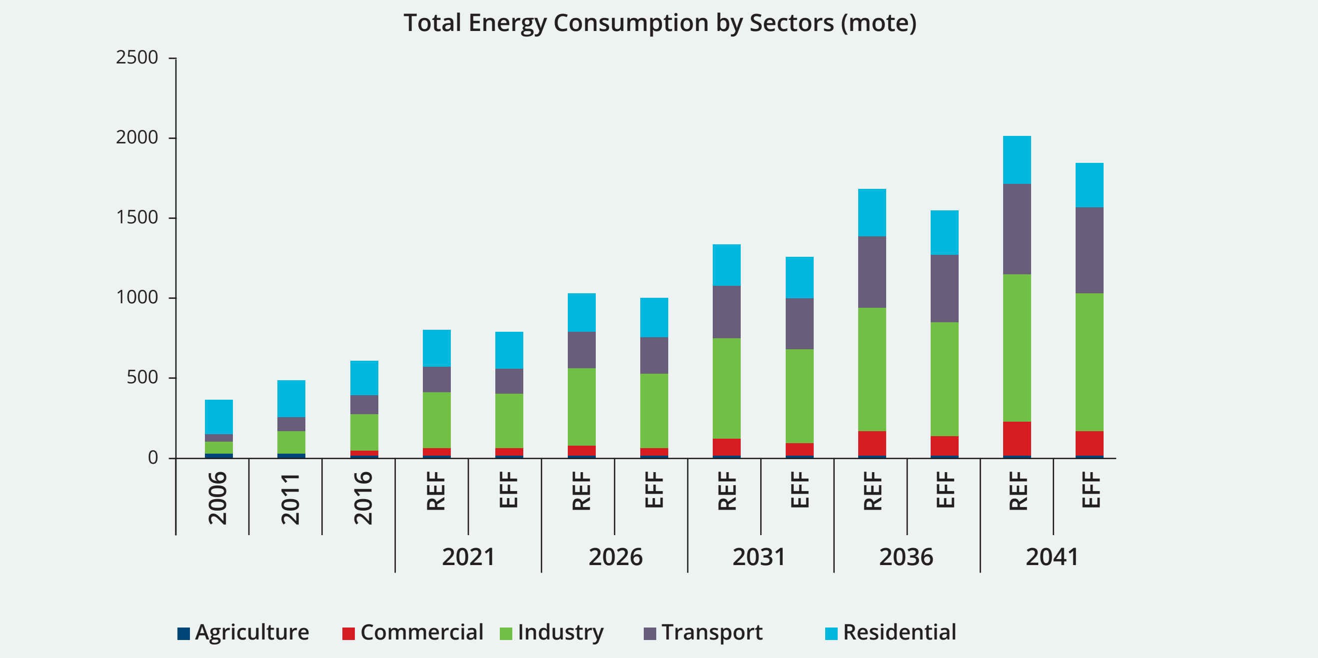
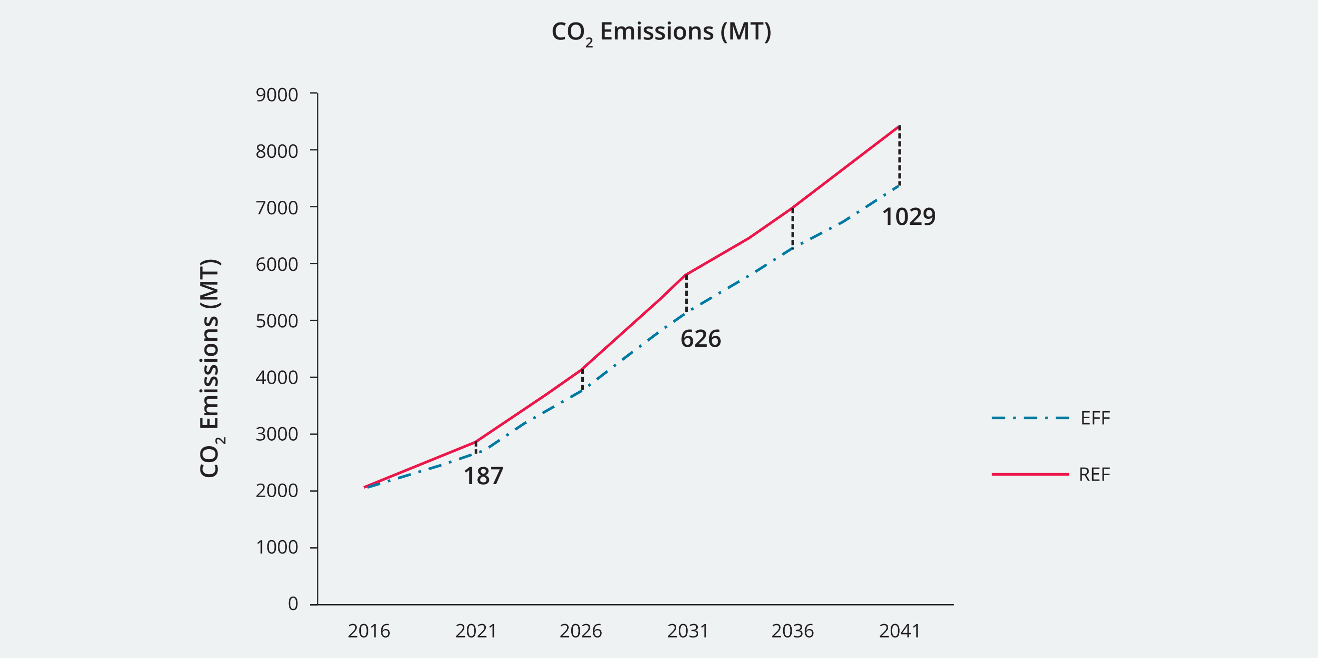


Figure 5-3: CO_2 Emissions



positive role that a push to energy efficiency can provide at the overall energy sector level.

India's NDC target related to emission intensity reduction is for all GHGs and would accordingly depend on how the profiles of growth and mitigation across various sectors and various GHG gases pan out over time. However, given that both CO2 emissions and the energy sector are major Study on Energy Efficiency Potential in

India contributors to overall GHG emissions [the share of energy related GHG emissions in total GHG emissions is 71% and the share of CO2 from energy in total GHG emissions is 67%], in a partial analysis of only efficiency improvements related to the energy sector (as in case of this study), some tracking in magnitude terms does help to visualize the effect of the mitigation options considered and to examine their relative contribution.

Therefore, while the study clearly indicates that energy efficiency has a key role to play in moving towards India's NDC objectives, it must be noted, that this does not imply that energy efficiency alone can meet India's NDC targets. Also, since the study considers full achievement of energy efficiency possibilities across some of the end-uses, in a sense it presents the maximum CO2 emission intensity reduction by 2030 due to energy efficiency in these sectors.

It must be pointed out that any cost analysis will however need a more careful scrutiny and a deep dive into costs of alternatives, since cost data has not been updated systematically in the database and while sector experts have pointed out discrepancies in some costs, actual numbers could not be shared in the short time frame of this study.

5.1 Sectoral results

5.1.1 Agriculture sector

In the agriculture sector, savings through energy efficiency improvements can be brought about majorly in the irrigation end-use sector. By 2021, 2031 and 2041 approximately 1 mtoe, 4 mtoe and 6 mtoe respectively can be saved due to efficiency improvements in this end-use across the 2 scenarios. This accounts for nearly 4% - 19% savings during this time period.

The energy usage across end-uses and technologies is shown in Figure 5-4. Across the 2 scenarios, we can see the energy savings due to efficiency improvements mainly by moving to efficient electric pumps for irrigation.

These savings are expected to accrue not only from the shift of diesel to electric pump-sets, but also

Figure 5-4: Energy use in Agriculture by End-Use

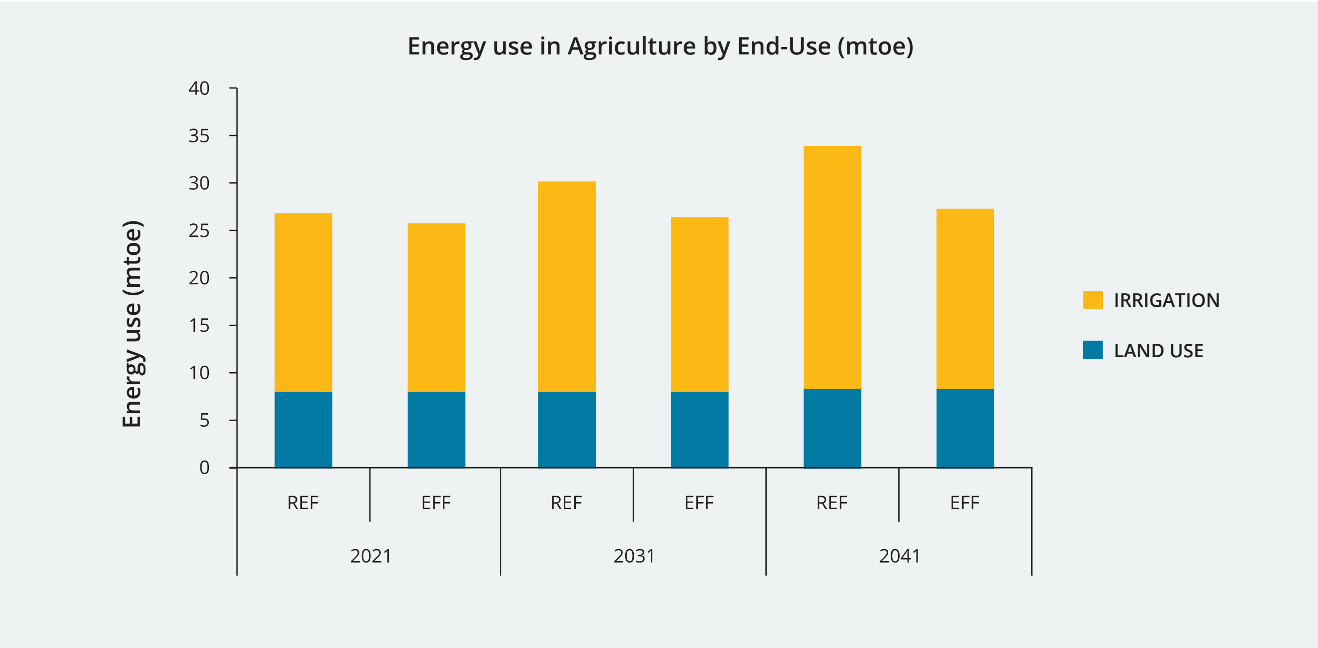
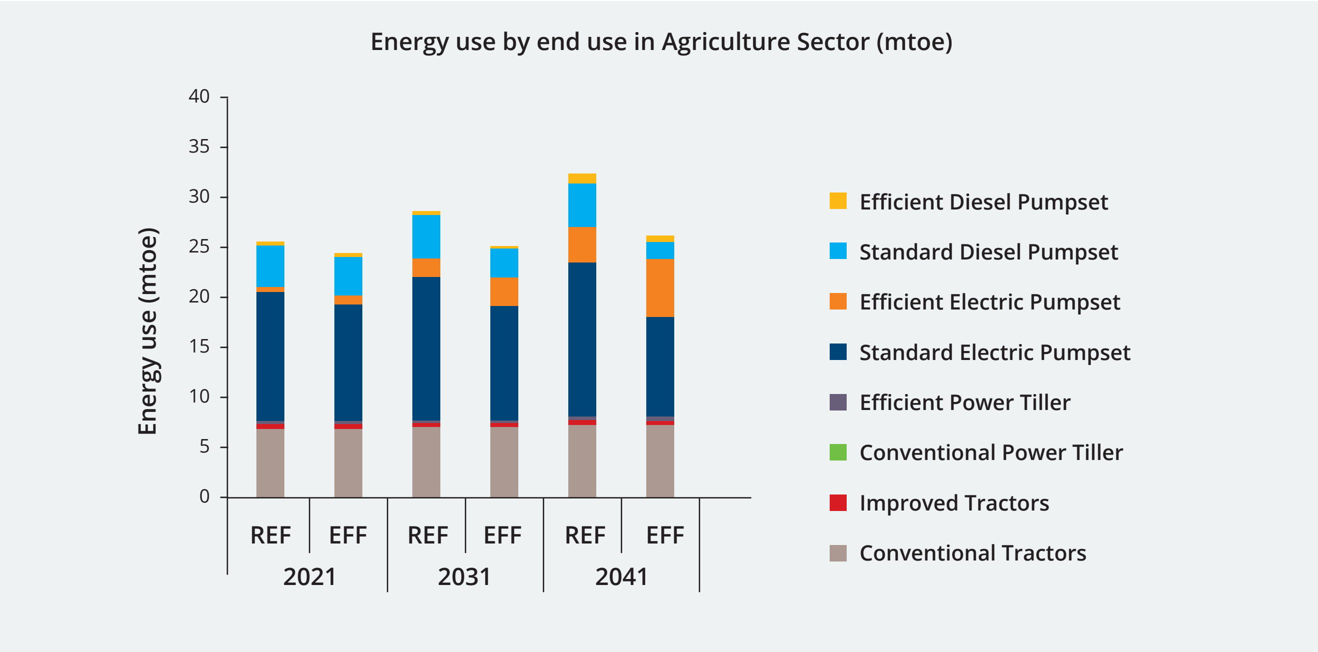


Figure 5-5: Energy Use by End-Use in Agriculture Sector



from the gradual increase in efficiencies of pump-sets (technical and managerial), wherein policies to reflect the true electricity prices could also bring in significant efficiencies.

5.1.2 Residential sector

In the residential sector, the main end-uses in which energy efficiency seems to have a significant potential is space conditioning and lighting. Although the appliances in the residential sector have already been improving their efficiencies in the past continuously, and this is partly already reflected in the REF scenario as well, by 2041, another 10% energy saving potential is envisaged. These energy efficiency savings are largely attributed to efficiency improvements in space conditioning and lighting in the residential sector.

