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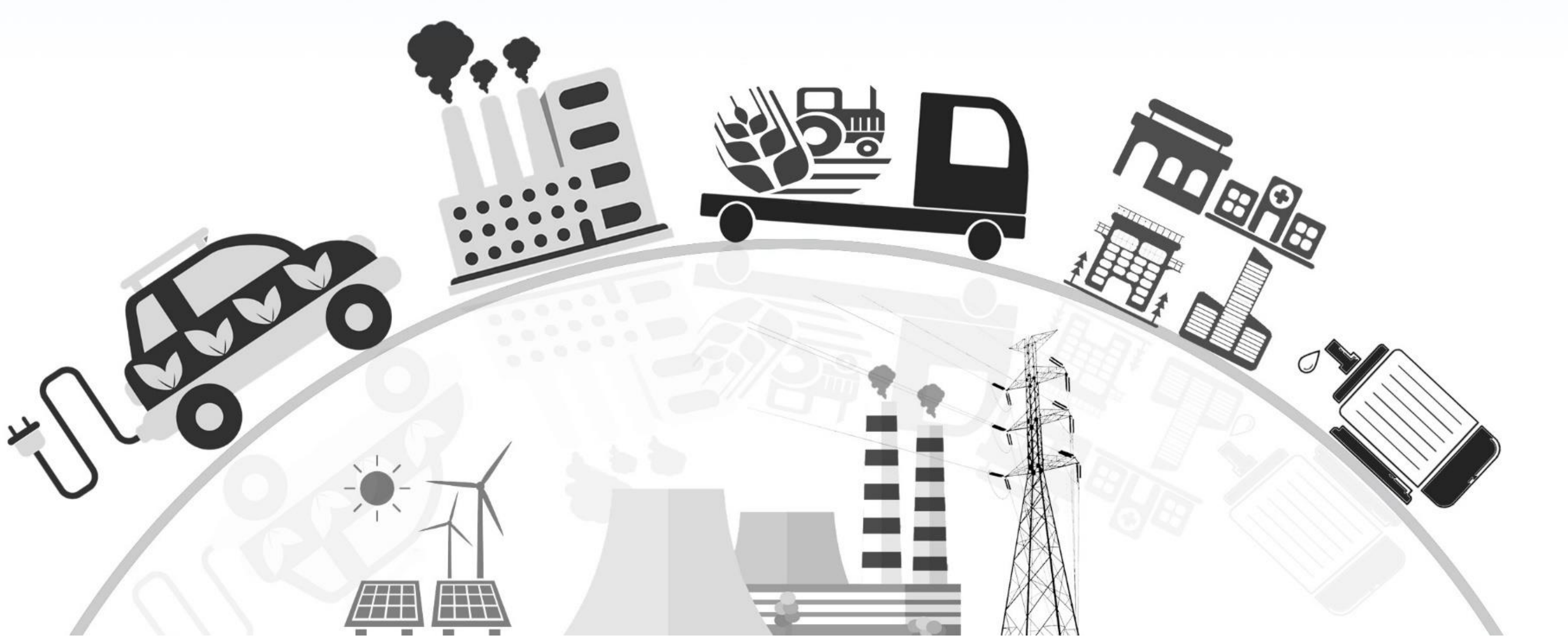
Roadmap for Achieving India's NDC Pledge



Roadmap for Achieving India's NDC Pledge

Center for Study of Science, Technology and Policy (CSTEP)

October, 2018

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Acronyms

AC	Air Conditioner
AFOLU	Agriculture, Forestry and Other Land Use
AFR	Alternate Fuel and Raw material
AgDSM	Agricultural Demand-side Management
BAU	Business-as-Usual
BEE	Bureau of Energy Efficiency
BF-BOF	Blast Furnace – Basic Oxygen Furnace
BIS	Bureau of Indian Standards
BLY	Bachat Lamp Yojana
BUR	Biennial Update Report
CAGR	Compounded Annual Growth Rate
CFL	Compact Fluorescent Lamp
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CoP	Conference of Parties
DRI	Direct Reduced Iron
ECBC	Energy Conservation Building Code
EE	Energy Efficiency
EESL	Energy Efficiency Services Limited
EPS	Electric Power Survey
EV	Electric Vehicle
FAME	Faster Adoption and Manufacturing of Hybrid Electric Vehicles
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHGPI	GHG Platform India
GoI	Government of India
GSDP	Gross State Domestic Product
GVA	Gross Value Added
ha	Hectare
HP	Horse Power
HVAC	Heating, Ventilation and Air Conditioning
IEA	International Energy Agency
IESS	India Energy Security Scenarios
IF	Induction Furnace
IMRT	India Multi-Region TIMES
INCCA	Indian Network on Climate Change Assessment
INR	Indian National Rupee
IP	Irrigation Pump
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IRADe	Integrated Research for Action and Development
ISEER	Indian Seasonal Energy Efficiency Ratio
KUSUM	Kisan Urja Suraksha evam Utthaan Mahabhiyan
kVA	Kilo Volt Ampere

kWh	kilo Watt hour
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, Land Use Change and Forestry
MIS	Micro Irrigation Systems
MNRE	Ministry of New and Renewable Energy
MoEFCC	Ministry of Environment, Forest and Climate Change
MSME	Medium, Small and Micro Enterprise
MT	Metric Tonnes
$MtCO_2e$	Million Tons of CO_2 Equivalent
Mtcs	Million Tonnes of Crude Steel
N_2O	Nitrous Oxide
NDC	Nationally Determined Contribution
NICRA	National Initiative on Climate Resilient Agriculture
NMEEE	National Mission for Enhanced Energy Efficiency
NREDCAP	New & Renewable Energy Development Corporation of Andhra Pradesh Ltd.
NSM	National Solar Mission
NSVA	Net State Value Add
OECD	Organization for Economic Co-operation and Development
OPC	Ordinary Portland Cement
PAT	Perform Achieve and Trade
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
PMUY	Pradhan Mantri Ujjwala Yojana
PNG	Piped Natural Gas
PPC	Portland Pozzolona Cement
PSC	Portland Slag Cement
PV	PhotoVoltaic
SEC	Specific Energy Consumption
SMAM	Sub-Mission on Agricultural Mechanisation
TIMES	The Integrated MARKAL-EFOM System
TWh	Terawatt hour
UJALA	Unnat Jeevan by Affordable LEDs for All
UNFCCC	United Nations Framework Convention on Climate Change
VFD	Variable Frequency Drive
WHR	Waste Heat Recovery

Executive Summary

In October 2015, India submitted its Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC). Among the goals was the pledge to reduce the emissions intensity of Gross Domestic Product (GDP) by 33–35% over 2005 levels, by 2030. In addition, the NDCs also targeted 40% fossil-free power generation capacity by 2030 and creation of additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent (CO_2e).

CSTEP evaluated the Green House Gas (GHG) emissions intensity pledge by its two components: (a) GHG emission intensity of energy (kgCO_2e/kWh $_{\text{Primary Energy (PE)}}$) and (b) energy intensity of GDP (kWh $_{\text{PE}}$ /INR). Addition of renewable energy capacity and policies to curb fossil fuel consumption help to reduce India's GHG emissions. The ratio of energy required to produce one unit of GDP showcases the energy efficiency of the economy. We analysed historic trends of economy-wide emissions and modelled future emission trajectories accounting for energy demand sectors.

The analysis indicated that our emissions intensity of energy is likely to grow by 15%–26% over 2005 levels by 2030. This is mainly due the growth in transport and industrial energy demands. Further share of cooking demand reduces while emission intensity of cooking increases with shift from traditional biomass to modern cooking fuel. Hence, to meet the emissions intensity of GDP target and compensate for this growth in emissions intensity of energy, India will have to reduce its energy intensity of GDP by 38–45% over 2005 levels.

We projected and evaluated scenarios with a combination of technology and policy options to evaluate the impact of energy efficiency in reducing aggregated energy demand till 2030. The analysis indicated that under rigorous implementation of current policy, India can achieve the required energy intensity reduction by 2030. In this Business-as-Usual scenario, total energy demand is calculated to be 9,111 TWh. CSTEP modelled best available technologies in policy scenarios (EE1 & EE2) and found that around 1,000–1,700 TWh (11%–19%) of energy demand can be avoided in 2030 by adopting these technologies.

The transport sector has the highest energy savings potential of around 40% in 2030, which is largely driven by ambitious adoption of electric vehicles and shift from private to public transport. Buildings (including cooking) contributes to around 30% of the estimated savings. This is largely driven by nearly 300 million people transitioning from traditional biomass to efficient stoves operating on LPG and PNG and adoption of super-efficient appliances. Industries presented modest savings potential of around 25%. This is because major industries like cement and aluminium production already use the global best practices and technologies, mainly due to industry competitiveness.

Government vision and support plays a pivotal role in seamless integration of energy-efficient practices, which will further bolster India's progress towards achieving the NDC pledge. In order to assess state preparedness, we considered a combination of macroeconomic indicators (Net State Value Add, Gross State Domestic Product and Population Growth) and key performance metrics (crop intensity, energy consumption per sq.m. and industrial value add) in each sector. We identified eight states (Andhra Pradesh, Maharashtra, Karnataka, Uttar Pradesh, Tamil Nadu, Gujarat, West Bengal and Rajasthan) where policies across all four sectors were mapped based on these metrics. To examine policy adequacy among these states, we created a policy maturity index to showcase current capacity for energy efficiency related policies, or lacuna thereof. The findings of this analysis indicate that several states lack energy efficiency focussed policies, and the interest towards addressing energy efficiency is primarily driven by the Government of India. Karnataka, Andhra Pradesh, Maharashtra and Gujarat have relatively better energy efficiency sectoral policies as compared to other states.

Key interventions that can be implemented across sectors to further improve energy efficiency are listed below:

(a) Higher adoption of electric vehicles, fuel efficiency improvements and increased fuel blending to reduce dependency on oil imports; a focus on public transportation systems such as metros instead of elevated flyovers at congested urban situations.
(b) Mandatory implementation of Energy Conservation Building Code (ECBC), with efficient services such as lighting and Heating, Ventilation and Air-Conditioning (HVAC) through star rated appliances.
(c) Improvements in specific energy consumption in industries through technology switch, improved auxiliary equipment, process switch and concerted efforts to increase the use of alternative raw materials and fuels.
(d) Strong support for research and development in potentially disruptive areas such as battery materials and technology for the mobility sector and next generation HVAC systems for Indian conditions.
(e) Replacement of existing irrigation pump sets with energy efficient star rated pump sets.

Table of Contents

List of Figures

List of Tables

1. Introduction

India announced its Nationally Determined Contributions (NDCs) at the Conference of Parties (CoP) meeting in Paris, 2015. In its NDCs, India seeks to (a) reduce the Greenhouse Gas (GHG) emissions intensity of its Gross Domestic Product (GDP) by 33–35% of 2005 levels, by 2030; (b) build 40% of fossil-free power generation capacity by 2030, and (c) create an additional carbon sink of 2.5 to 3 billion tonnes of carbon dioxide equivalent (CO_2e) by 2030. The NDCs embody efforts by countries to reduce national emissions and adapt to the impacts of climate change. The Paris Agreement (Article 4, Paragraph 2) requires each country to prepare, communicate and maintain successive NDCs that it intends to achieve. In this sense, India's current NDCs are just the beginning of a long series of in-country efforts to pursue domestic mitigation measures.

Emissions intensity is the level of GHG emissions per unit of economic activity, usually measured at the national level as emissions intensity of GDP. The metric is a composite of two other indicators—energy intensity[1] and fuel mix (which reflects the fossil intensity of energy consumed) (Kevin A, Timothy, & Jonathan, 2005). Further, it also accounts for non-energy GHG emissions. Hence, progress against the NDC pledge to reduce emissions intensity of GDP needs to account for economic activity, fossil intensity of energy supply and energy efficiency in end-use sectors.

Using government-reported data, we estimated that GHG, emissions intensity of GDP declined at around 4% Compounded Annual Growth Rate (CAGR) between 2005 and 2010[2]. In this period, India's GDP grew at about 6%, and overall emissions grew at 4.7%. Interestingly, the two component metrics, emission intensity of energy and energy intensity of GDP, declined at around 2.38% and 2.43%, respectively (Table 1). In the 1990s, India had higher levels of fossil-fuel intensity and efficiency levels were poor across several production sectors; with persistent technological improvements, a steeper decline in emission intensity of GDP till 2000 (at 9% CAGR) was reported (Kevin A et al., 2005).

Table 1: Recent trends in India's key climate metrics

Metrics	2005	2010	CAGR	% Reduction
Emission Intensity of GDP (Energy Sector) (kg CO_2/INR$_{@2011\text{-}12\ prices}$)	0.024	0.019	-4.7%	21%
Energy Intensity of GDP (kWh/INR$_{@2011\text{-}12\ prices}$)	0.12	0.10	-2.4%	12%
Emissions Intensity of Energy (kg CO_2/kWh)	0.21	0.18	-2.4%	11%

Source:(CEA, 2018; GoI, 2015c; MoEFCC, 2015)[3]

[1] Energy intensity is a metric used to reflect the level of Energy Efficiency (EE) and overall economic structure of a country and the value of goods traded across borders.

[2] The government's biennial update report (BUR) to the UNFCCC reported a decline of 2.5% in the overall emission intensity in the same period with GDP at 2004-05 prices. In this report the emission intensity reduction appears higher with GDP at 2011-12 prices.

[3] Since emission values in official inventories are available for calendar years, the real GDP obtained for financial years for the period 2004-05 to 2010-11 was approximated to calendar year estimates using a 25:75 ratio.

In the future too, technological changes and supporting policies will play a crucial role in reducing fossil-fuel intensity of energy supplied and end-use efficiency. With regards to fossil-fuel intensity reduction, India's NDC target, of 40% fossil-free electricity generation by 2030, aspires for ambitious technological change. This has found mention in several policy documents—most notably, in the National Electricity Plan (CEA, 2018). The plan foresees no new coal capacity during 2022–2027. India's coal power plants used to be predominantly subcritical[4], with a generation efficiency of 32%. However, new coal plants have higher efficiency boilers (supercritical or ultra-supercritical). The Government of India (GoI) has initiated numerous efforts to accelerate development and deployment of renewable energy in the country; Moreover it plans to increase India's renewable energy capacity from 30 GW in 2016-17 to 175 GW by 2021-22 (CEA, 2018). In pursuit of supporting renewable energy development, India has also spearheaded the International Solar Alliance (ISA). However, the extent to which the renewable energy targets are achieved and deployment plans are implemented, remains to be seen.