As indicated in the figure above, while space conditioning and lighting are expected to bring in further energy savings, a significant proportion of energy use in the residential sector is on account

Figure 5-6: Energy Use in Residential Sector

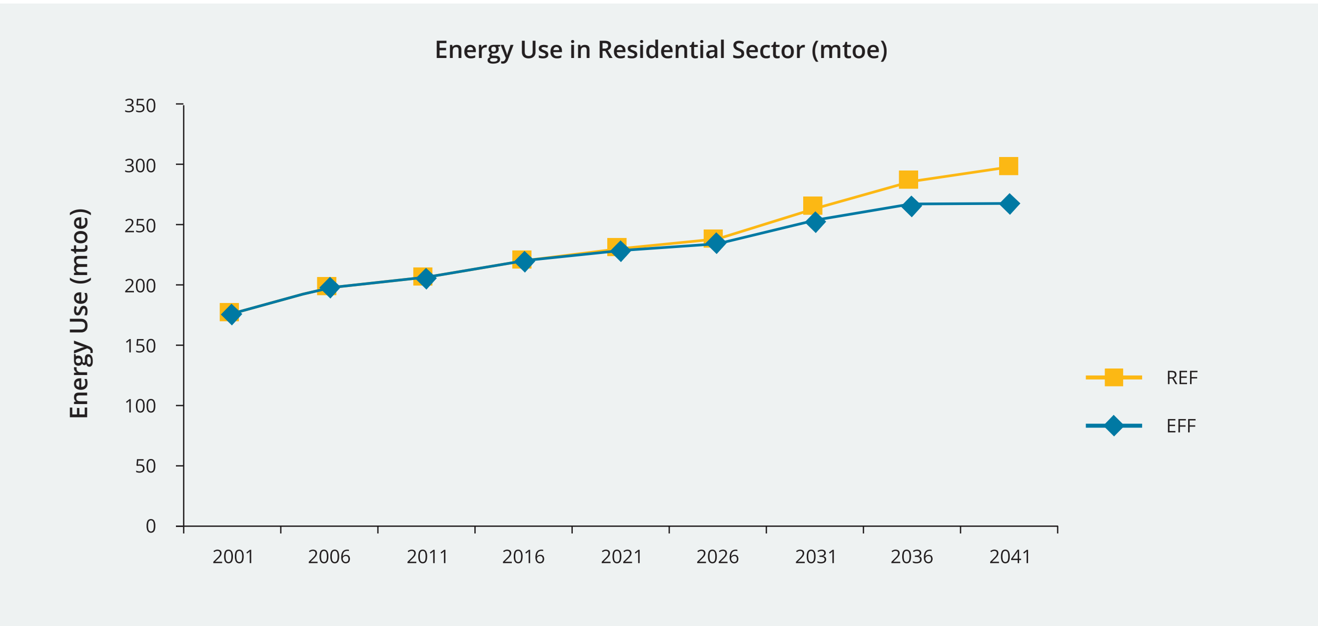
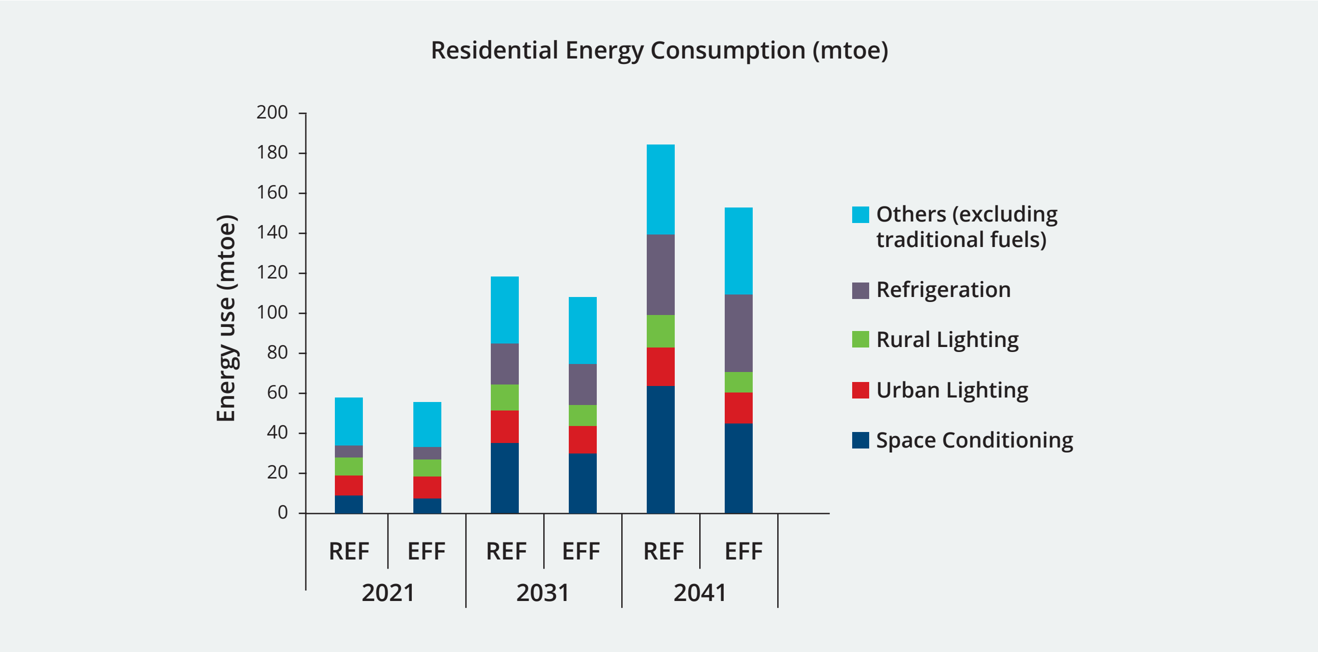


Figure 5-7: Residential energy consumption [REF vs EFF scenarios]



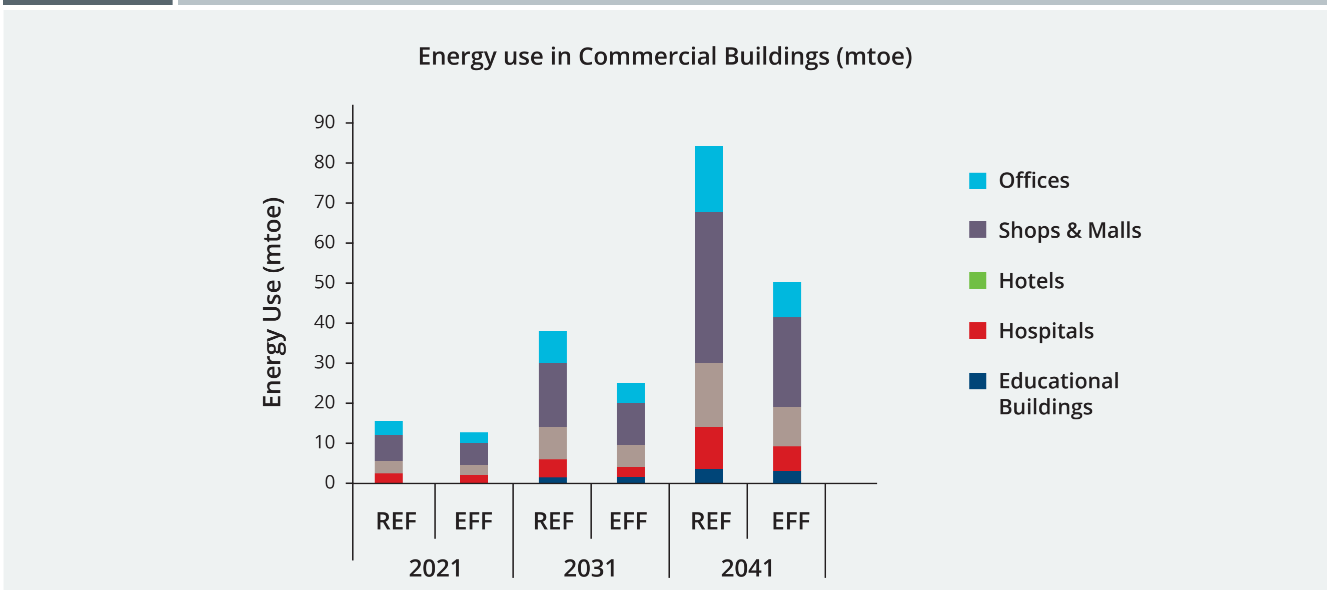
of cooking as well apart from other electricity based appliances. In fact, with the recent policies & measures providing a thrust to cleaner modern cooking fuels, while issues related with indoor air pollution would get partly addressed, the level of CO_2 emissions due to increased usage of LPG (which is a fossil fuel) would also rise. Therefore, while the current study does not include a deep dive into the scope for induction stoves, it may be worthwhile in future to look deeper into energy efficiency potential within the cooking end-use sector.

Further, while not explicitly captured as an end-use in the model, building design in the residential sector could also have significant saving potential.

5.1.3 Commercial sector

The commercial sector indicates a significant potential for energy efficiency, ranging from about 7% in 2021, 15% in 2031 and 18% by 2041 in the EFF scenario as compared to the REF scenario. By 2021, 2031 and 2041 around 3 mtoe, 13 mtoe and 34 mtoe respectively could be saved between the two scenarios. These savings could accrue by energy efficiency in commercial buildings as well as efficiency improvements in end-uses such as street

Figure 5-8: Energy use in Commercial Buildings



lighting. However, improvements through building efficiency seem to be the largest component. Further, the potential of energy efficiency in buildings seems to be the largest in the category of shops and malls, followed by offices and then hotel buildings as indicated in Figure 5-8.

5.1.4 Industry sector

The key large energy-intensive industry sub-sectors that indicate a potential for energy efficiency improvements include the iron & steel sector, followed by the bricks, cement and aluminium sectors. While these key energy intensive sub-sectors account for around 50% of the energy use of the sector in our model, the other industries including the MSMEs account for a significantly large share of energy use of this sector, and use a variety of fuels, processes and technologies of different vintages and efficiencies.

By 2021, 2031 and 2041, savings of 1%, 6% and 8% can be achieved in the industry sector in the EFF scenario as compared to the REF scenario.

As indicated in Figure 5-10, the scope for energy efficiency is largest in the iron and steel sub-sector (about 27 mtoe by 2031 itself and 45 by 2041), followed by the bricks sector (with savings of around 2 mtoe in 2031 and 4 mtoe by 2041).

Even though we adopt a conservative view of the potential for energy efficiency improvements across the dispersed SMEs, this category also indicates a significantly large potential for achieving savings via

Figure 5-9: Energy Use in Industrial Sector

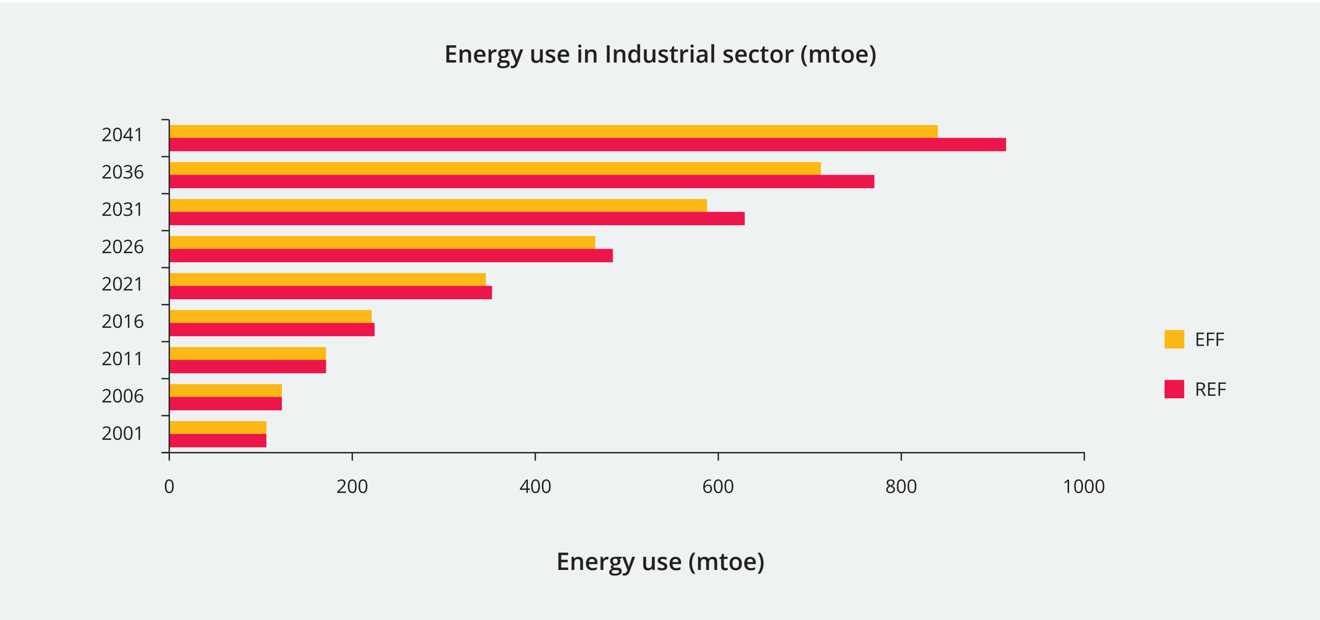
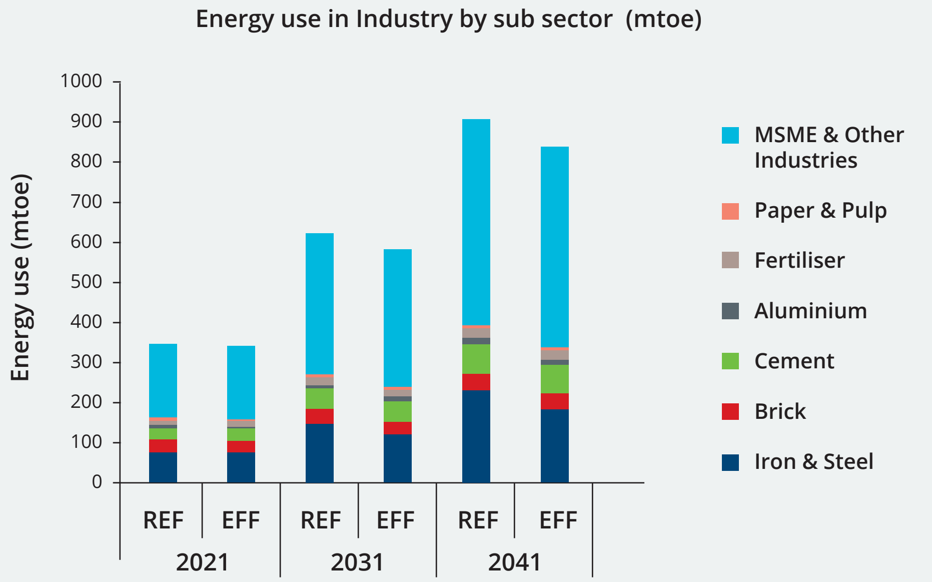


Figure 5-10: Energy use in Industrial sector by End-Use



EE (approximately 7 mtoe by 2031 & 15 mtoe by 2041).

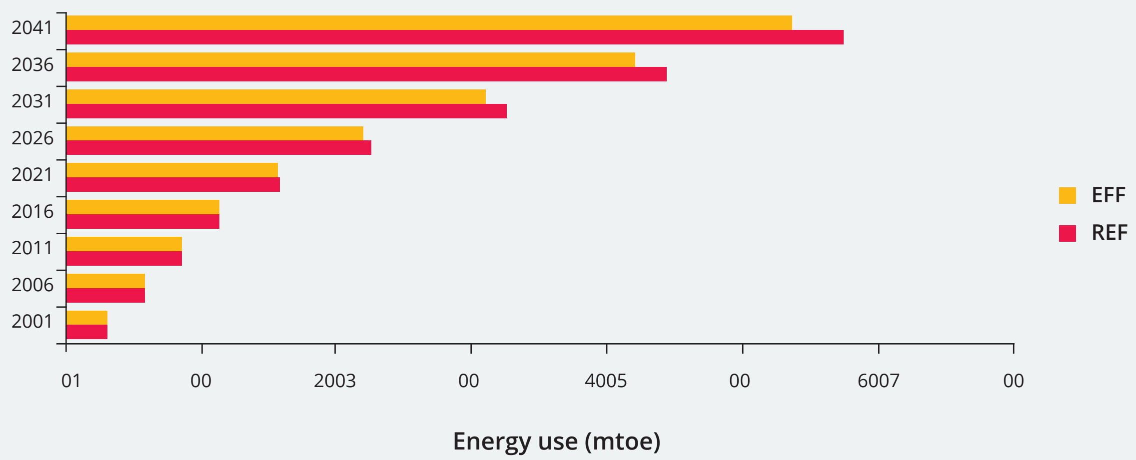
5.1.5 Transport sector

In the transport sector, efficiency improvements are expected to accrue on account of shifts from road to rail based movement, improvement in efficiencies of road based vehicles as well as improvements of efficiencies in the aviation sector.