In terms of end-use efficiency, the key sectors can be broadly categorised into power generation, industry, transport, buildings, cooking and agriculture. Certain sectors like cooking and transport still exhibit highly inefficient behaviour and planning practices. The GoI has developed and framed several policies to support efficiency improvements in alignment with the NDC target. Some states have taken on progressive action while others are still in the process of developing a supportive policy environment. A systematic analysis of the policy efforts, compared alongside modelled efficiency targets, can help identify and prioritise policy interventions for achieving the NDC target.

It is in this context that CSTEP undertook this study to decode the NDCs and estimate the contributions from end-use efficiency and fuel-requirements (in end-use sectors) on overall emission intensity. The main objectives of this study were the following:

(1) Decode the NDCs: CSTEP developed a mathematical model to examine the role of energy and non-energy emissions, and estimated the role of energy efficiency towards realising NDC commitments. Trends in historical emissions by sector and analysis from energy systems modelling were used to quantify implications for energy efficiency improvements.

(2) Assess the role of technologies and policies: Contributions from each sector under different technological and policy scenarios were analysed using detailed spreadsheet-based analyses.

(3) Evaluate state-level preparedness: Finally, policy gaps and state preparedness were analysed to evaluate state requirements in order to achieve the NDCs.

The subsequent chapters will present the key insights from the analysis.

[4] The difference between subcritical, supercritical and ultra-supercritical versions of pulverised coal combustion technology relates to the steam pressure within the boiler.

2. Background and Historical GHG Emissions

India is the fourth largest GHG emitter, after China, the United States and the European Union. As per the GoI, the economy-wide emissions in 2010 were 1,884 $MtCO_2e$. The Land Use, Land Use Change and Forest (LULUCF) sector negated 252 $MtCO_2e$ of emissions (MoEFCC, 2015). It is important to note that this is the most recent emission inventory published by the Ministry of Environment, Forest and Climate Change (MoEFCC), GoI, in 2015.

In order to establish a credible baseline for the NDC targets, CSTEP developed an emission inventory after a thorough review of available sources depicted in Figure 1. The activity data was sourced mainly from government sources and publically available literature (GHGPI, 2017).

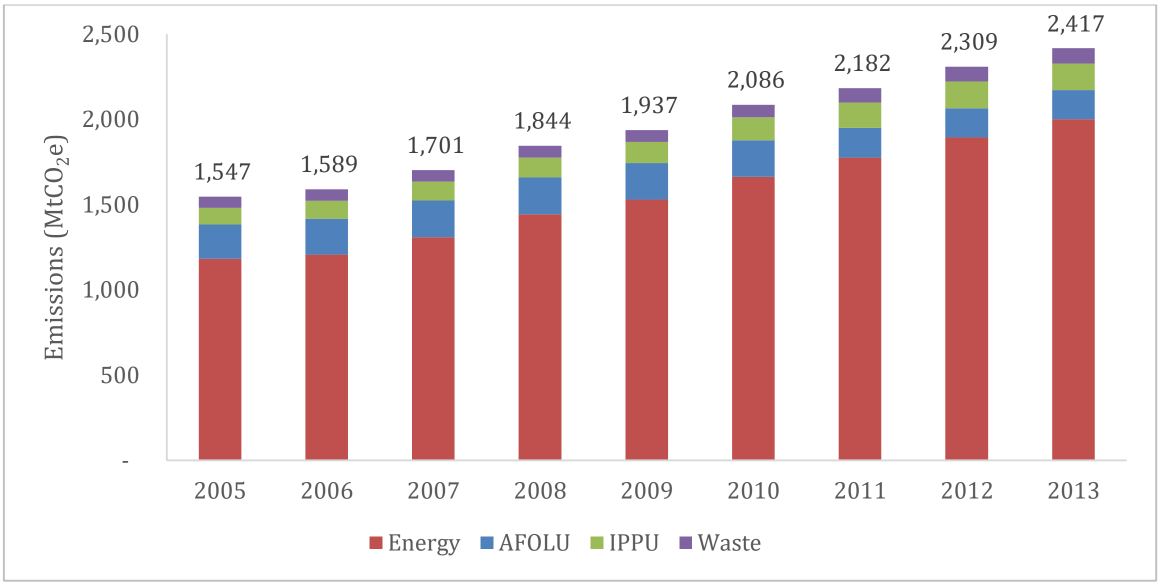

Figure 1: Historical emissions (2005–2013)

In 2013, emissions from energy, Industrial Processes and Product Use (IPPU), waste and Agriculture, Forestry and Other Land Use (AFOLU) sectors were 2,417 $MtCO_2e$, as compared to 1,547 $MtCO_2e$ in 2005 (GHG Platform-India, 2017). The energy sector has been the largest contributor of GHG emissions (83% in 2013), with a steady increase since 2005 (76%). In absolute terms, IPPU sector emissions have nearly doubled in this period, from 98 $MtCO_2e$ to 156 $MtCO_2e$; however, this sector's contribution to overall emissions is relatively low (roughly 6%). It is important to note that emissions from AFOLU sector declined at 2%, while the waste sector contribution has grown at around 4%.

Owing to economic growth, the overall demand for energy across all the sectors is increasing at a rapid rate. Emissions from the energy sector have also seen a steady increase despite the influx of renewable energy. This is primarily due to the dominant role of fossil fuel (coal, oil and natural gas) in the energy mix. The increase in emissions from IPPU can be attributed to the growing demand for core industrial commodities such as cement and steel, wherein large quantities of CO_2 are released due to decarbonation processes.

Sectoral Trends

(a) Energy based emissions primarily include two key activities—fuel production and fuel combustion. Fugitive emissions occur when fuel (coal, oil and natural gas) is produced at the mining facility and transported to end-users. Emissions from fuel combustion include activities such as electricity generation and fuel use in demand sectors like agriculture, buildings, industries and transport. In 2013, emissions from the energy sector were 2,005 $MtCO_2e$ (Ananthakumar Murali R, Rachel R, Lakshmi A, & Malik Y, 2017). Between 2005 and 2013, emissions from the energy sector grew at a CAGR of 6.8%. Emissions from electricity generation contribute to 55% of energy sector emissions, followed by industries (24%) and transport (12%) (GHG Platform-India, 2017).

(b) Emissions from IPPU account for process-based emissions in industries such as cement (decarbonation of limestone), steel (reduction of iron ore) and ammonia production. These emissions registered an annual growth rate of 6% between 2005 and 2013. The absolute emissions were noted to be 156 $MtCO_2e$ in 2013 (Gupta, Biswas, & Ganesan, 2017). The cement sector contributed to over 50% of IPPU emissions in 2013 (Indian Bureau of Mines, 2015).

(c) Solid waste disposals and waste water (domestic and industries) are two key sources of emissions from the waste sector. These emissions grew from 66 $MtCO_2e$ in 2005 to 89 $MtCO_2e$ in 2013 (Chaturvedula, Kolsepatil, & Jha, 2017)—registering an annual growth rate of 3.9% (GHG Platform-India, 2017).

(d) AFOLU-based emissions reduced marginally due to increased removal of CO_2 by land (sinks). Emissions from livestock and rice cultivation are two primary sources of AFOLU-based emissions. Livestock emissions accounted for almost 65% of AFOLU emissions during this period (2005 — 2013), while emissions from rice cultivation and other aggregate sources (biomass burning, agriculture soils and manure management) accounted for 35% of emissions (Dhingra & Mehta, 2017).

3. Approach

In order to identify policy interventions required to achieve NDCs, a deeper understanding of major GHG-emitting sectors was needed. This study quantified targets mentioned in various policies pertaining to NDCs and other key sectoral mitigation strategies of the GoI. Further, a historical emissions inventory was compiled and recent trends were analysed. To assess the shortfall or progress of current mitigation plans, a systemic assessment of current technologies and future applicability was necessary. Using a mathematical formulation, the target on emissions intensity of GDP was decomposed into its sub-components: *energy intensity of GDP* and *emissions intensity of energy*. Considering the NDC targets (higher installed fossil-free generation capacity and creation of additional carbon sinks), the required reduction in energy intensity of GDP was determined. The study, thus, established a quantitative basis for energy-efficiency improvements required across the economy and within sectors.

Further, keeping in mind current technologies, the energy savings potential associated with leapfrogging to global best available technologies in end-use sectors was also assessed. The possible reduction in energy intensity across key energy demand sectors was determined by examining the impact of current and proposed technologies and policies in these sectors. A spreadsheet-based accounting framework was soft linked to CSTEP's India Multi-Regional TIMES (IMRT[5]) model for scenario analysis. The analysis was conducted to determine the potential energy savings in each key demand sector, and thereby, the overall energy intensity of GDP.

Finally, as successful policy formulation and implementation is key to enabling energy efficiency, this study also evaluated gaps in national and state-level policy frameworks and provides recommendations. Based on the potential for energy intensity reduction across the demand sectors, state-level policy preparedness was assessed. Eight states were identified on the basis of their energy savings potential, informed by sector-specific metrics. A qualitative policy maturity index was prepared and states were ranked in order to identify policy recommendations.

[5] The India Multi Regional TIMES model (IMRT) is a partial equilibrium cost-optimisation model, where the power sector is formulated as an optimisation model while the end-use sectors follow an accounting framework. TIMES (The Integrated MARKAL EFOM System) is a dynamic partial equilibrium optimisation model, which is widely used for energy and environment systems analysis to explore least cost and low emission pathways (Loulou, Remne, Kanudia, & Goldstein, 2005).

4. Decoding the NDCs

According to IPCC, economy-wide CO_2 emissions can be divided into two categories, namely energy and non-energy. Energy emissions account for a major share of overall emissions and constitute emissions from all energy-related activities such as electricity generation, transport, etc. Non-energy emissions contribute a minor share and include the net value of the IPPU, agriculture, waste and LULUCF sectors (as in Equation 2).

Equation 1

$$CO_2 = [CO_2]_{Energy} + [CO_2]_{Non-energy}$$

Equation 2

$$[CO_2]_{Non-energy} = [CO_2]_{Agriculture} + [CO_2]_{IPPU} + [CO_2]_{Waste} + [CO_2]_{LULUCF}$$

Equation 3

$$\left[\frac{CO_2}{\text{GDP}}\right] = \left[\frac{[CO_2]_{Energy}}{\text{GDP}}\right] + \left[\frac{[CO_2]_{Non-energy}}{\text{GDP}}\right]$$

Emissions intensity is the amount of emissions generated per unit of activity. It can be used as a metric to assess the cleanliness of an energy system or economy depending on the unit of activity considered. This can be decomposed as follows:

Equation 4

$$\left[\frac{[CO_2]_{Energy}}{\text{GDP}}\right] = \left[\frac{[CO_2]_{Energy}}{\text{Energy}}\right] \times \left[\frac{\text{Energy}}{\text{GDP}}\right]$$

In Equation 4, the first term on the right is the CO_2 emissions per unit energy generated. It reflects the extent to which energy supply depends on fossil fuels and other renewable sources. Further, it takes into account the conversion efficiency of energy technologies. For instance, super-critical power plants are more efficient than sub-critical power plants. Therefore, super-critical plants generate lower CO_2 per unit electricity than sub-critical plants.

The second term represents the amount of energy required to generate one unit of GDP. It depends on the structure of the economy and the relative share of end-use sectors, namely industry, services (transport, buildings and cooking) and agriculture sectors, in addition to the energy efficiency of these sectors. For instance, penetration of Light Emitting Diode (LED) lamps results in reducing the energy footprint of the buildings sector, without compromising on the lighting service offered. This results in efficient consumption of energy for every unit of GDP generated in the buildings sector.

Equation 5

$$\left[\frac{CO_2}{GDP}\right] = \left[\frac{[CO_2]_{Energy}}{Energy}\right] \times \left[\frac{Energy}{GDP}\right] + \left[\frac{[CO_2]_{Non-energy}}{\text{GDP}}\right]$$

This equation can be rewritten as:

Equation 6

$$p = xy + r$$

Where,

$p = \left[\frac{CO_2}{GDP}\right]$ In the base year (2005),

$x = \left[\frac{(CO_2)Energy}{kWh}\right]$ In the base year (2005),

$y = \left[\frac{kWh}{GDP}\right]$ In the base year (2005)

$r = [\frac{(CO_2)Non-Energy}{GDP}]$ in the base year (2005)

The change in values of these parameters between 2005 and 2030 can be written as:

Equation 7

$$(p + \Delta p) = (x + \Delta x)(y + \Delta y) + (r + \Delta r)$$

Equation 8

$$\Delta p = x\Delta y + y\Delta x + \ \Delta x\Delta y + \Delta r$$

Some further simplification leads to the following equation:

Equation 9

$$\frac{\Delta \mathrm{p}}{\mathrm{p}} = \frac{\frac{\Delta \mathrm{x}}{\mathrm{x}} + \frac{\Delta \mathrm{y}}{\mathrm{y}} + \left(\frac{\Delta \mathrm{x}}{\mathrm{x}}\right)\left(\frac{\Delta \mathrm{y}}{\mathrm{y}}\right) + \left(\frac{\Delta \mathrm{r}}{\mathrm{xy}}\right)}{1 + \left(\frac{\mathrm{r}}{\mathrm{xy}}\right)}$$

Here, the values of p, x, y, r and s refer to the base year of 2005. The change in values are between 2030 and 2005. For instance,

Equation 10

$$\frac{\Delta p}{p} = \frac{p_{2005} - p_{2030}}{p_{2005}}$$

Therefore, the NDC commitment implies changing the x and y terms to achieve a value of 0.33 or 0.35 for $\frac{\Delta \mathrm{p}}{p}$. We contend that while this is a simplistic mathematical representation of a complex economy-wide target, estimating the terms in this equation provides us some analytical basis for evaluating sectoral targets.

4.1 Methodology

This section examines the contribution of various factors in Equation 9. The approach is as follows:

- We examine the role of non-energy sectors (IPPU, waste, agriculture and LULUCF) and project emission trajectories of these sectors till 2030 based on historical trends.
- Similarly, we analyse the potential of the energy sector; that is, estimate the likely value of $\frac{\Delta x}{x}$ between 2005 and 2030. This is based on the results from various energy models like India Energy Security Scenarios (IESS)-2047 tool (IESS, 2015a), CSTEP's IMRT model and studies commissioned by MoEFCC.
- Subsequently, emission reduction strategies such as high renewable penetration and the carbon sink targets from the NDC are accounted for, to determine the value of $\frac{\Delta y}{y}$ or change in energy intensity required to achieve the NDC commitments.