The transport sector indicates a saving of around 37 Mtoe in 2041, with energy efficiency related savings ranging between 2-7% between 2021 and 2041.

Although we do consider efficiency improvement of the vehicle fleet gradually in the model, this is likely to occur in sync with autonomous efficiency improvements over time globally in the automobile industry rather than something specific that India as a country does on its own. Further, while some displacement of petroleum products is envisaged to occur with introduction of electric vehicles, especially in the later time periods when electricity

Figure 5-11: Energy use in Transport sector (Mtoe)



generation itself is much more decarbonised, may be an important element in the transitions within this sector, but not considered as an efficiency improvement element alone.

5.1.6 Power generation sector

Due to efficiency improvements largely on the end-use demand side, but also with regard to some improvements in T&D losses, the level of electricity generation required would also reduce, leading to the need for a lower power generation capacity as well. The results of the model indicate that nearly 23 GW by 2021, 77 GW by 2031 and 280 GW by 2041 could be reduced due to the efficiency improvements envisaged in the EFF scenario vis-à-vis the REF scenario.

Figure 5-12 shows the fuel-wise centralised power generation in the 2 scenarios. Coal based power generation capacity reflects a significant decrease in the EFF scenario, reflecting positive implications for emissions reductions. Therefore through energy efficiency more than 100 GW additional coal capacity can be avoided (Figure 5-12). Improvements in T&D further contribute to the energy savings in terms of the "Negawatts" it can bring in.

Table 5-1 provides a listing of each of the major options in the energy sector that indicate an energy

Figure 5-12: Centralized electricity capacity

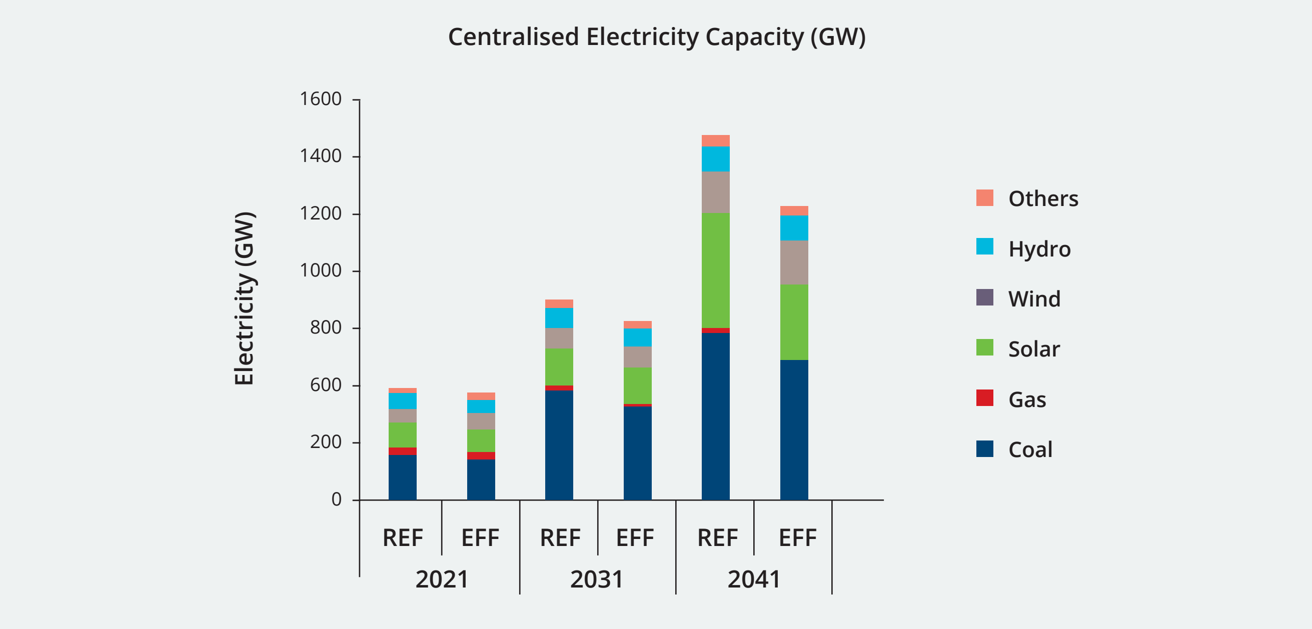
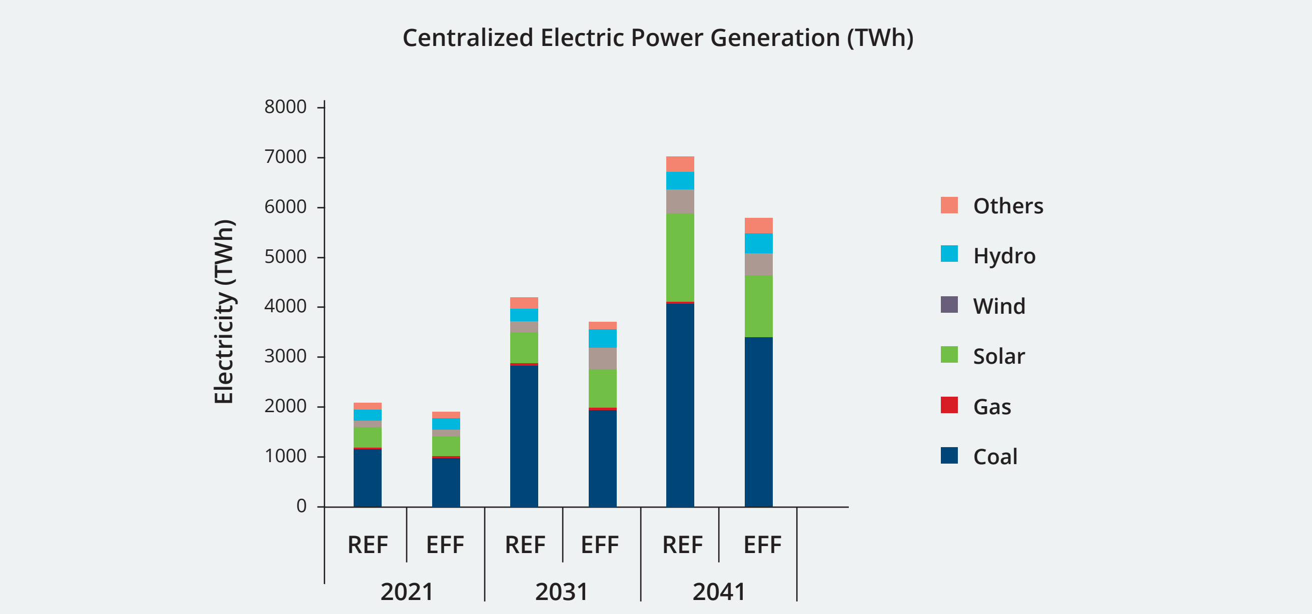


Figure 5-13: Centralized electric power generation



saving potential based on the scenarios modelled. In the agriculture sector, while we observe that there is a significant scope for moving to efficient irrigation technologies and practices in the EFF scenario as compared to the REF scenario, the energy saving in the sector is relatively modest, even by 2041. This is also because the growth in the agriculture sector and energy consumption by the sector as such is not as rapid in the longer term.

In the residential sector, significant changes through energy efficiency in appliances are already occurring

Table 5-1 Energy saving by end use based on scenario (mtoe)

SECTOR	END USE	2021		2031		2041	
		SAVINGS	% SAVINGS	SAVINGS	% SAVINGS	SAVINGS	% SAVINGS
Agriculture	Irrigation	1.18	6%	3.5	16%	6.4	25%
Residential	Space Conditioning	0.20	2%	4.6	13%	17.9	28%
	Lighting	1.11	6%	5.1	17%	10.7	30%
	Refrigeration	0.03	1%	0.4	2%	1.9	5%
Commercial	Educational Buildings	0.02	3%	0.2	12%	0.6	17%
	Hospitals	0.53	34%	1.7	39%	4.1	40%
	Hotels	0.48	15%	2.6	33%	6.6	41%
	Shops & Malls	1.18	18%	5.5	34%	15.0	40%
	Offices	0.46	15%	2.8	37%	7.8	47%
Industry	Iron & Steel	0.74	1%	26.9	18%	45.3	19%
	Brick	0.88	3%	2.5	7%	4.3	10%
	Cement	0.03	0%	0.9	2%	1.9	3%
	Aluminium	0.14	2%	0.7	7%	1.7	12%
	Fertiliser	0.07	1%	1.1	6%	3.3	14%
	Paper & Pulp	0.78	14%	1.4	18%	2.0	22%
	MSME & Other Industries	1.21	1%	6.7	2%	15.2	3%
Transport		2.65	2%	15.0	5%	36.6	6%
Power *	Thermal Power Plants	42	15%	109	17%	163	20%

The percentages shown in the above table are with respect to the energy consumed for that end-use for the given year in the reference scenario.
*The energy savings in Power sector here are due to reduced energy demand, shift to more efficient coal power plants and displacement of coal based electricity generation by renewable based electricity.

even in the REF scenario. Accordingly, in the short term, we do not observe scope for further reduction by 2021 (based on the expectation that penetration of the available efficient appliances would continue to increase). However, the scope for enhancing the penetration of efficient appliances may have scope for further increase with greater awareness, further improvement in efficiencies of technologies and further reduction in their cost. Moreover, the current analysis does not include the energy saving from Green buildings in the residential sector, which would be an additional potential for this sector.

In the commercial sector, the energy saving potential is largely on account of the efficiency that could be brought in through energy efficient buildings in each of the commercial categories of buildings (viz, shops, offices, schools, hotels, hospitals etc.).

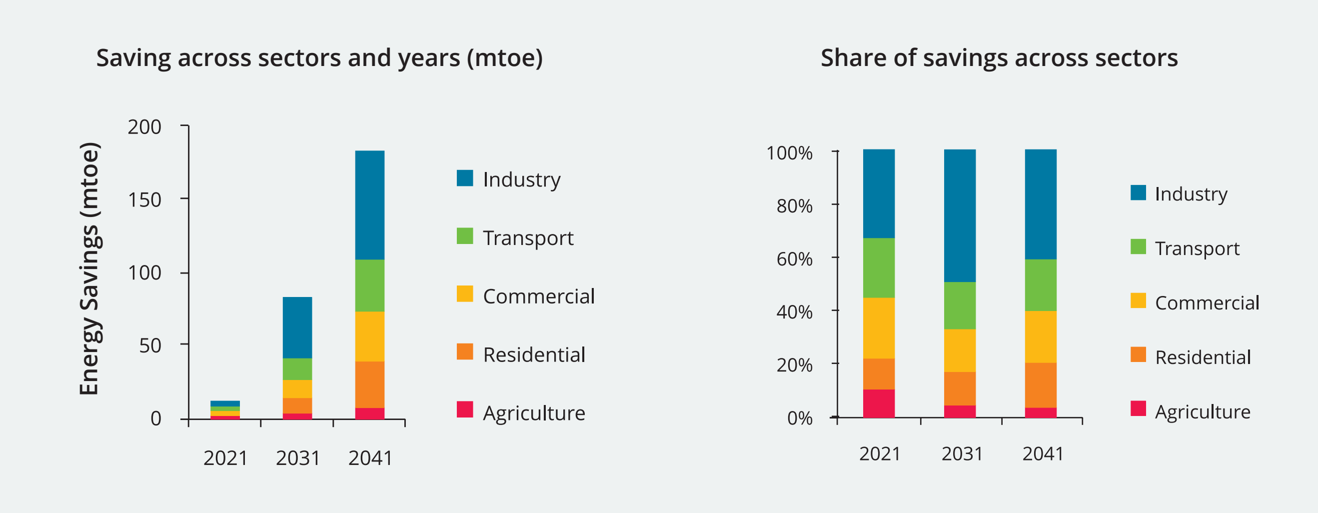
We observe that while the industry sector does not indicate a large scope for energy efficiency improvement in the immediate short term (partly because of the expectation that part of this potential would be captured already in the REF scenario), but by 2031 and 2041, the industry sector offers the largest energy efficiency potential.
Table 5-2 lists the sector-wise savings and the total saving achieved across the Indian energy system on account of the efficiency improvements considered in the study. The demand side energy savings are estimated at the point of end-use whereas the total energy savings account for the same across the entire energy system. The energy savings in the power sector in table 5-1 accounts for energy savings in thermal power generation. This saving comes from the need for lesser electricity generation due to efficiencies in the end-use demand sectors, improved energy efficiency of coal plants as well as displacement of coal based generation capacity by a higher share of renewables. The same in Table 5-2 provides the difference in total electricity generated across the two scenarios- thus, this includes energy savings on account of efficiencies alone (in demand sectors and power sector).

Table 5-2 Sectoral Energy Savings (mtoe)

SECTOR	2021		2031		2041	
DEMAND SECTORS*	SAVINGS	% SAVINGS	SAVINGS	% SAVINGS	SAVINGS	% SAVINGS
Agriculture	1.18	4%	3.52	12%	6.40	19%
Residential	1.37	0.15%	10.42	2%	31.01	8%
Commercial	2.69	7%	12.90	15%	34.36	18%
Industry	3.85	1%	40.15	6%	73.70	8%
Transport	2.65	2%	15.02	5%	36.57	6%
SUPPLY SECTORS**						
Power	15	15%	39	17%	108	20%
TOTAL* **	**49**	**5%**	**174**	**10%**	**338**	**12%**

Figure 5-14 reflects the potential for energy saving (additional to that considered in the REF scenario) in the EFF scenario for 2021, 2031 and 2041. It must be noted that the additional potential of around 12 mtoe in 2021 may seem to be on the lower side due to the higher levels of certainty associated with its achievement (leading to much of the potential being considered in the REF scenario itself). Therefore, based on the results of the scenario based exercise, the industry sector followed by transport and commercial sectors reflect the largest share of energy savings possibility in 2021. Over time, the relative positions of the sectors remain same but the saving potential increases significantly (except in agriculture sector). By, 2031, additional saving potential in the residential and commercial sectors also becomes significant. Savings in the transport sector become significant after 2031 because the effect of the changes in efficiency starts to become visible at the sectoral level only gradually with improvements in the share of rail based movement, higher electrification and improvement of efficiencies of the stock of vehicles/ aviation fleets. The share of energy saving potential in the agriculture sector though increasing is relatively small across all years, and when compared in terms of the overall role of efficiency improvement at the national level, it may not be very high in the long term. At the same time, the significance of efficiency improvements in irrigation through the use of appropriate technologies and policies should not be undermined, as overall efficiency improvement in this sub-sector would also have benefits in terms of saving indiscriminate water use in the agriculture sector.

Figure 5-14: Energy saving potential across sectors based on model results



5.2 Results of Sensitivity Analysis: Constrained Coal Scenario [EFF-S]

In light of the large recent additions to coal based power generation capacity in the country, the present scenario has developed as one with excess capacity resulting in a scenario with low PLF. This implies that even with increase in energy demand over the next few years, we may not need further increase in capacity and as the cost of solar (with storage) decreases, there is an expectation that renewables would be able to take on all the additional generation capacity needs. Accordingly, we also include a sensitivity analysis to examine the case where no further investments are made towards additional coal capacity post 2021.