4.2 The Role of Non-Energy Sectors in the NDCs

The overall share of emissions from the non-energy sector was accounted to be 33% (including LULUCF) in 2010. Historical emissions corresponding to each sector are obtained from 2005 onwards, from reports published by MoEFCC and the GHGPI.

IPPU: This sector covers the GHG emissions from various industrial activities during the production process. The industrial process emissions increased from 108 to 172 $MtCO_2e$ from 2005 to 2007 (MoEFCC, 2015). Increase in production and the kind of process technologies deployed in industries mainly drive IPPU emissions. More than 62% of the IPPU emissions are from the cement industry, about 15% from the ammonia industry and the remaining from various other mineral, chemical and metal industries. IPPU emissions in the cement industry are likely to grow in the future due to increased urbanisation and concretisation of cities (GBPN, 2014).

IPPU emissions have been witnessing a steady growth owing to growth in key industries. The emissions from this sector have seen a yearly growth rate of 7% from 2005 to 2013[6]. This can be attributed to mainly the increase in cement production. However, the government has promoted the use of alternative cements like Portland Pozzolana Cement (PPC) and Portland Blast Furnace Slag Cement (PSC), which have lower process emissions. Further, the emissions from ammonia production has grown on account of demand from the fertiliser industry, where ammonia is used as an intermediary product. The National Urea Policy ((MoEFCC, 2015)) seeks to reduce urea import. This, coupled with the recent decline in natural gas prices and gas pooling policy, could increase emissions from ammonia production in the coming years. If the historic trend continues, IPPU emissions could increase from 172 to 597 $MtCO_2e$ during 2010–2030 at a CAGR of 6% (Refer Figure 16 in Appendix II).

Agriculture: The overall annual emissions from the agriculture sector increased between 2005 and 2010 (Dhingra & Mehta, 2017) from 374 $MtCO_2e$ to 390 $MtCO_2e$. The sub-sectors of agriculture contributing to emissions include enteric fermentation in livestock, manure management, rice cultivation, agricultural soils and field burning of crop residue. The latter sub-categories (especially agricultural soils) have been influential in determining overall agricultural emission trends. Livestock emissions, in contrast with the overall agricultural emissions, have stabilised and declined after 2007 due to a declining livestock population (Jha, Singh, Sharma, Singh, & Gupta, 2011).

Policies and measures at the national level that impact this sector include: the National Mission for Sustainable Agriculture (under the National Action Plan for Climate Change, 2008); Rain-

[6] The activity data for calculating the emissions in IPPU sectors were sourced from Annual Survey of Industries (ASI) datasets published by the Ministry of Statistics and Programme Implementation (MOSPI).

fed Area Development Programme; Sub-Mission on Agricultural Mechanisation (12th Financial Year Plan); National Innovations on Climate Resilient Agriculture (NICRA), 2011; National Food Security Mission; National Agroforestry Policy; System of Rice Intensification; National Horticulture Mission; Pradhan Mantri Krishi Sinchayee Yojana; crop diversification from transplanted paddy to other food crops and Agriculture Demand Side Management (AgDSM)(GoI, 2015a). In this analysis, it is assumed that the sector's emissions will progress as per historic trends. Agricultural emissions are estimated to grow at 0.2% CAGR to about 400 Mt by 2030 (Refer Figure 17 in Appendix II).

Waste: GHG emissions from the waste sector, mainly CH_4 and N_2O, increased by 36% from 2005 to 2013. They constituted 3% of India's total GHG emissions in 2010. The IPCC categorises waste emissions from three sources: solid waste disposal, domestic wastewater and industrial wastewater handling. In 2010, domestic wastewater handling accounted for 45% of total waste emissions, followed by industrial wastewater (33%) and solid waste (22%). Emissions from solid waste disposal are driven by factors such as population (urban and rural) and composition as well as disposal mechanisms of municipal waste. As a result of population growth and poor landfill management, emissions from this sub-sector have increased by about 60% during the same period (Chaturvedula, Kolsepatil, & Jha, 2017). If the historic trend continues, waste emissions could grow to 135 Mt by 2030 (Refer Figure 18 in Appendix II).

LULUCF: CO_2 from the atmosphere accumulated as carbon in soil and vegetation is referred to as 'carbon sink'. The LULUCF sector in recent times has affected net GHG inventories. This is because of an increase in GHGs due to human settlements and a decrease in emissions due to sinks created in forest and croplands. India's mitigation strategies in LULUCF have focused on increasing the sinks via forest management strategies. Sustainable management, planting and rehabilitation of forests can increase forest carbon stocks and, thereby, increase the sinks. The following analysis arrives at a plausible LULUCF sink value for 2030. For this, historic values of forest cover and carbon stock were compared to determine the impact on the NDC target.

LULUCF values changed from -301 $MtCO_2e$ in 2005 to -252 $MtCO_2e$ in 2010 (at a CAGR of -3.5%). Unlike other non-energy sectors, India's NDC sets targets for the LULUCF sector, that is, creation of an additional carbon sink of 2.5 to 3 billion tonnes of CO_2e via forest and tree cover by 2030 (GoI, 2015a).

In this analysis, to arrive at a LULUCF sink value, the additional carbon sink target from CO_2e was converted to the additional carbon stock value using molar weights. The additional forest carbon stock to be created (as per NDC targets) can be represented as 681-817 MtC[7]. The government also publishes historical carbon stock values. Using this, we estimate that the additional carbon stock to include the NDC target would be around 10-12% of the 2013 reported stock of 6,941 MtC. As mentioned in the official inventory reported in India's 2014 Biennial Update Report (BUR), India's LULUCF sink value was around 315 $MtCO_2$ in 2010. Similar to the 10-12% increase of the carbon stock value, the sink value was assumed to grow commensurately. CO_2 contributions from LULUCF were assumed to be constant at 63 $MtCO_2e$. Hence, this study estimated the net LULUCF contribution to be about –286 $MtCO_2e$ by 2030. This implies that the CO_2e sink value would grow at a marginal CAGR of around -0.6% p.a. (Refer to Table 20 in Appendix II for comparison with alternative targets and land

[7] Additional tC stock=additional t CO_2e stock/(44/12)

implications). Over all, by 2030, the projected emission values from the non-energy sector was estimated at 577 $MtCO_2e$ (i.e. the LULUCF sink is deducted from the total of IPPU, Agriculture and Waste, which is about 863 $MtCO_2e$). (This value was used to decode the NDC implication in further sections.)

4.3 Emissions Intensity of Primary Energy

We estimate that in 2005 India's emission intensity of primary energy was around 0.21 $kgCO_2e/kWh$. This is based on India's BUR emission inventory estimates for energy based emissions of 1,271 $MtCO_2e$ and CEA's National Electricity Plan for primary energy estimate of 6,020 TWh (518 Mtoe) (CEA, 2018)[8]. According to the analysis conducted at CSTEP using the IMRT model, India's NDC target of installing 40% fossil-free power generation capacity by 2030 will reduce India's grid emission factor (CSTEP, 2015).

In various scenarios in the IESS Calculator[9] (IESS, 2015a), it was found that across the economy, emissions intensity of primary energy is expected to increase between 0.24 to 0.27 $kgCO_2e/kWh$ by 2031–32 (compared with 2005 levels of 0.21 $kgCO_2e/kWh$). This growth, with respect to the 2005 emission intensity by 2030, is in the range of 15%-26%[10].

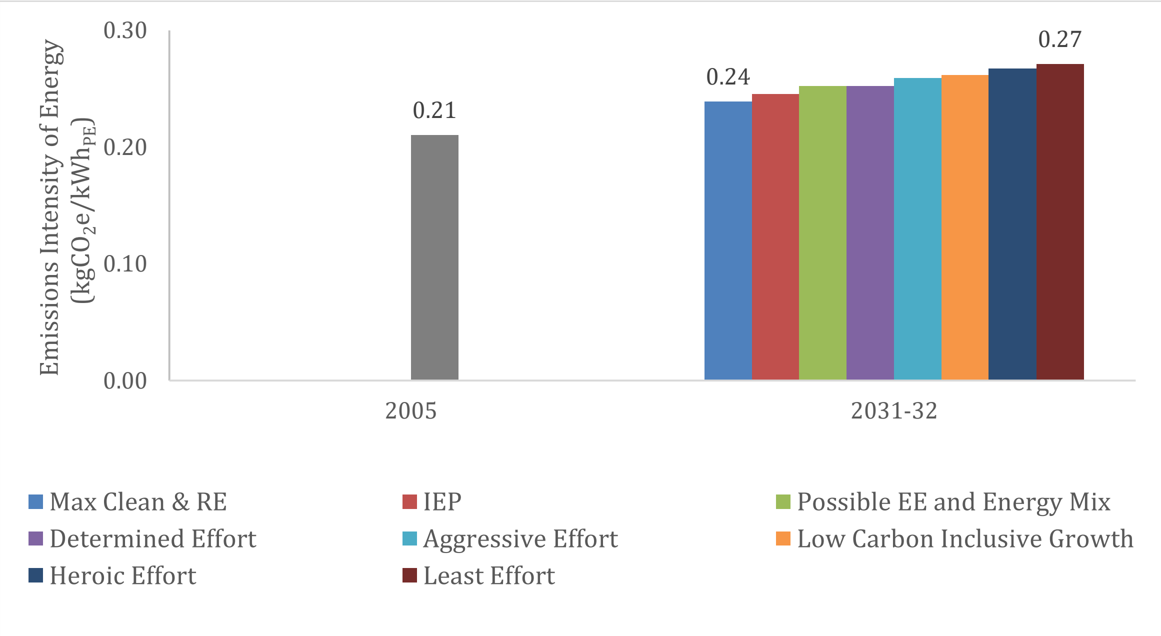

Figure 2: Trends in Emission Intensity of Energy in IESS

[8] The CEA report is one of many estimates for primary energy in the base year 2005. This value was considered as it is a government reported number, and also in line with the Planning Commission's Integrated Energy Policy (IEP) (2006) document (Planning Commission, 2006). With a lower value of primary energy in 2005, emission intensity would be higher. The estimation of energy intensity of GDP based on NDC pledge is sensitive to this assumption.

[9] All example scenarios from the IESS web-version, with varying levels of efficiency and fuel mix across energy demand and supply sectors, were considered to arrive at the projected emission intensity range for 2031-32.

[10] This trend was further corroborated by modelling results of MoEFCC commissioned studies in 2009 (Ghosh 2009) and CSTEP's IMRT scenarios (Byravan et al., 2017). Illustratively, the Integrated Research for Action and Development (IRADe) model also projects a 22% growth in this value during 2003–04 and 2030–31 while CSTEP's Sustainable Development scenario reflected a growth of about 29% (Byravan et al., 2017; Ghosh, 2009).

There are two main reasons for this increase:

1. In absolute terms, transport and industry sectors are expected to grow at a much faster rate than overall growth in primary energy during 2005–2030. The emissions per unit of energy of these sectors is likely to decline, but only marginally. In the transport sector, despite efforts to introduce alternative fuels, the technology lock-ins to liquid fuels are likely to continue. In the industry sector, the emissions intensity of energy will decline marginally because of adoption of more efficient manufacturing technologies. However, the rapid growth of these sectors leads to increasing share in primary energy demand, which in turn off-sets the impact of marginal decline in emissions intensity of energy.

2. In the cooking sector, a large number of people who rely on traditional biomass for cooking will shift to modern cooking fuels which are based on petroleum and electricity. As a result, cooking based emissions will increase since CO_2-neutral biomass is replaced by fossil fuels or electricity. However, absolute energy requirements for cooking will reduce significantly because of much higher efficiency of conversion than traditional biomass based stoves. This will further increase the share of transport and industry sectors in total primary energy in 2030.

Hence, the emission intensity of primary energy is projected to increase by 15–26% over 2005 levels by 2030[11]. For the purpose of this analysis, i.e. to decode implications on the y term, the value of $\frac{\Delta x}{x}$ is considered to be in the range of 0.15 to 0.26[12] from 2005 (i.e. growth of emission intensity from 0.21 $kgCO_2e/kWh$ in 2005 to 0.24-0.26 $kgCO_2e/kWh$ in 2030).

4.4 NDC Emissions Intensity Reduction Target and Implications for Energy Intensity

As mentioned earlier, the second component of the emissions intensity of GDP is the energy intensity of GDP. The change in energy intensity needed for a 33–35% reduction in $\frac{\Delta p}{p}$ can be estimated as follows:

Equation 11

$$\frac{\Delta y}{y} = \left(\frac{\left(\frac{\Delta p}{p} \times 1 + \left(\frac{r}{xy}\right)\right) - \frac{\Delta x}{x} - \frac{\Delta r}{xy}}{(1 + \frac{\Delta x}{x})} \right)$$

The value of each term in Equation 11 is presented in

[11] In India, during 2005-10, data (IEA & EIA) suggests that emission intensity of primary energy supplied declined marginally and then increased. This can be attributed to an increased share of gas-based fuel consumption in the economy which then reverted to coal-heavy consumption.

[12] This range in 2030 declines marginally since the IESS example scenarios range for 2031-32 was adjusted to reflect a 2030 estimate. We consider this, as IESS data and projections have been validated by various government stakeholders.

Table 2. These values are based on macroeconomic and baseline emissions mentioned in Table 18 and Table 19 (in Appendix II).

Table 2: Input values for decoding analysis

Parameters	Range	
r (Non-energy emissions $_{2005}$)	0.007	
xy[13] ($MtCO_2e$)	0.039	
Δr (difference in non-energy emissions $_{2030\text{-}2005}$)	-0.004	
$\frac{\Delta x}{x}$	0.26	0.15
$\frac{\Delta p}{p}$	0.33–0.35	
$\frac{\Delta y}{y}$	-(0.43–0.45)	-(0.38–0.40)

Based on these values, the estimated value for $\frac{\Delta y}{y}$ or rate of change in energy intensity of GDP is in range of -38% and -45%.This implies that the energy intensity of GDP will have to reduce to compensate for the increase in emissions intensity of energy.

Assuming fixed growth of economic output, the rate of reduction in energy intensity of GDP will have to be around 2% (CAGR) during 2005-2030 to meet the NDC target. As mentioned in the Introduction, energy intensity of GDP has shown a declining trend at around 2.4% CAGR from 2005 to 2010. Thus, in order to achieve the target by 2030, the decline rate would have to be around 1.7% to 2.3% going forward. In the following section, we evaluate the role of sectoral growth, end-use efficiency and ongoing policy ambition in achieving this reduction in the y term (energy intensity of GDP in 2005).

[13] For making the xy value not account for GDP units in the equation, the 2005 value of GDP was assumed to be a unitless dimension with a value of 1. xy hence denotes the energy emissions value in 2005.