The current capacity of coal power plants is about 185 GW which increases to 249 GW in 2021.

To meet the increasing power demand, coal is substituted by renewable sources, mainly solar and wind as the other sources hold a very small share in the energy mix. Figure 5-15 shows the distribution of the capacity across different sources. It is evident from the graph that solar becomes the most important source of electricity in the absence of coal. The capacity of solar electricity is 100 GW in 2021 which rises to 449 GW and 301 GW in 2031 and 1361 GW and 896 GW in 2041 in REF and EFF scenario respectively.

The capacities of wind and hydro rise to 170 GW and 100 GW respectively in 2041. It is important to note that we have considered that solar thermal (with storage) would be viable after 2021. Accordingly while the solar based generation capacity required to replace coal based generation is not as high as it may have been in case of solar without storage, by 2041 in the sensitivity case, the generation capacity is much higher than in the EFF scenario. In 2031 however, the generation capacity required in the EFF-S case is still lower than in the EFF scenario since the efficiency gains are able to displace the additional generation capacity requirements.

In the sensitivity case (EFF-S), the CO_2 emissions could further decline as shown in figure 5-16. In the EFF scenario, the CO_2 emission was at 5.15 GT in 2031 which falls to 4.24 GT in absence of coal based power generation in the EFF-S scenario.

Figure 5-15: Centralized Electricity Capacity (Sensitivity Analysis)

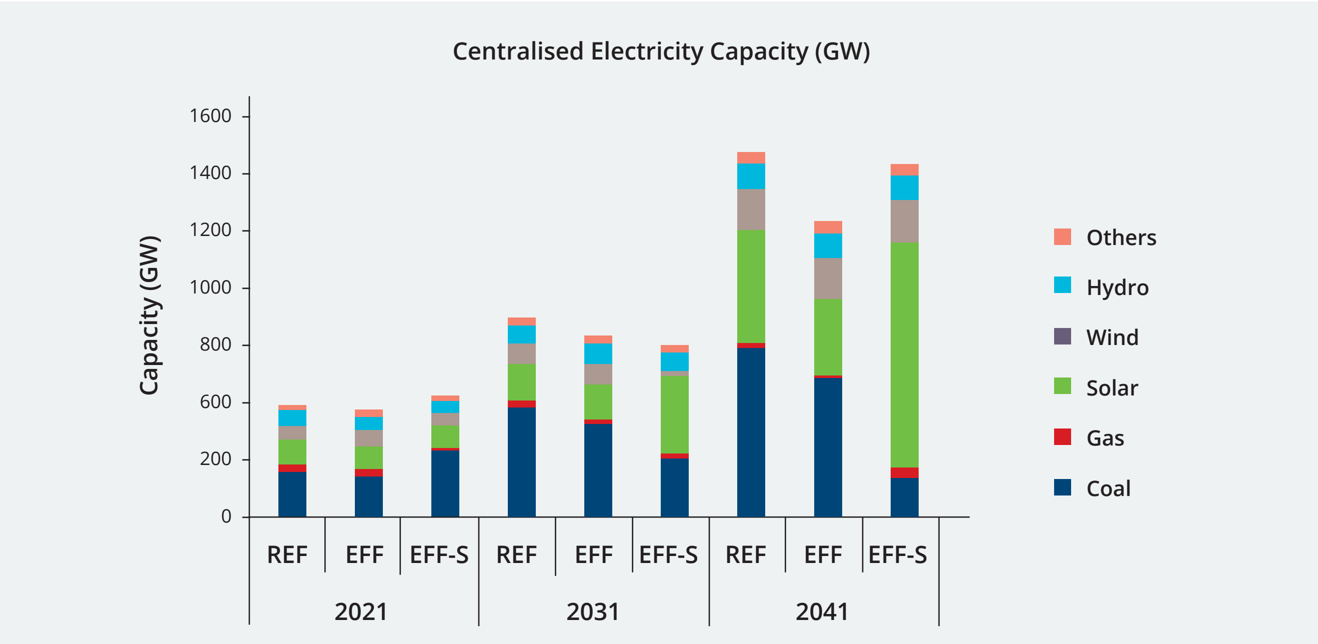
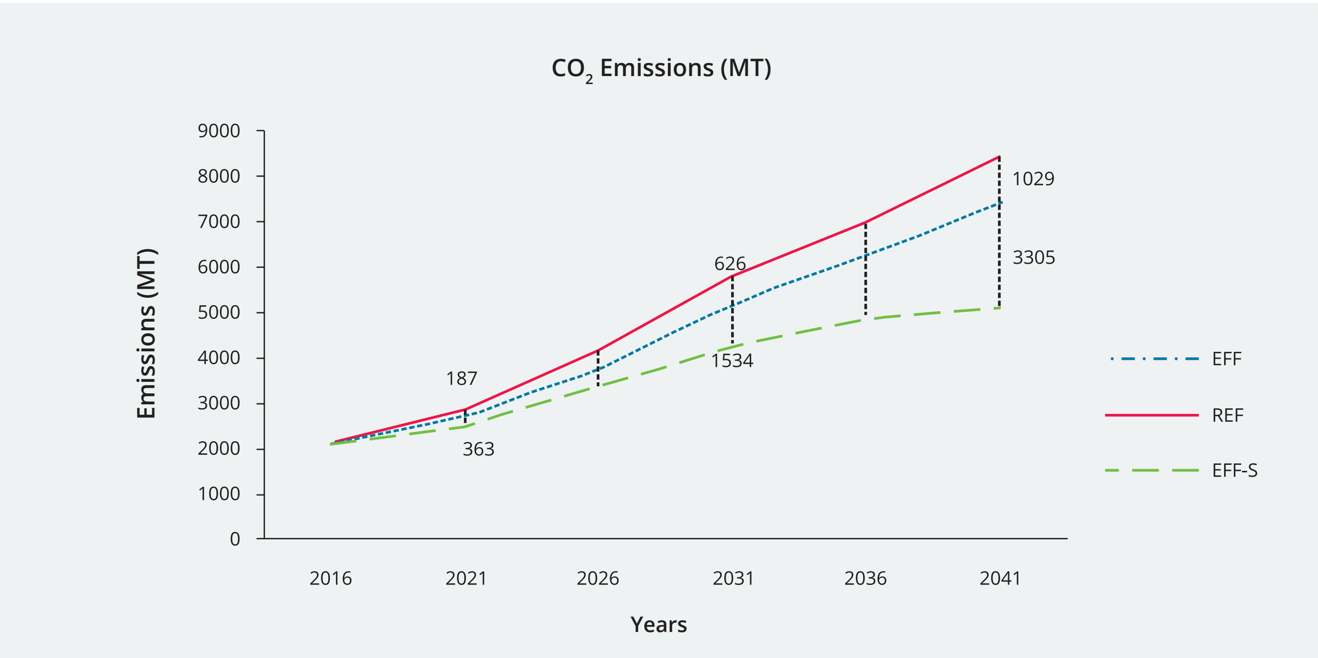


Figure 5-16: CO_2 Emissions (Sensitivity Analysis)



5.3 Barriers and challenges to energy efficiency improvements

This section lists out some of the barriers and constraints to energy efficiency improvements. Based on discussion with various sector experts we provide an understanding of the major barriers that end-users face through some examples.

Although the iron & steel sector has made rapid strides to promote energy efficiency, there are a number of barriers and challenges facing the sector that include apprehensions associated with high investment costs, apprehension on production loss and exaggerated claim of high benefits from such technologies under Indian conditions. This concern is more pronounced in new emerging technologies which are yet to be commercialized/ adapted under Indian conditions.

Moreover, it is felt that efficiency gains have been made by Indian steel industries over the past few years mainly in response to volatility in energy prices. Further improvements towards energy efficiency are felt to be more costly and relatively less effective and organizational barriers become more influential.

Also, the industries extend preferences towards reliability and continuous operation of the plant which is a major hindrance to install new energy efficiency-related equipment as production shutdowns could greatly jeopardize the integrity of the plants in terms of loss of production and delivery schedules.

The scale of energy efficiency projects can also play a significant factor. An energy-saving innovation may require operational improvements, incremental technological changes, retrofitting or introduction of completely new equipment and processes. The willingness to pursue these investments may depend on existing projects in the pipeline more than the returns of the individual energy saving proposals. Besides the fact, that opportunities for access to capital is also limited for financing energy efficiency projects.

Economies of scale and financial constraints in the secondary sector are another major barrier to the adoption of energy efficient technologies. For example, the secondary steel sector, which contributes sizably to steel production in the country, comprises small units operating with smaller module of production processes. Most of the developments which have taken place towards energy efficiency improvements over past two decades focused on larger module size to capture larger global market and achieve shorter payback period on investment. These units have limited resources for making investment on energy efficient technologies and hence provide little or no priority for introduction of energy saving technologies/ equipment.

In case of the fertilizer sector, production and sale of fertilizers are governed by the Essential Commodity Act. The Government of India continues to control/ regulate end prices of fertilizers for farmers in order to keep the cost of cultivation within reasonable levels. Hence, the government controls fertilizer sector through different policies of pricing of products and subsidies. To keep the cost fertilizers low for farmers, government provides fertilizer subsidy of almost USD 12 billion per year which is routed through fertilizer producers and importers. By and large, there has been no gap or delay in transfer of latest technologies and their incorporation in existing production facilities. It has reflected in significant downward trend in average energy consumption of Indian fertilizer plants. Pricing and subsidy policies do have some incentives for energy efficiency improvements, but high controls on fertilizer industry prevent industry from taking investment decisions on purely techno-commercial basis. The fertilizer industry has been demanding for complete decontrol of sector and payment of subsidy directly to the farmers. This would allow fertilizer industry to operate on competitive basis which will in turn spur investment for improving efficiencies and bring innovative products to the market that are most cost effective.

6. Conclusion

6.1 Key Findings

This study indicates that the most relevant end-uses and sub-sectors that indicate potential for energy efficiency include the following:

- Iron & Steel, Cement, Bricks, and other industries including MSMEs
- Energy efficiency in transport through improvements in the aviation sector, switch towards rail based movement and electric vehicles and improvement in vehicle efficiencies
- Efficient buildings for shops/malls, hotels and offices as well as hospitals.
- Improvement in irrigation efficiencies in agriculture sector
- Lighting and space conditioning appliances in the residential sector.

The main barriers mentioned to the uptake of the efficient technological options were either the high upfront costs of alternative technologies and processes and/or the need for a stronger policy push /business model to scale up the uptake of the more efficient options. Where targeted programs such as the PAT scheme or the LED lighting program are already underway, there was greater certainty of achieving the EE potentials in a shorter period. However, where the pick-up of efficient options is low and dispersed, there is less optimism regarding rapid scale-ups.

The key findings of this study are:

- Energy efficiency in industry has the highest savings potential for India, therefore the PAT schemes must be continued, strengthened and widened.
- Energy efficiency in the SME sector is increasingly important with new support schemes to be designed.
- Through energy efficiency more than 100 GW additional coal capacity can be avoided until 2047 already taking into account the future capacity mix with renewable energies.
- After the iron & steel sector other sectors such as transport, bricks, space cooling and hospitals will become significantly important.
- Need for a roadmap for energy efficiency until 2047 identified.

6.2 Overall Recommendations

While a more detailed study should be undertaken to conduct a deep-dive especially for the sectors that indicate significant energy efficiency potential, and to fine-tune the analysis of associated costs and benefits across various sectors, this study clearly indicates that energy efficiency can play an important role in contributing to India's NDC targets and helping to move ahead along a sustainable energy path.

For a developing country like India, the role of energy efficiency is instrumental in dampening the rate of increase in final energy use even as the country seeks to enhance the provisioning of useful energy demands. The energy efficiency potential as envisaged through the scenarios also indicates that it would play a positive role in contributing towards India's NDC target. While the REF scenario indicates a possibility of achieving only the lower end of the NDC target of 33% emission intensity reduction, pursuing the EFF scenario could achieve an emission intensity of around 41%. Through energy efficiency more than 100 GW additional coal capacity can be avoided until 2047 already taking into account the future capacity mix with renewable energies.

Different end-use sectors face different kinds of challenges, policy environment and availability of technological alternatives. Accordingly, there are opportunities in some sub-sectors such as irrigation in the agriculture sector or lighting and space conditioning in the residential and commercial sectors wherein changes could possibly be brought in fairly quickly.

Given that rapid growth in building infrastructure is expected (in particular, for commercial buildings), it is critical that energy efficiency in the building sector is pursued through a policy and regulatory regime to harness the potential of energy savings. Energy benchmarking of buildings (differentiated by varying profile of buildings), strengthening of institutional capacities at various levels to implement ECBC developing technical expertise and compiling credible databases are some of the important steps that should be undertaken to trigger in efficiency improvements quickly in the buildings sector.

Energy efficiency in the industry has the highest savings potential for India. Through PAT mechanism, Government of India is mandating large industries to reduce their current energy consumption levels. Encouraged by the achievements of PAT-1 cycle, Government is widening its ambit in terms of expanding the scope by including other large energy consuming industrial sub-sectors. Efforts in this direction must be continued, strengthened and widened. In addition, as has been pointed out in the report in earlier sections, there are many sub-sectors including MSMEs, which are energy intensive but presently outside the purview of PAT mechanism. Although a few initiatives have been undertaken by Government/bilateral/multilateral organisations to help MSMEs improve their energy performance, there is a lot more that can be done to improve their energy performance. Hence, efforts need to be directed towards developing programs for this sector, which is a very important contributor of Indian economy.

In other sub-sectors such as irrigation, again the larger benefits of savings of water resources as well would be applicable and need to be given importance. The results of this study indicate the need for a roadmap for energy efficiency until 2047.

7. Appendix: Policies & Measures facilitating Energy Efficiency across Sectors

As India seeks to provide enhanced access to clean & modern energy forms to all its people, the country is constantly also seeking to ensure that it does so in an efficient manner. Given that 1 unit of energy saved is equivalent to almost 1.5 unit of avoided generation, the role of energy efficiency cannot be undermined. India's emissions intensity has in the past constantly been improving over time due to a number of policies and measures that were put in place over the years. Recognizing the importance of continuing this trend, several energy efficiency measures have also been introduced in recent years through numerous policies and schemes. For example, the Ministry of Power, through the Bureau of Energy Efficiency (BEE), has initiated a number of energy efficiency initiatives in the areas of household lighting, commercial buildings, standards and labelling of appliances, demand side management in agriculture/ municipalities, SME's and large industries including the initiation of the process for development of energy consumption norms for industrial sub sectors, capacity building of SDA's etc. The target of energy savings against these schemes during the XI plan period was kept 10,000 MW of avoided generation capacity. These initiatives have resulted in an avoided capacity generation of 10,836 MW during the XI plan period. On the generation side, the government is promoting increasing use of renewable in the energy mix and at the same time enhancing efficiencies by targeting T&D efficiency improvements and moving towards more efficient fossil fuel technologies such as supercritical coal based technology instead of sub-critical for coal based power plants.

An overview of some of these schemes is provided in this Annexure. The table below provides a snapshot of some of the policies and measures while details are discussed subsequently.

7.1 Energy Efficiency programs in a nutshell

NAME OF PROGRAM	STARTED IN	KEY OBJECTIVE	TARGET	STATUS
Standards and Labeling (S&L)	May, 2006	To provide information to the consumer about the energy-saving and cost saving potential of the marketed appliances.	• Avoided generation of over 3000 MW during 11th five year plan (2007-12) and 7766 MW during 12th plan (2012-17). • Energy saving by S&L for transport sector is to be 22.97 mtoe by 2025.	21 appliances are covered under S&L

NAME OF PROGRAM	STARTED IN	KEY OBJECTIVE	TARGET	STATUS
Energy Conservation Building Codes (ECBC)	May, 2007	To reduce the energy usage in buildings without compromising the comfort level	• Avoided generation of about 500 MW during 11th five year plan (2007-12) and 928 MW during 12th plan (2012-17). • 75% of all new commercial buildings and 20% of the existing commercial buildings to be ECBC compliant by 2022.	About 22 states are mandating ECBC by December 2018
Agriculture DSM	2010	To induce energy efficiency in agriculture sector by adoption of energy efficient pump sets	• To replace 20 million pump sets in three-and-half years.	Plans to replace 10 lakh inefficient agricultural pump sets with BEE star-rated pumps during the current fiscal.
Municipal DSM (Street Lighting)	2015	To induce energy efficiency in street lighting sector	• 3.5 Cr. conventional street lights to be replaced by LEDs by March, 2019	64.75 lakh street lights have already been replaced with LED bulbs (as on 15th August 2018)
Capacity building of DISCOMs	-	To carry out load management program, energy conservation program, development & implementation of DSM plan	• Creation of about 500 Master Trainers from officials of DISCOMs • Training of 4000-5000 circle level officials of DISCOMs	Establishment of DSM Cell by selected DISCOMs
Energy Efficiency in SMEs	-	To reduce energy consumption in manufacturing SMEs by 6%	• Avoided generation of about 500 MW during 11th five year plan (2007-12) and 131 MW during 12th plan (2012-17).	BEE initiated energy efficiency interventions in selected 25 SMEs during 11th plan and in 100 projects in further 5 SMEs during 12th Plan.
UJALA	2015	To provide LED bulbs to people at affordable price	• 77 crore LED bulbs is to be distributed to the people by 2019	Price of each LED bulb fell down from over Rs.300 in 2014 to around Rs.55
Strengthening of State Designated Agency (SDAs)	-	To carry out the work relating to energy efficiency in the state	• Increasing thrust on enforcing energy efficiency work at the State level	35 SDAs has been established across states and UTs in India
Contribution to State Energy Conservation Fund (SECF)	-	To overcome the major barriers for implementation of energy efficiency projects	Not applicable	Till date, an Amount of Rs.82 Cr. has been disbursed to 26 states
School Education Program	-	To create awareness about energy efficiency in children	• Mandatory chapter on energy efficiency in study curriculum for classes 6th to 10th	Numerous proposals are received to undertake several activities from all SDAs
Perform, Achieve and Trade (PAT)	2012	To enhance the cost effectiveness in improving the Energy Efficiency in industries	• The industrial energy savings to reach 10% by 2019	Energy savings of around 4% from selected industries in 2014-15
Bachat Lamp Yojana (BLY)	April, 2010	To promote use of LED lights	• Avoided generation of about 4000 MW during 11th five year plan (2007-12)	Over 60 million incandescent bulbs have been replaced

NAME OF PROGRAM	STARTED IN	KEY OBJECTIVE	TARGET	STATUS
Super-Efficient Equipment Program (SEEP)	January, 2013	To promote market for super-efficient appliances	• 30-35 million ceiling fan deployed in 12th plan is to be energy efficient	Ceiling fan has been identified as area for tremendous energy saving potential
Domestic Efficient Lighting Program (DELP)	January, 2015	To promote efficient lighting in domestic sector	• 77 crore LED bulbs is to be distributed to the consumers by 2019	Over 30 crore LED bulbs have been distributed (as on 15th August, 2018)
Energy Efficiency Financing Platform (EEFP)	-	To facilitate financing to project developer for implementing energy efficiency work	• To provide more financing arrangements to developers	BEE signed MoUs with several banks on Energy Efficiency Financing
Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE)	May, 2012	To partial coverage of risk involved in energy efficiency projects	Not applicable	A Guarantee of Rs.10 Cr. per project or 50% of loan amount, whichever is less. This scheme covers government buildings, private buildings (commercial or multi-storey residential buildings), municipalities, SMEs and industries.
Venture Capital Fund for Energy Efficiency (VCFEE)	March, 2017	To provide equity capital for energy efficiency projects	Not applicable	Risk capital support to a maximum of 15% of total equity required, or Rs.2 Cr., whichever is less. . The scheme covers government buildings, private buildings (commercial or multi-storey residential buildings) and municipalities.

7.2 Standards and Labeling (S&L)

The Standards and Labeling Scheme (S&L) scheme was launched on May, 2006 by the Ministry of Power. The main objective of this scheme was to provide information to the consumers about the energy saving and thereby cost saving potential of the marketed appliances such as Room Air Conditioners, Fluorescent Tube Lights, Refrigerators, Distribution Transformers, Agricultural pump sets and so on wherein energy performance labels need to be displayed and minimum energy performance standards are laid down.

The appliances covered under the S&L schemes are as follows:

Mandatory

1. Frost Free Refrigerator
2. Tubular Florescent Lamps
3. Distribution Transformers
4. Room Air Conditioners (Cassette, Floor Standing Tower, Ceiling, Corner AC)
5. Direct Cool Refrigerator
6. Colour TV
7. Electric Geysers
8. Induction Motors
9. LED Blubs
10. Inverter type AC

Mandatory

11. Agricultural Pump Sets
12. Ceiling Fans
13. LPG Stoves
14. Washing Machines
15. Laptops/Notebooks
16. Office Equipment
17. Ballast
18. Diesel Engine Driven Monoset Pumps for Agricultural Purposes
19. Solid State Inverters
20. Diesel Generator
21. LED Retrofit lamps

Developmental Status

The S&L scheme targeted an avoided capacity addition (generation) of over 3000 MW during the 11th five year plan (2007-12) and 7766 MW during the 12th plan (2012-17). In order to ensure more participation by manufacturers in the mandatory & voluntary Programs, higher market demand for Star labelled Products needs to be created through consumer awareness and linking the scheme with procurement policy. Also norms of Room Air Conditioner, Refrigerator, Distribution Transformers, color television etc. are planned to be upgraded.

Furthermore, S&L for Transport sector is identified. There are total 13.3 million passenger cars (2010 – 11) in India which consume about 9 m toe. The average annual sales of new passenger cars in the country are about 1.1 million. Energy consumption standard have also been notified for passenger cars and would be applicable from 2017-18 for the 1st phase & 2022-23 for the 2nd phase. The targeted energy saving by 2025 is estimated at 22.97 m toe.

7.3 Energy Conservation Building Codes (ECBC)

Commercial building sector in India is expanding rapidly at over 9% per year spurred largely by the strong growth in the services sector. It has been estimated that atleast 60% of the overall building stock that will exist in the year 2030 is yet to come up in the country – a situation that is fundamentally different from developed countries. Having regard to the fact that the rate of growth in commercial building sector is amongst the highest, and that this sector needs to be moderated in its energy consumption, BEE introduced the Energy Conservation Building Code (ECBC) in 2007 to reduce the adverse impact of buildings on the environment. ECBC defines norms of energy performance for various building components, and takes into consideration, the climatic region. The application of these norms lowers the building's energy requirement without affecting the function, comfort, health or productivity of the occupants. It was developed for new commercial buildings having a connected load of 100kW or a contract demand of 120 KVW and above. While the Central Government has powers under the Energy Conservation Act 2001, the State Governments have the flexibility to modify the code to suit local or regional needs and notify them.

Developmental Status

BEE has launched a new version of code ECBC 2017 in June 2017. The newly developed code is futuristic, pragmatic and easy to implement. The new version has three levels of compliance: ECBC, ECBC+, and Super ECBC. These additions are geared to encourage public and private sectors to not only meet the basic ECBC criteria, but to exceed them as well. Although the code was developed at Central level, its enforcement lies with the State Government. As per EC Act 2001, the State Government has been given power to notify the code as per their regional/local requirements. Long-term success of the ECBC will depend heavily on the collaborative roles various stakeholders would play towards the development, adoption and implementation of building code. Barriers and challenges for implementation of ECBC vary in terms of technical and design aspects, market barriers, policy and enforcement issues.

7.4 Demand Side Management (DSM) Scheme

7.4.1 Agriculture DSM

In order to tap the energy saving potential, Agriculture Demand Side Management (Ag DSM) program was started by BEE with an objective to induce energy efficiency in agriculture sector by adoption of energy efficient pump sets (EEPS). The first pilot project in this regard was undertaken in 2010 in Solapur circle of Maharashtra wherein 2209 old inefficient pump were replaced with star rated EEPS which resulted in energy savings of about 30%. (Release, 2016)

A few undertaken projects pertaining to Demand side management in Agricultural sector (Ag DSM) are described below:

- 11 Detailed Project Reports (DPRs) have been prepared in 8 states for 11 DISCOMs covering 20,750 pump sets. Average 40% (96 MUs) energy saving potential assessed.
- Punjab & Haryana mandated the use of BEE star rated pump sets for every new agricultural connection in the state. 67843 and 1599 pumps have been reported installed under the regulation in the state of Haryana and Punjab respectively.
- ESSL, in 2013, had been assigned the task of replacing over one lakh nos. of less efficient IP sets by highly efficient pump sets in the distribution area of BESCOM. Out of this nos., 13,864 pump sets were replaced in the district of Tumkur which resulted in energy saving of around 31%. (BESCOM, 2015) (BEE, 2015)
- 1337 inefficient IP sets were replaced in Mandya District of Karnataka which resulted in energy saving of around 37%. (EESL, 2015)

Developmental Status

EESL plans to replace 10 lakh inefficient agricultural pump sets with BEE star-rated pumps during the current fiscal. Moreover the vision is to replace 20 million pump sets in three-and-half years. (Business Line, 2016).

BEE aspires to accelerate the energy efficiency programs in pump sets through following interventions:

- Regulatory mechanism to mandate the use of BEE star labeled pump sets for new connections
- Facilitate implementation of DPRs and setting up monitoring & verification protocol
- Technical assistance and capacity development of all stakeholders
- Demo projects in pumping efficiency in Rural Public Health & Drinking water systems.
- Selection of beneficiary States as per the selection criteria for providing financial assistance to farmers for promotion of Energy Efficient Pump sets and for implementation of demonstration projects on efficiency improvement of Rural Drinking Water Pumping systems.

7.4.2 Municipal DSM (Street Lighting)

The Prime Minister of India launched the LED based Street Lighting National Program (SLNP) in 2015. The programs envisaged to cover 100 cities by March, 2016 and balance by March, 2019 targeting 3.5 crore conventional street lights to be replaced by LEDs which could results in energy saving of annual energy saving of 9 billion units causing saving of Rs.5500 Cr. every year for Municipal corporations. SLNP, the world's largest street light replacement program, is implemented by the Energy Efficiency Services Limited (EESL), a joint venture under the Ministry of Power, Government of India. (EESL, 2015). EESL has already executed the project successfully in 18 cities and work is under process in 82 cities. Out of successfully implemented projects, monitoring and verification work has been done in 5 cities which show a very positive result in terms of energy savings.

Table 7-1 LED street light installation and energy savings under SLNP			
CITY	TOTAL LED STREET LIGHT INSTALLED	TOTAL ANNUAL ENERGY SAVINGS (MUs)	TOTAL PERCENTAGE SAVINGS (%)
Varanasi, Uttar Pradesh	947	1.56	71%
Jhalawar, Rajasthan	2449	0.37	55%
Mount Abu, Rajasthan	1807	0.65	60%
Visakhapatnam, Andhra Pradesh	91775	23.54	60%
Agartala, Tripura	34200	3.90	53%
Total	131178	30.02	

Source: EESL India

It can be seen from the table that the installation of 131178 LED street lights in the 5 cities has led to an annual energy savings of 30.02 million units. Furthermore, based on the projections by EESL, the total connected load of street lights across the country is around 3400 MW that can be reduced to 1400 MW by simply replacing conventional lights with LED based street lights.

Developmental Status

Out of targeted 3.5 crore conventional street lamp to be replaced across the country, a total of 64.75 lakh street lights as on 15th August 2018 have already been replaced in the country with LED bulbs according to EESL, which is resulting in average energy savings per light per day by 0.363 kWh, avoiding power generation capacity of 55.15 MW.

Under SLNP, states, particularly, Rajasthan, Andhra Pradesh and Delhi, the program has resulted in massive replacement of lights. In Delhi, 2 lakh street lights are replaced alone in the South Delhi Municipal Corporation (SDMC) area. The cumulative annual energy savings in SDMC through this program is 26.5 million units with estimation of Rs.135 crore to be saved in next seven years. Furthermore, the Phase II of the street lighting program is inaugurated, under which EESL has signed a tripartite agreement with BSES and SDMC to install 75,000 more street lights with more focus on installation in parks. (Press Information Bureau, 2017)

7.4.3 Capacity building of DISCOMs

The objective of capacity building of DISCOM is for carrying out load management program, energy conservation program, development of DSM action plan and implementation of DSM activities in their respective areas. This program would help the DISCOMs for reducing peak electricity demand so that they can delay building further capacity.

Developmental Status

According to the National electricity Plan 2016, the following activities would be carried out by BEE and DISCOMs under capacity building program.

- Establishment of DSM Cell by selected DISCOMs.
- Creation of about 500 Master Trainers from officials of DISCOMs under Training of Trainers (ToT).
- Training of 4000-5000 circle level officials of DISCOMs under Capacity building workshops.
- Providing Manpower Support to DISCOMs for facilitating DISCOMs for implementation of DSM measures in their areas.
- Providing Consultancy support to DISCOMs for load survey, load research, load strategies etc. and preparation of DSM action plans.
- Adoption of DSM regulations by the Regulator.
- Incorporation of DSM plan along-with Multi-Year Tariff (MYT).
- Implementation of DSM Action Plan.
- Monitoring and Verification and reporting to the SERC.

7.4.4 Energy Efficiency in Small and Medium Enterprises (SMEs) sector

Indian MSME sector consumes energy equivalent to about 50 million tons of oil equivalent annually, which is about 20 to 25% of the energy consumption by large industries. SMEs in India are existing in form of clusters which are spread across the length and breadth of the country. The projected energy consumption in MSMEs in coming years is expected to increase to 68.2 mtoe with a projected annual growth rate of 6.0 percent.
A large number of MSMEs continue to depend on obsolete, low efficiency technologies that result in wasteful energy consumption and reduce profitability and competitiveness. On a broader scale for the MSME sector as a whole, it can be said that many of these issues have remained the same for years. This is primarily due to the enormity, geographical spread and complexity of the sector. Within the MSME sector, one has seen lots of technological changes/ advancements in certain sub-sectors like the MSMEs catering to the Information technology or automotive sectors. However, for many energy intensive sectors, there is an urgent need to develop, demonstrate and disseminate energy efficient technologies at the cluster level that can be adopted by local MSMEs. Technology need assessment and technology development to suit the requirements of the local MSMEs at the cluster level has emerged as one of the most important aspects that needs to be addressed in the MSME sector. Hence energy efficiency improvement through adoption of cleaner energy efficient (EE) technologies and practices offers great potential for reduction in CO_2 emissions as well as improvements in product quality and profitability.