5. Scenario Analysis for Energy Efficiency

The previous sections illustrated that the energy intensity of GDP will have to reduce by 38–45% by 2030 from 2005 levels to achieve the NDC commitments. This compensates for the likely increase in emissions intensity of energy. This section further analyses the 'energy intensity of GDP' term and explores the roles of key demand sectors in achieving this reduction.

5.1 Methodology

In order to estimate the potential of EE, a bottom-up model (refer Figure 3) is constructed to examine the technologies and policies relevant to each demand sector—agriculture, buildings, industries and transport. The service demand in each sector has been projected using key performance indicators such as GDP, per capita consumption of an industrial product, floor space area, population, etc. The choice of indicator is contingent upon the nature of service offered by each sector. For example, GDP growth rate is used to project cement production till 2030. The final estimate is then validated using secondary literature published by reputed organisations and industry associations.

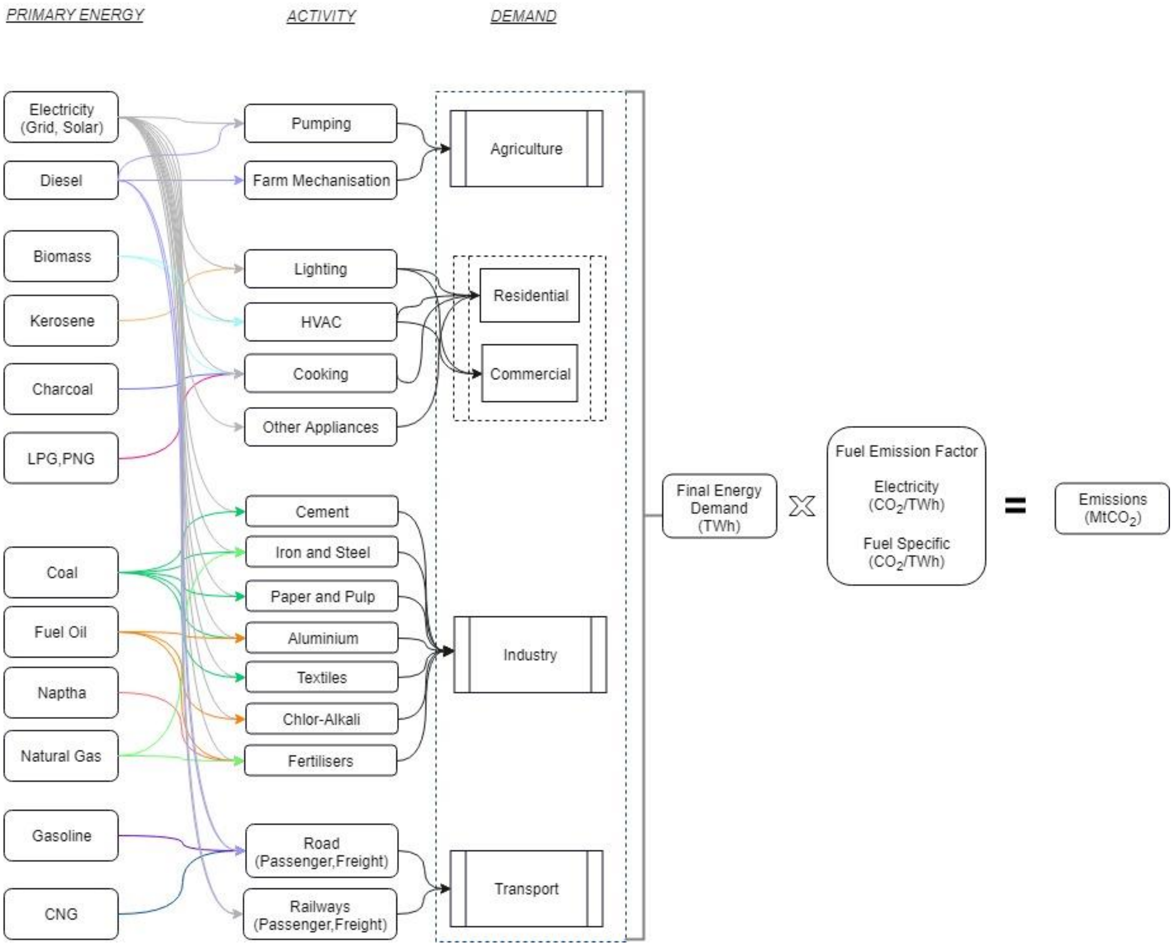

Figure 3: Methodology for estimation of energy in demand sectors

Reduction in energy demand can be achieved by implementing energy-efficient processes and alternative measures across demand sectors. CSTEP conducted a sector-wise assessment to quantify overall potential for EE. Three scenarios, namely Business-as-Usual (BAU), Energy Efficiency Scenario 1 (EE1) and Energy Efficiency Scenario 2 (EE2), were designed to envisage overall energy reductions in four key demand sectors. The BAU scenario showcased projections driven by focused implementation of existing energy-efficiency norms until 2030. The policy scenarios were modelled to examine the role of energy efficiency towards the NDC pledge. EE1 scenario depicts a pathway using proposed government policies and designated roadmaps, in addition to policies that have already been implemented or are under implementation. EE2 scenario illustrates a trajectory where, along with proposed policies being completely implemented, there is an additional push to achieve current global best practices. Assumptions and policy interventions pertaining to each of these scenarios are presented in Table 17 in Appendix I.

5.2 Industries

The industry sector accounts for one third of the total energy used worldwide and emits nearly 40% of total CO_2 emissions (Trudeau, Tam, Graczyk, & Taylor, 2011). In India, this sector consumed 1,257 TWh in 2005, accounting for 36% of the total energy consumption (de la Rue du Can, McNeil, & Sathaye, 2009). It produced 290 $MtCO_2e$ emissions—contributing to 25% of the total energy emissions (de la Rue du Can et al., 2009). From 2005 to 2012, the industrial value-add to the economy grew at 8% CAGR (GoI, 2015c), while the energy consumption grew at 3.3% (IESS, 2015a). This slower rate of growth in energy compared to value added from the industry reflects a decoupling of energy and industrial output. Growth in both energy and output of this sector has been on account of large expansion in the energy-intensive sub-sectors such as steel, cement, aluminium, pulp and paper and fertilisers. However, per capita consumption of key industrial outputs such as steel, cement, aluminium, etc. still remain well below the world average consumption levels, as shown in Table 3 (Vishwanathan et al., 2017). India's huge infrastructure needs for increased housing, improved network of highways and urban transport infrastructure, etc., over the next few decades is expected to drive the demand for energy-intensive materials. This indicates a significant potential for growth in India's industrial output.

Table 3: Per capita consumption of key industrial outputs (in kg/cap)

Sub-Sector	India (kg/cap)	World (kg/cap)
Cement	195.0	520.0
Iron and Steel	59.4	216.6
Aluminium	1.4	8.0
Chlor - Alkali	5.2	30.0
Fertilisers	22.8	26.2
Pulp and Paper	9.0	58.0
Textile	5.5	11.0

Source: (Vishwanathan et al., 2017)

This sector can be broadly classified into energy-intensive industries (comprising key sectors such as iron and steel, cement, aluminium, pulp and paper, chlor-alkali, fertilisers, textiles) and other industries comprising Medium, Small and Micro Enterprises (MSMEs), including food processing, metal processing, etc. The larger energy-intensive industries account for approximately 55%–60% of the total energy consumption, while the smaller industries account for the rest (ESMAP, 2011), (IESS, 2015b).