Developmental Status

The energy efficiency program in SMEs overall targeted an avoided capacity addition (generation) of about 500 MW during 11th five year plan (2007-12) and 131 MW during 12th plan (2012-17). BEE had initiated the energy efficiency interventions in selected 25 SMEs clusters during the 11th plan. During the 12th plan, implementations of 100 technology demonstration projects in 5 SME sectors are envisaged to facilitate large scale replication.

7.4.5 Unnat Jyoti by Affordable LEDs for All (UJALA)

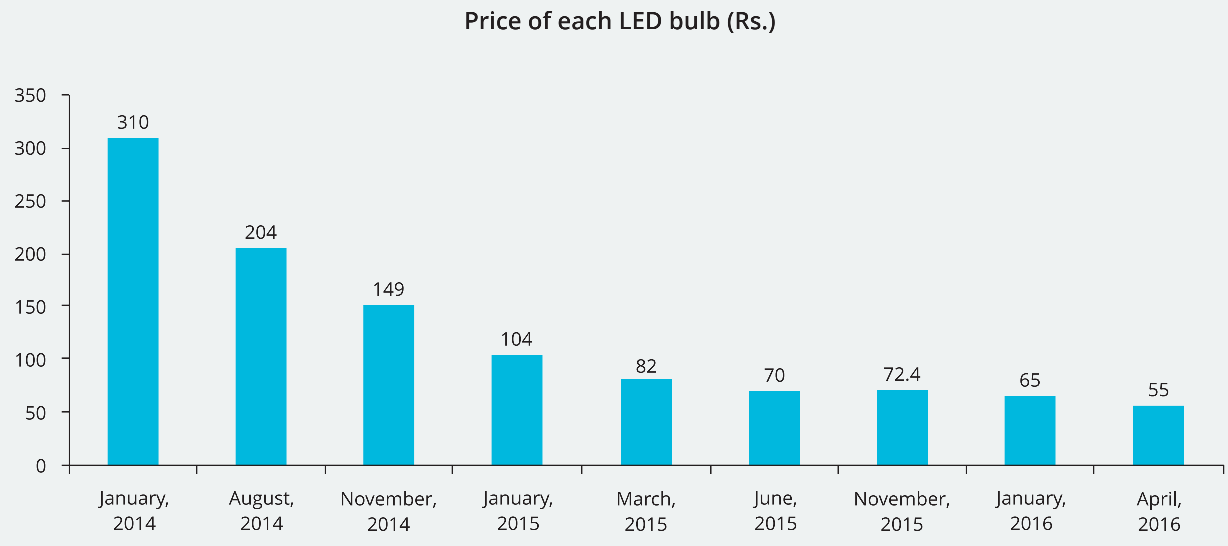
Furthermore, the UJALA (Unnat Jyoti by Affordable LEDs for All) scheme was launched in 2015 which aims at providing LED bulbs to people, through nodal agency EESL, on either upfront cost or through instalments payment. The key objective of this program is to promote the use of the most efficient lighting technology by consumers at affordable rates. As per the source of EESL, cost of LED bulbs has already decreased by over 80% in last 2 years.

Developmental Status

On account of arising competition amongst the LED bulb manufacturer for supplying the products to EESL, the price of each LED bulb fell down from over Rs.300 in 2014 to around Rs.55 in 2016. Also large scale and transparent procurement of bulbs by EESL from manufacturer has led to sharp decline in price.

According to EESL data as on August 23, 2016, over 14.4 crore LED bulbs have been distributed and is targeted at 77 crore LED bulbs by 2019 with continuous decline in cost of bulbs.

Figure 7-1: Price trend of LED bulbs



Source: EESL India as on August 2016

According to EESL data as on August 23, 2016, over 14.4 crore LED bulbs have been distributed and is targeted at 77 crore LED bulbs by 2019 with continuous decline in cost of bulbs.

7.5 Institutional Mechanism

7.5.1 Strengthening of State Designated Agency (SDAs)

The State Designated Agencies (SDAs) have been notified by the State Governments under section 15 (d) of the Energy Conservation Act, 2001 either by establishing a stand-alone SDA or by assigning additional responsibilities to the existing agencies / departments. 35 SDAs have been notified under EC Act. Out of these 35 SDAs, 16 are Renewable Energy Development Agencies, 4 are Power Department of State Governments, 7 are Electrical Inspectorate offices, 6 are Distribution Companies and 2 are "Stand-Alone" SDAs. The major roles and responsibilities of SDAs are to coordinate, regulate and enforce the various provisions of the Energy Conservation Act in the State level.

In order to implement energy efficiency measures and reduce energy intensity of the country, the Ministry of Power approved the scheme on "Strengthening of SDAs on the efficient use of energy and its conservation" during the XI plan, which was continued during the XII plan. The scheme comprises of the following two major components.

- Providing financial assistance to the State Designated Agencies to coordinate, regulate and enforce efficient use of energy and its conservation.
- Contribution to State Energy Conservation Fund (SECF)

Developmental Status

As on date, 35 SDAs has been established across states and union territories in India. In order to strengthen the SDAs, Ministry of Power provided financial assistance to them for strengthening their institutional capacities and capabilities during the XI plan. The major achievements were:

- Internet platform was developed by 26 SDAs
- 47 demonstration projects implemented in street lighting and water pumping stations.
- LED Village Campaign implemented by 28 States.
- Investment grade energy audit completed in 491 Govt. buildings.

During the XII plan, thrust will be on establishment of the enforcement machinery at the State level.

7.5.2 Contribution to State Energy Conservation Fund (SECF) Scheme

The State Energy Conservation Fund (SECF) is an instrument to overcome the major barriers for implementation of energy efficiency projects in the state. The scheme provides financial assistance to all the State/UTs with a maximum ceiling of Rs.4 Cr in two equal instalments. The second instalment of contribution to SECF is to be released only after the states have provided a matching contribution to the BEE's first instalment.

Developmental Status

The terms and conditions for release of financial assistance under Contribution to SECF remains the same during the 12th plan, only with exemption for North Eastern States. The matching contribution by State Government for North Eastern States is relaxed to Rs.25 lakhs instead of Rs.2.0 Cr. Till date, an amount of Rs.82 Cr. has been disbursed to 26 states. Out of these, 15 states have provided matching contribution.

7.6 School Education Program

The practice of energy efficiency measures and technology needs to be infused in children from early age and thereby the next generation could be made more aware about efficient use of energy resources. Therefore, BEE is implementing the student's capacity building program under energy conservation awareness scheme for 12th five year plan and intends to prepare the text/material on Energy Efficiency in the existing science syllabi and science text books of NCERT for classes 6th to 10th. (BEE, 2016)

Developmental Status

- Proposals were invited from all SDAs to undertake various Students Capacity building program as approved for XII Plan. SDAs of Maharashtra, Kerala, Chhattisgarh, Punjab, Tripura, Andhra Pradesh, Arunachal Pradesh, Nagaland and Uttar Pradesh submitted their proposals.
- Huge proposal was received in one of the activity - 'Development of Material for incorporation in the ITI's and Diploma Engineering Colleges' Curriculum'. Total of 8 SDAs (MEDA, EMC Kerala, CREDA, PEDA, Tripura SDA, NREDCAP, Arunachal Pradesh SDA, UP SDA) were considered for this and grant of Rs.8 lack was released to each SDAs.
- Furthermore, another activity – 'Debates on energy efficiency and conservation at ITI, Diploma Engineering College(Polytechnic), and Engineering College level' was organized by these 8 SDAs. (MEDA, EMC-Kerala, CREDA, PEDA and NREDCAP @ Rs.6 lakhs each, and Arunachal Pradesh SDA, Tripura SDA and Nagaland SDA @ Rs.5 lakhs each)
- Total of 8 proposals were received under the activity - Establishment / strengthening of energy clubs in schools – and were sanctioned Rs.10 lakh each. It is felt that this is very important activity and should be undertaken by majority of SDAs.

7.7 Human Resource Development (HRD)

The potential for improvement of energy efficiency of processes and equipment through awareness creation is vast. A sound policy for creation, retention and up gradation of skills of Human Resources is very crucial for penetration of energy efficient technologies and practices in various sectors. The component under HRD comprises of theory cum practice oriented training program and providing Energy Audit Instrument Support.

7.8 National Mission for Enhanced Energy Efficiency (NMEEE)

The National Mission for Enhanced Energy Efficiency (NMEEE) is one of the eight missions under the National Action Plan on Climate Change (NAPCC). NMEEE aims to strengthen the market for energy efficiency by creating conducive regulatory and policy regime. The government of India, in 2010, had allotted fund of Rs.235.50 Cr. under NMEEE for two years of the 11th Plan period (2010-12) and later on approved a total outlay of Rs.775 Cr. for 12th Plan. The Mission seeks to adopt market based approach to harness energy efficiency opportunities, which is estimated to be around Rs.74000 Cr. and help achieve total avoided capacity addition of 19598 MW per year. The NMEEE spelt out four initiatives to enhance energy efficiency in energy intensive industries which are as follows:

7.8.1 Perform, Achieve and Trade (PAT)

The PAT is a market based mechanism to enhance the cost effectiveness in improving the Energy Efficiency in industries through certification of energy saving which can be further traded. While the PAT was launched formally in 2012, the first cycle of it ended in year 2014-15 wherein 478 industrial units in eight sectors (Aluminum, Cement, Chlor- Alkali, Fertilizer, Iron & Steel, Paper & Pulp, Thermal Power, Textile) have been mandated to reduce their specific energy consumption (SEC) i.e. energy used per unit of production by certain percentage. The target reduction for each unit was based on their current levels of energy efficiency. Overall, it was aimed to reduce SEC by 4.05% in these industries.

The industrial units which are able to achieve this energy reduction target can receive energy savings certificates (ESCerts) for their excess savings which could be traded on the Power Exchanges and bought by other units under PAT who can use them to meet their compliance requirements. While, industries that are not able to meet their targets either through their own actions or through purchase of ESCerts are liable to financial penalty under the Energy Conservation Act. ESCerts are maintained in the demat form and each ESCert is equivalent to 1 Metric Tonne of Oil Equivalent (MTOE).

Developmental Status

Development of Energy Saving Certificates (EScerts) trading infrastructure is in process in collaboration with CERC. Moreover, PAT "Deepening" process has already been initiated to include more industrial units participate in the energy enhancement scheme. Similarly, "Widening" of the PAT i.e. inclusion of more sector in the PAT fold has also been initiated. PAT Cycle – II commenced from April, 2016 and 621 units have been assigned reduction targets covering 11 sectors with projected savings of 8.869 million toe. With the inclusion of three new sectors namely Railways, DISCOMs and Refineries. PAT Cycle – III has commenced from April, 2017 with the addition of 116 new energy intensive industries with projected savings of 1.06 million toe. Hotels under Commercial Buildings category and petrochemical plants have been notified as new sectors and assigned reduction targets during PAT cycle-IV. The total no. Designated Consumer has now reached to 846.
The EScerts (Energy Saving Certificates) trading infrastructure has been developed by BEE in collaboration with Central Electricity Regulatory Commission (CERC) and was launched by Hon'ble Minister of State (IC) for Power and NRE in September, 2017. So far about 13 lakhs ESCerts have been traded at an overall cost of INR 100 crores.

7.8.2 Market Transformation for Energy Efficiency (MTEE)

Under MTEE, three programs have been developed i.e. Bachat Lamp Yojana (BLY), Super-Efficient Equipment Program (SEEP) and Domestic Efficient Lighting Program (DELP).

Bachat Lamp Yojana (BLY)

It is a public-private partnership program comprising of BEE, Distribution Companies (DISCOMs) and private investors to accelerate market transformation in energy efficient lighting. It was registered in April 2010.

In the next phase of BLY, BEE will promote use of LED lights using the institutional structure of BLY Program. BEE provides support to Rural

Electrification Corporation (REC) for framing technical specification and monitoring and verification of the energy savings from the LED bulbs distributed under RGVVY scheme to BPL households. BEE will also undertake outreach activities to promote large scale adoption of LEDs.

Developmental Status

The BLY program overall targeted an avoided capacity addition (generation) of around 4000 MW during 11th five year plan (2007-12). (Planning Commission, 2013) Under this, over 29 million incandescent bulbs have been replaced by CFLs and 13 tripartite agreements have been signed between BEE investors and DISCOMs.

Super-Efficient Equipment Program (SEEP)

Super-Efficient Equipment Program (SEEP) is designed to promote market for super-efficient appliances by providing financial stimulus innovatively. Under this program, ceiling fan has been identified as the first appliance to adopt. It was assessed that the average power rating of current ceiling fan sold in Indian market is about 70W and therefore, goal is to support the introduction and deployment of super-efficient 35W ceiling fans.
A time bound incentive is to be provided to fan manufacturers to manufacture super-efficient fans and sell them at discounted price.

Domestic Efficient Lighting Program (DELP)

The Domestic Efficient Lighting Program (DELP), introduced in January 2015, is a service model where EESL works with DISCOMs through a benefit sharing approach. The Program obviates the need for DISCOMs to invest in the upfront cost of LED bulbs; EESL procures the LEDs bulbs and provides to consumers at a rate of Rs.10 each as against their market price of Rs.350-600. In addition, at least 3 years free replacement warranty is ensured to the consumers and payment to EESL from DISCOM is spread over 5 years from energy savings achieved. (MD EESL, 2016)

Developmental Status

According to EESL data as on August 23, 2016, over 14.4 crore LED bulbs have been distributed which has resulted in more than 52 million units of energy saving per day. In order to meet the target of installing 77 crore LED lights across India under DELP, EESL has already executed the project successfully in many towns and cities. Out of successfully implemented projects, monitoring and verification work has been done in five towns namely Puducherry, Guntur, Anantapur, Srikakulam and West Godavari which shows a very positive result in terms of energy savings.

7.8.3 Energy Efficiency Financing Platform (EEFP)

To provide a platform to interact with financial institutions and project developers for implementation of energy efficiency projects the Energy Efficiency Financing Platform (EEFP) was launched as one of the initiatives under NMEEE. Under this programme, MoUs have been signed by BEE with M/s. PTC India Ltd, M/s. SIDBI, HSBC Bank, Tata Capital and IFCI Ltd to promote financing for energy efficiency projects.
For capacity building of FIs, BEE signed MoU with Indian Banks' Association for the Training Programme on Energy Efficiency Financing. Till date four Training of Trainers workshops were organized and more than 100 banking/NBFC officials have been trained on EE financing. BEE launched a booklet on "Success Stories for Energy Efficiency Projects Financed in India" and a "Training Manual for Energy Efficiency Financing in India". This booklet of 50 success stories of Energy Efficiency projects financed by SIDBI covers 20 industrial sectors across the country to adopt energy efficient technologies and processes. The training manual covers all the training modules/presentations required for the understanding of energy efficiency projects and their characteristics, and it aims to help in technical/ financial evaluation of EE projects.

7.8.4 Framework for Energy Efficient Economic Development (FEEED)

Framework for Energy Efficient Economic Development (FEEED) is targeted to provide appropriate fiscal instruments that may supplement the efforts of the Government for creation of energy efficiency market. Under FEEED, BEE has constituted two funds namely Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE) and Venture Capital Fund for Energy Efficiency (VCFEE). Under EEFP, awareness workshops for financial instruments available for EE financing are being organized and market assessment for PRGFEE and VCFEE was done in 2016 on which a report was published.

Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE)

Under NMEEE, in 2012 BEE has institutionalized PRGFEE for addressing the debt related issues in financing EE projects. PRGFEE is a risk sharing mechanism to provide Participating Financial Institutions (PFIs) with a partial coverage of risk involved in extending loans for EE projects. PRGFEE guarantees 50% of loan amount or Rs. 10 crore per projects, whichever is less. PRGFEE support has been provided to government buildings, private buildings (commercial or multi-storey residential buildings), municipalities, SMEs and industries. This guarantee is extended to financial institutions extending loans to ESCOs for implementing EE projects.

Developmental Status

- Under PRGFEE, MoP has constituted Supervisory committee for monitoring the implementation of PRGFEE.
- BEE has appointed a consortium of RECPDCL-REC-EESL as Implementing Agency (IA) for operationalization of PRGFEE in July 2015.
- Operation Manual for PRGFEE has already been approved.
- PRGFEE rules have been notified by the government in May 2016.
- Four FIs have been empanelled under PRGFEE which are Andhra Bank, Yes Bank, Tata Cleantech Capital Ltd. and IDFC Bank till date

Venture Capital Fund for Energy Efficiency (VCFEE)

To encourage equity investment in EE projects, BEE has institutionalized Venture Capital Fund for Energy Efficiency (VCFEE) in India. VCFEE Rules have been notified by the government on 31st March 2017. Venture Capital Fund for Energy Efficiency is a fund to provide equity capital for energy efficiency projects. The Fund shall provide last mile equity support to specific energy efficiency projects, limited to a maximum of 15% of total equity required, through Special Purpose Vehicles or Rs. 2 crores, whichever is less. The support is available for only government buildings, private buildings (commercial or multi-storey residential buildings) and municipalities.

Developmental Status

- The VCFEE has been constituted under the provisions of Indian Trust Act 1882. The trust deed was registered with jurisdictional sub-registrar Government of Delhi.
- Board of Trustees for VCFEE has been constituted.
- Fund Manager for operationalization of VCFEE has been identified.

7.9 Power sector related Policies

7.9.1 Mega Power Policy

The Government, in 1995, recognized that in order to improve the power supply situation in the country, India needs to set up more than 10,000 MW of capacity every year in the next few years which required large resources and posed a challenge for the public sector. Subsequently, the private power policy was introduced in order to attract domestic and foreign private investment & the Ministry of Power formulated the Mega Power policy in 1995 and thereafter modified it on several occasions (in 1999, 2006, 2009, 2012, 2014 and 2017) to smoothen the procedures further. At present, the existing provisions and norms prevailing under this policy are as follows. (Ministry of Power, 2017)

- Thermal power projects of capacity 1000 MW or more; or a thermal power plant of capacity of 700 MW or more located in the States of J&K, Sikkim, Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland and Tripura; or a hydel power plant of capacity of 500 MW or more; or a hydel power plant of a capacity of 350 MW or more, located in the States of J&K, Sikkim, Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland and Tripura, should be considered as a mega project.
- The import of capital equipment would be free of customs duty for these projects. In order to ensure that domestic bidders are not adversely affected, price preference of 15% would be given for the projects under public sector. However, the price preference will not apply to tariff based competitively bid project/s of PSUs. (Ministry of Power, 2009)
- Deemed Export Benefits is available to domestic bidders for projects both under public and private sector.
- The income-tax holiday regime, as per the income tax act 1961, is applicable. (Press Information Bureau , 2012)
- The State Governments are requested to exempt supplies made to mega power plants from sales tax and local levies.
- Power Trading Company (PTC) would purchase power from the identified private projects and sell it to the identified distribution utilities. In this way, PTC would enable mega-projects to negotiate with one buyer only and would eliminate mega-projects risk regarding payments. Such security would substantially bring down the tariff from such projects.
- The projects would be offered to the developers only after all the clearances/ land have been obtained so that projects can start soon after they are granted to the most competitive bidder.
- Mega Power Projects would be required to tie up power supply to the distribution companies/ utilities through long term PPA(s) in accordance with the National Electricity Policy and Tariff Policy. (Ministry of Power, 2014)

Scheme development status and impact

The Cabinet Committee on Economic Affairs (CCEA), on 31st March 2017, extended the time period for thermal power producers to receive a "mega power" certificate for tax purpose to 10 years, from the existing 5 years from the date of import. The Mega Power Policy, announced in 2014, identified 25 power plants totaling 32,300 MW for earning additional benefits of about Rs10,000 crore under the policy. According to Business Standards, GMR Energy, Lanco Power, IL&FS, Essar Power and Torrent are among those which would benefit. Only 11,000 MW of these projects are commissioned, while the remaining is under various stages of implementation. Power plants under construction will benefit by way of savings to the tune of ~30-35 lakh per MW. To avail of the benefits, electricity producers need to enter into purchase agreements for at least 70% of the power generated through competitive bidding and balanced through a regulated market. (Press Information Bureau, 2017) (Business Standards, 2017)

Under the Mega Power Policy of 2009, 25 projects have been given provisional mega power project status. But to avail incentives such as lower customs duty and excise duty exemption for equipment, they are required to sign long-term power purchase agreements of eight years for 85% of the power generated, for which they were given five years from the date of the import of equipment. However, only projects accounting for 1,320 MW managed to achieve this. Extending extra time by five more years will enable the remaining projects too to take advantage of the scheme. (LiveMint, 2017)

7.9.2 Renovation and Modernization (R&M) / Life extension (LE) Programme

The new capacity installation being capital intensive, it is always considered wiser to maximise the generation from the existing power stations to ensure optimal utilisation of resources. Renovation and Modernisation (R&M) and Life Extension (LE) have been recognized as cost effective options to achieve additional generation from existing units and better asset management due to its low cost and short gestation period. Besides generation improvement and improvement in availability, other benefits achieved from R&M / LE include life extension, improved safety, reliability and environmental conditions. Many of the thermal power plants are not operating to their full potential and large numbers of thermal units including 200/210 MW units are old and have outlived their normal economical design life. The 66 LMZ units of 200/210 MW Capacity are best potential candidates for Energy Efficiency R&M (EE R&M). A centrally sponsored R&M Programme was launched in 1984 as Phase-I programme under which financial assistance for implementing R&M works was provided by Govt. of India. Further, the R&M and Life Extension of thermal power stations were emphasized to maximize generation and improve their overall performance.

The main objective of R&M of power generating units is to make the operating units well equipped with modified / augmented latest technology equipment /components/ systems with a view to improving their performance in terms of output, reliability and availability to the original design values, reduction in maintenance requirements, ease of maintenance and enhanced efficiency. However, R&M is not a substitute for regular annual or capital maintenance/overhaul which forms a part of operation and maintenance (O&M) activity. Middle life R&M comes up preferably after 100000 hours of operation. The investment made under the scheme should however be evaluated in terms of internal rate of return, net present value, payback period etc. and according to CEA the payback period for R&M / LE should be about 5-7 years (CEA, 2009)

Scheme development status and impact

A large existing capacity i.e. 129 units of total capacity 26283 MW and 95 units of total capacity 21212 MW has been identified for R&M/LE works during 11th plan and 12th plan period. Further, though there has been gradual improvement in plant load factor over the years, there exists a lot of scope for further improvement. The progress of implementation of R&M/LE scheme of over Rs.100 Cr. shall be monitored by MoP/CEA.

R&M/LE works in 32 units with aggregate capacity of 4702.26 MW have been completed during 12th Plan up to 31-12-2016, the detail for this is provided in below table. At present, 4 coal based generating units with aggregate capacity of 530 MW are under shut down for carrying out the R&M/LE works.

7.9.3 Power Distribution

The distribution segment is the key of entire value chain of power sector as this is responsible for supplying electricity to the end user. However this has always remained the main area of concern on account of operational and technical inefficiency, even after more than 13 years of enactment of Electricity Act

Table 7-2 R & M / LE during 12th Five year Plan

SL.NO.	PARTICULARS	LE/R & M WORKS COMPLETED DURING 12TH PLAN NO. OF UNITS & CAPACITY (MW)		TOTAL (STATE SECTOR + CENTRAL SECTOR)
		STATE SECTOR	CENTRAL SECTOR	
1	LE	10 (1380)	11 (1261.76)	21 (2641.76)
2	R & M	5 (850)	6 (1210.5)	11 (2060.5)
Total		15 (2230)	17 (2472.26)	32 (4702.26)

Source: (CEA, 2016)

2003. The financial health of distribution companies (DISCOMs) had degraded mainly on account of non-regular tariff revisions, inefficiency in metering and billing and high network losses due to aged infrastructure. While some progress has been made at reducing the Transmission and Distribution (T&D) losses, these still remain substantially high in many states, much higher than the national average. In order to address some of the issues in this segment, reforms have been undertaken through unbundling the State Electricity Boards into separate Generation, Transmission and Distribution units. Furthermore, privatization has been undertaken in few states (incurring high losses) either through outright privatization or the franchisee model. While there has been a slow and gradual improvement in metering, billing and collection efficiency, the current loss levels still pose a significant challenge for distribution companies going forward. A few key policies and regulations marking impact on distribution segment are described here.

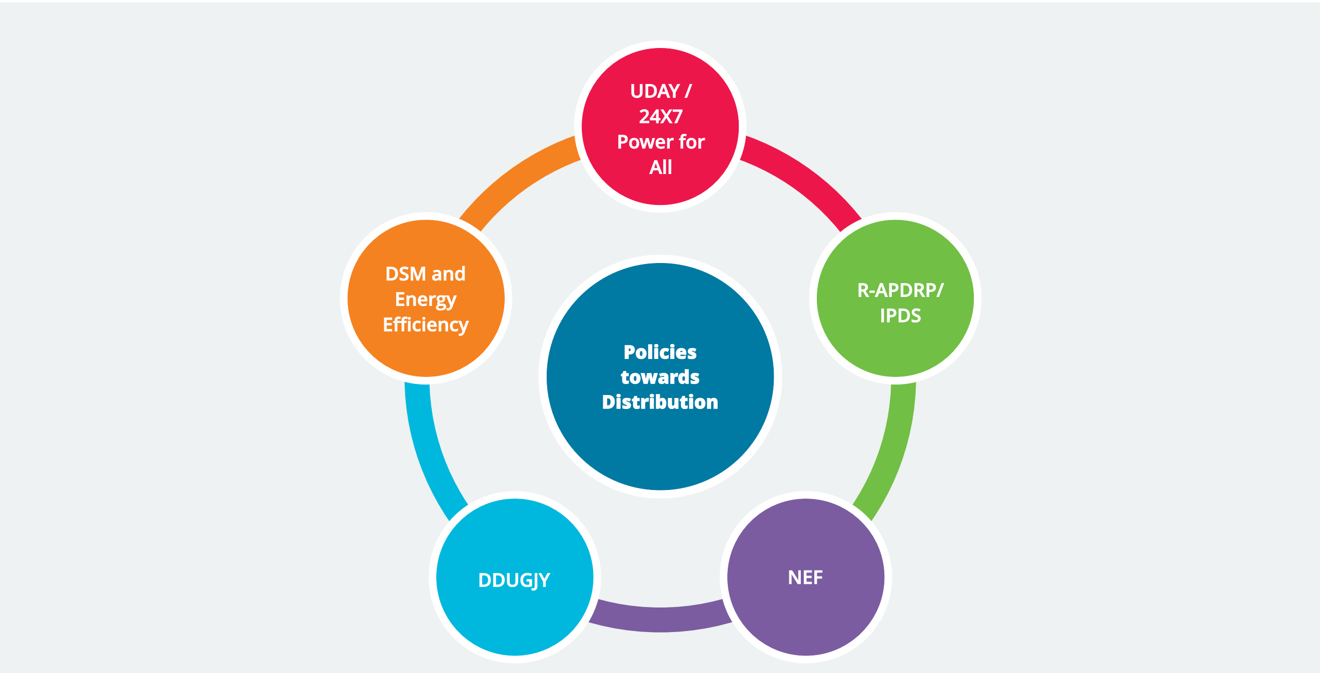
UDAY

DISCOMs in the country, the weakest link in the value chain, had accumulated losses of approximately Rs.3.8 lakh crore and outstanding debt of approximately Rs.4.3 lakh crore (as on March, 2015). Furthermore, DISCOMs were trapped in a vicious cycle with increasing operational losses and interest rate was raised up to 14-15%.

UDAY (Ujwal DISCOM Assurance Yojna), launched in November 2015, is a path breaking reform for the financial turnaround of DISCOMs with an objective to improve the financial and operational efficiency of the state DISCOMs. Adopting UDAY is optional for States, but provides the fastest, most efficient and financially most feasible way for providing 24X7 Power for All. It will be operationalized through a tri-partite agreement amongst the Ministry of Power, State Government and the DISCOM. '24x7 Power for All' (PFA) program is implemented by state Government with active support from Government of India with the objective to connect the unconnected in phased manner by FY 19, ensure 24x7 quality, reliable and affordable power supply to all Domestic, Commercial and Industrial consumers and adequate supply to Agriculture consumers within a fixed time frame. UDAY empowers DISCOMs with the opportunity to break even in the next 2-3 years. This is through four initiatives

i. **Improving operational efficiencies of DISCOMs**
   Operational efficiency improvements like compulsory smart metering, up gradation of transformers, meters etc., energy efficiency

Figure 7-2: Policies and regulations impacting power distribution segment



measures like efficient LED bulbs, agricultural pumps, fans & air-conditioners etc. will reduce the average AT&C loss from around 22% to 15% and eliminate the gap between Average Revenue Realized (ARR) & Average Cost of Supply (ACS) by 2018-19.

ii. **Reduction of cost of power**
Reduction in cost of power would be achieved through measures such as increased supply of cheaper domestic coal, coal linkage rationalization, liberal coal swaps from inefficient to efficient plants, coal price rationalization based on GCV (Gross Calorific Value), supply of washed and crushed coal, and faster completion of transmission lines.

iii. **Reduction in interest cost of DISCOMs**
States shall take over 75% of DISCOM debt as on 30 September 2015 over two years - 50% of DISCOM debt shall be taken over in 2015-16 and 25% in 2016-17. This will reduce the interest cost on the debt taken over by the States to around 8-9%, from as high as 14-15%; thus improving overall efficiency.

iv. **Enforcing financial discipline on DISCOMs through alignment with State finances**
A permanent resolution to the problem of DISCOM losses is achieved by States taking over and funding at least 50% of the future losses (if any) of DISCOMs in a graded manner.

Important features of UDAY

Under the scheme, States shall take over 75% of DISCOM debt as on 30 September 2015 over two years - 50% of DISCOM debt shall be taken over in 2015-16 and 25% in 2016-17. Thereafter, States will issue non-SLR including SDL bonds in the market or directly to the respective banks / Financial Institutions (FIs) holding the DISCOM debt to the appropriate extent. DISCOM debt which is not taken over by the State shall be converted by the Banks / FIs into loans or bonds with interest rate not more than the bank's base rate plus 0.1%.

Furthermore, States shall take over the future losses of DISCOMs in a graded manner and shall fund them as follows:

Scheme development status and impact

Jharkhand was the first state to join UDAY, in December 2015, and thereafter many states have shown their interest in this scheme. With Mizoram coming on board recently, a total of 27 states/ UTs have joined UDAY scheme as on 02nd April, 2017. Based on data available from states up to 31st December 2016, bonds of valuation Rs.232375 Cr. (85.35%) has been issued. While tariff has been revised for 19 UDAY states, the country AT&C loss figure has come down to 22.49% as on 31st December 2016. Furthermore, the revenue gap, which at a time used to be around Rs.1/unit, has reduced to Rs.0.49/ unit. According to power ministry data, a total of 15 states have issued bonds worth Rs.1.83 trillion, as on 31st March 2017, which accounts for 63% of the total debt of all the utilities in these states. In addition to these financial indicators, a few operational indicators are provided below.

Table 7-3 DISCOM losses to be taken over by State

YEAR	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Previous Year's DISCOM loss to be taken over by State	0% of the loss of 2014-15	0% of the loss of 2015-16	5% of the loss of 2016-17	10% of the loss of 2017-18	25% of the loss of 2018-19	50% of the previous year loss

Source: (Press Information Bureau, 2015) (Ministry of Power, 2015)

Table 7-4 Operational indicators for UDAY

PARAMETERS (STATUS AS ON 31ST DECEMBER 2016)	NUMBER	PERCENTAGE	REMARKS
Feeder Metering (Urban)	28270	100%	Data of 17 states
Feeder Metering (Rural)	75949	97%	Data of 17 states
DT Metering (Urban)	589794	48%	Data of 17 states
Feeder Metering (Rural)	1470847	48%	Data of 17 states
Electricity Access to Un-connected Households	1062.89 Lakh	82%	Data of 17 states
Smart Metering above 500 kWh	108382	4%	Data of 15 states
Smart Metering above 200 and up to 500 kWh	130095	2%	Data of 15 states
Feeder Segregation	34660	69%	Data of 13 states
Rural Feeder Audit	98811	100%	Data of 17 states
Distribution of LEDs Under UJALA	1456.57 Lakh	79%	Data of 17 states

Source: (Ministry of Power, 2016)

Table 7-5 AT&C Loss (%) trajectory submitted by States on account of several ongoing reforms process

S. NO	STATES	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
1	Andhra Pradesh	10.00	9.00	8.50	8.25	8.00	
2	Arunachal Pradesh	51.26	46.76	42.76	37.76	33.26	30.00
3	Assam	27.00	25.00	23.00	21.00	19.00	17.00
4	Bihar	43.80	42.00	36.00	29.00	21.00	15.00
5	Chhattisgarh	22.41	21.00	19.50	18.00	15.00	
6	Delhi	13.50	13.00	13.00	12.00	12.00	12.00
7	Goa	21.06	21.06	18.75	16.59	15.00	
8	Gujarat	14.64	14.50	14.00	13.50	13.00	
9	Haryana	32.80	28.80	24.80	19.80	15.00	
10	Himachal Pradesh	14.00	13.85	13.50	13.25	13.00	12.80
11	J&K	61.30	56.00	37.00	34.00	16.00	15.00
12	Jharkhand	39.37	35.00	28.00	22.00	15.00	
13	Karnataka	18.06	15.73	15.50	15.00	14.20	
14	Kerala	11.91	11.68	11.45	11.23	11.00	10.78
15	Madhya Pradesh		26.27	21.15	18.15	17.00	15.00
16	Maharashtra	18.47	17.31	16.74	15.61	14.39	14.00
17	Manipur		44.20	25.15	18.70	15.00	
18	Meghalaya	24.00	23.00	22.00	21.00	20.00	19.00
19	Mizoram	26.14	25.27	23.59	21.99	20.13	18.62
20	Nagaland	68.69	65.50	55.15	44.80	34.45	24.21
21	Orissa	38.89	35.14	31.62	28.44	25.60	22.98
22	Puducherry		19.88	19.00	15.00	12.00	
23	Punjab	16.66	16.16	15.30	14.50	14.00	
24	Rajasthan		24.00	20.00	17.50	15.00	
25	Sikkim	42.00	39.56	34.53	29.50	24.00	
26	Tamilnadu	19.72	19.22	18.97	18.72	18.47	18.00
27	Telengana	13.13	12.88	12.58	12.28	12.00	12.00
28	Tripura	26.35	24.85	21.85	19.85	18.50	16.00
29	Uttar Pradesh	34.22	32.36	28.27	23.63	19.36	14.86
30	Uttrakhand	18.64	17.00	16.00	15.00	14.50	
31	West Bengal	29.00	28.00	25.75	23.50	22.50	21.00

Source: (Ministry of Power, 2016)

R-APDRP / IPDS

The Restructured Accelerated Power Development and Reforms Program (R-APDRP) was launched in July 2008 with focus on establishment of base line data, fixation of accountability, reduction of AT&C losses up to 15% level through strengthening & up-gradation of Sub Transmission and Distribution network and adoption of Information Technology. Projects under the scheme shall be taken up in two parts. Part-A shall include the projects for establishment of baseline data and IT applications for energy accounting/auditing & IT based consumer service centers. Part-B shall include regular distribution strengthening projects and will cover system improvement, strengthening and augmentation etc. The activities to be covered under each part are as follows:

Part – A:

Preparation of Base-line data for the project area covering Consumer Indexing, GIS Mapping, Metering of Distribution Transformers and Feeders, and Automatic Data Logging for all Distribution Transformers and Feeders and SCADA / DMS system (only in the project area having more than 4 lack population and annual input energy of the order of 350 MU). It would include Asset mapping of the entire distribution network at and below the 11kV transformers and include the Distribution Transformers and Feeders, Low Tension lines, poles and other distribution network equipment. It will also include adoption of IT applications for meter reading, billing & collection; energy accounting & auditing; MIS; redressal of consumer grievances; establishment of IT enabled consumer service centres etc. The base line data and required system shall be verified by an independent agency appointed by the Ministry of Power. The list of works is only indicative.

Part – B:

Renovation, modernization and strengthening of 11 kV level Substations, Transformers/Transformer Centers, Re-conductoring of lines at 11kV level and below, Load Bifurcation, feeder separation, Load Balancing, HVDS (11kV), Aerial Bunched Conductoring in dense areas, replacement of electromagnetic energy meters with tamper proof electronics meters, installation of capacitor banks and mobile service centres etc. In exceptional cases, where sub-transmission system is weak, strengthening at 33 kV or 66 kV levels may also be considered.

Under the R-APDRP scheme, utility needs to achieve the following targets of AT&C loss reduction:

a) Utilities having AT&C loss above 30%: Reduction by 3% per year
b) Utilities having AT&C loss below 30%: Reduction by 1.5% per year

Furthermore, they have to submit previous year's AT&C loss figures of identified project area and furnish detail of measures to be adopted for better accountability at all levels in the project area. (PFC, 2017)

The scheme has below mentioned funding mechanism and provision.

i. GoI will provide 100% Loan for part A of the R-APDRP schemes. This entire loan, later on, shall be converted into grant after establishment of the required Base-Line data system within a stipulated time frame and duly verified by TPIEA (Third Party Independent Evaluation Agencies).
ii. GoI will provide up to 25% (90% for special category States) Loan for Part B of the R-APDRP schemes. Only up to 50% (90% for special category States) of this loan shall be converted into grant on achieving 15% AT&C loss in the project area duly verified by TPIEA on a sustainable basis for a period of five years.
iii. If the utility fails to achieve or sustain the 15% AT&C loss target in a particular year, that year's tranche of conversion of loan to grant will be reduced in proportion to the shortfall in achieving 15% AT&C loss target from the starting AT&C loss figure.
iv. The entire loan from GoI will be routed through PFC/REC

The Integrated Power Development Scheme (IPDS) was launched in 2013. The component of IT enablement of distribution sector and strengthening of distribution network envisaged under R-APDRP for 12th and 13th Plans was subsumed in IPDS scheme. The scheme will help in reduction in AT&C losses; establishment of IT enabled energy accounting / auditing system, improvement in billed energy based on metered consumption and improvement in collection efficiency. The projects will be sanctioned by the IPDS Monitoring Committee. After sanction of projects, contracts for execution of projects are to be awarded by States DISCOMs / Power Departments. The projects are to be completed within 24 months from date of award. (IPDS, 2016)

Scheme development status and impact
According to IPDS Project monitoring data, an amount of Rs.25866 Cr. has been sanctioned under the scheme. Out of this amount, only 9.6% of fund has been disbursed and balance 90.4% of funds is yet to be released, as on 31st March 2017.

DDUGJY

The flagship program towards rural electrification, Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), was launched in July 2015. The erstwhile Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) scheme for village electrification and providing electricity distribution infrastructure in the rural areas has been subsumed in the DDUGJY scheme. Rural Electrification Corporation is the Nodal Agency for implementation of DDUGJY. The scheme focuses on feeder separation (rural households & agricultural) and strengthening of sub-transmission & distribution infrastructure including metering at all levels in rural areas. This will help in improving power supply situation to rural households and agricultural consumers as well. (Press Information Bureau, 2015)

Scheme development status and impact
The scheme has an outlay of Rs.76000 Cr for implementation of the projects under which Government of India shall provide Grant of Rs.63000 Cr.

Under DDUGJY-RE, Ministry of Power has sanctioned 5236 projects (incl. 3709 DDG projects) to electrify 128432 un-electrified villages, intensive electrification of 655247 partially electrified villages and provide free electricity connections to 420.04 Lakh BPL rural households. As on 31st March, 2016, works in 116144 un-electrified villages and intensive electrification of 351233 partially electrified villages have been completed and 232.25 Lakh free electricity connections have been released to BPL households. (Ministry of Power, 2016)

Furthermore, according to 'Garv' apps, which show status of rural electrification work, out of 597,464 census villages, 592,972 villages (99.2%) have been electrified as on 03rd April 2017.

7.10 Energy efficiency technologies and measures adopted by Railways

The Energy Efficiency and Conservation Program (EECP) aims at progressively introducing or expanding the adoption of a number of traction and non-traction energy efficiency technologies and measures in the railways system to reduce energy consumption. The technologies and measures which have been proven successful in India are described below.

1) **Installation of LED lights in Coaches:**
   Train coaches usually have conventional lighting arrangement by 20 Watt lamps which consume 28 Watts including 8 Watts for choke. On the other hand, LED replacement lights will require only 12 Watts that also gives better light and save approximately 60% of electricity. Moreover conventional lamps last for about 5000 hours while the LED light is expected to last for 50,000 hours.

   United Nations Development Program (UNDP) revealed that the work was undertaken to replace the lamps in 200 AC coaches with LED lights at an investment of around USD 6383 for every coach. It was estimated to obtain reduction in electricity consumption by about 6048 kWh per coach annually. The total investment was assumed to be recovered in a period of 2.5 years (Payback period) in terms of reduction in expenditure on account of energy saving brought by LEDs.

2) **Installation of Automatic Switched Capacitor Bank (ASCB) to reduce electrical losses in Traction Sub Stations (TSS)**

Provision for Automatic switched Capacitors help correcting the power factor of electrical loads at Traction Sub Stations (TSS). All TSS at present have fixed capacitor banks to compensate Power Factor (PF) to save electricity losses in line. Due to fluctuating nature of traction demand, they are unable to optimally compensate the losses. Modern Automatic switched Capacitor Banks can compensate PF to 0.98 as compared to PF of 0.85 achieved at TSS with older capacitor banks. (PF of 1 has minimum losses.) While, Electrical load with low power factor draws more current and thereby account more line loss than a load with high power factor, it is assumed that the line losses presently at 5% of traction energy will reduce by 25% (of the line losses) on introduction of Intelligent Capacitor Banks and the device is expected to have a life of 20 years.

3) **Replacement of Fluorescent tube lights with low energy consumption lights (T5 fluorescent tubes in place of T12 tubes for lighting for stations, workshops and railway offices)**
T12 consumes about 55 Watts, whereas T5 consumes only 32 Watt and also provides better light (104 lumen/ Watt) as against the T12 (60 lumen/ Watt). Approximately, 42% reduction in electricity consumption could be expected with this replacement. In addition, life of T5, approximately 20,000 hours, is four times longer than T12 (5,000 hours).

United Nations Development Program (UNDP) revealed that the work was proposed by IR to replace 5 Lakh number of T12 with T5 at the total investment cost of over USD 8.5 million. On account of this, it was estimated to achieve total energy saving of around 27.6 million units every year. And the payback period on investment was in tune of 2.9 years.

4) **Replacement of incandescent bulbs with CFLs bulbs for service buildings and railway quarters**
IR has about 650,000 houses for employees which are mostly fitted with incandescent bulb of 60 Watts for lighting. Replacement of these bulbs with 9 Watt CFL could provide electricity savings of almost 80%. Moreover CFL, with service life of over 8000 hours, has upper edge over incandescent bulb which last for only around 1000 hours.

It was proposed to replace 650,000 incandescent bulbs of those houses by CFLs at the total investment cost of almost USD 1.4 million. On account of this, it was estimated to achieve total energy saving of around 79.56 million units every year. And the payback period on investment was estimated to be just 0.2 year.

5) **Installation of VVVF (Variable Voltage Variable Frequency) drives for machine**
VVVF drives for electric motors are more versatile and draw minimum energy from source for the duty cycle and have minimum losses in starting. These drives will be installed on machines with frequent starts and stop, and variable load duties, like lifts, compressors, lathes, pumps etc.

It was proposed to install VVVF drives on 1,000 machines in IR. It is expected to save about 30% in energy demand due to this. .For an average motor Electricity consumption without VVVF drive is about 10,800 kWh per drive per annum while machine with VVVF drive would consume be 7,560 kWh per annum (a reduction of 30% electricity). The cost of a VVVF drive is about 1,064 USD per device. It is expected that the life of such drive is about 20 years. The payback period on investment is 3.1 years.

Energy efficiency implemented activities in Railways

Under Domestic Efficient Lighting Program (DELP) Scheme, more than 10 lakh LED bulbs have been distributed to railway staff till Sept.'16. In addition, 1.68 lakh LED bulbs were installed by Zonal Railways in railway stations and service buildings till now. Some other measures implemented on non-traction side for energy conservation are:

- Replacement of tube lights with LED tube lights
- Replacement of 90 W ceiling fans with 60 W ceiling fans
- Automation of Pumps with GSM based techniques
- Use of energy efficient pumps
- Micro-controller based Automatic Platform

Lighting Management System with segregation of 70% / 30% circuits

- Use of 3 stars and above labeled electrical products and equipment
- Solar based LED lighting system for level crossing gates
- Use of solar water heater in place of electric geyser
- Provide occupancy sensors in offices.
- To take up this goal of energy efficiency, IR has become a part of PAT scheme of BEE. Under this, 22 Designated Consumers has been declared (16 Zonal Railways and 6 production units).
- Policy issued for use of LED lighting for all Railway applications.

Over the last six years Railways have been able to improve upon Specific Energy Consumption (SEC) by about 18.9% through various energy conservation initiatives. This in effect means a saving of about Rs.2656 Cr according to BEE.

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