The industry sector is dominated by the use of coal (refer Figure 4), both as feedstock in industrial processes and captive power generation. In industries, 43% of final energy is accounted for coal, followed by electricity (22%), oil (21%) and gas (12%) in 2012 (Byravan et al., 2017; IESS, 2015a). With increasing demand from various sub-sectors, share of coal is further expected to increase in the future (46% by 2030 in BAU scenario) (Byravan et al., 2017; ESMAP, 2011). Hence, concerted efforts are needed to diversify the fuel mix in industries through technology and process switch.

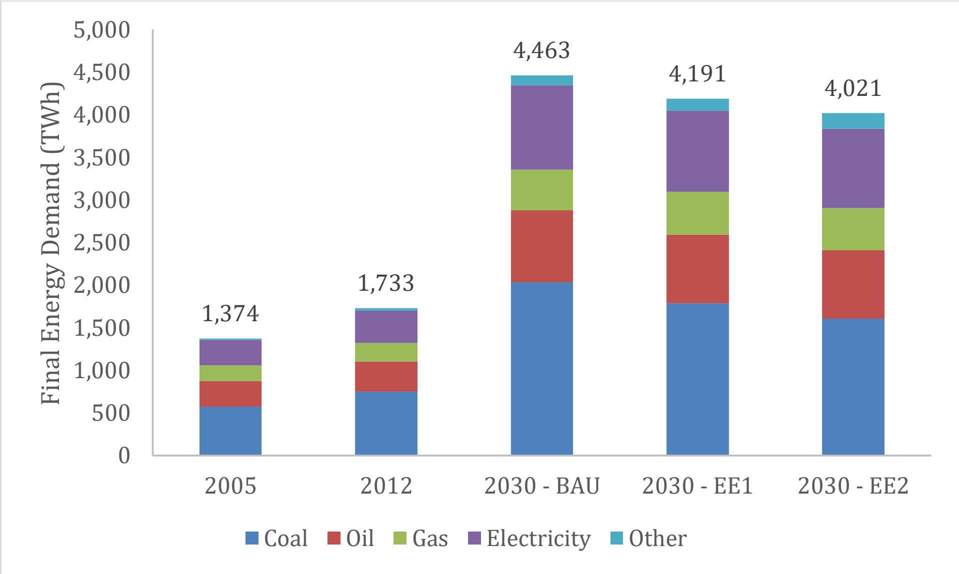

Figure 4: Final energy demand in industries sector

Modelling Approach

A bottom-up estimate of energy consumption by energy-intensive industries was made with technology and process-level disaggregation (represented in the equation below where '*i*' represents the sub-sectors). The growth in key industrial outputs such as cement, iron and steel, etc., was projected based on historical trends and GoI projections in each subsector (IESS, 2015a). A set of energy-efficiency indicators were identified across the subsectors to indicate the energy use per tonne of output (PJ/t) and the level of process switch and technological advancement needed to improve energy efficiency.

Equation 12

$$Energy\ Demand_{\ Industries}\ (PJ) = \sum_{i=1}^{9} [Production_{sub-sector}(t) * Specific\ Energy\ Consumption_{process}\ (PJ/t) * \%\ Share_{process}\ ]$$

Iron and Steel

India is the third largest steel producer in the world, after China and Japan (WSA, 2018). The iron and steel sector is the largest energy user in the industry sector. In 2013, this sector alone consumed about 21% (528 TWh) of the total energy in the industry sector (OECD, 2015). With the expansion of manufacturing and infrastructure sectors in the future, their energy consumption is expected to grow further.

Energy costs constitute around 40% of the total steel production in India, compared with 25% in other developed nations such as Japan (WSA, 2018). This implies that there is significant potential to improve the energy consumption per unit of steel produced in India. Historically, Specific Energy Consumption (SEC) of steel production in India has shown a downward trend, thanks to voluntary efforts from manufacturers to reduce the energy input costs (ESMAP, 2011). The industry is also gradually shifting to the Direct Reduction based production route from the more energy-intensive Blast Furnace-Basic Oxygen Furnace (BF-BOF) production route. Policies such as the Perform Achieve and Trade (PAT) scheme have further helped in reducing the SEC of the iron and steel sector (Krishnan, Vunnam, Sunder P, J V, & Murali, 2013).

India's steel output is projected to grow at a CAGR of 6.7%, from 77 Million Tonnes of Crude Steel (Mtcs) in 2012 (Indian Bureau of Mines, 2015) to 249 Mtcs in 2030. Taking into account the historic trends in efficiency improvements and shift to less energy-intensive processes in the BAU scenario, final energy consumption in the iron and steel sector (represented in Figure 5) is expected to grow at a CAGR of 6.3% from 2012 to 2030. With the National Steel Policy 2017 (Ministry of Steel, 2017) and corresponding energy-efficiency targets (refer Table 17 in Appendix I.) in place, growth in energy consumption is expected to slightly reduce in the EE1 scenario (CAGR of 5.5%).

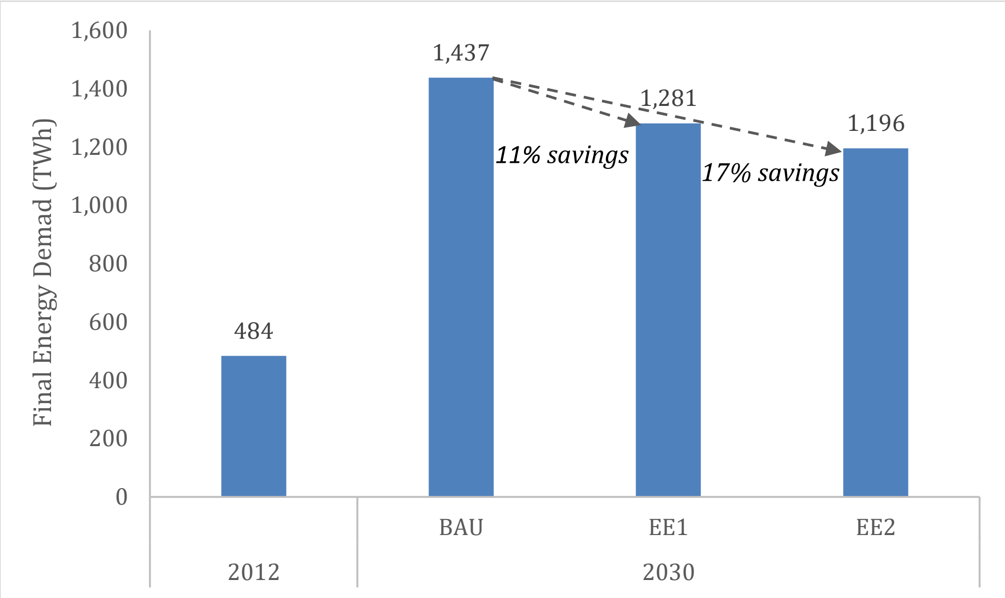

Figure 5: Final energy demand in the iron and steel sub-sector

Assuming that most of the iron and steel industry units achieve global best practice levels for SEC by 2030 in the EE2 scenario, growth in energy consumption is expected to further reduce to 5% from 2012. This reduction is also attributed to the process shift to Induction Furnace (IF) based production and increased use of scrap steel. Increased replacement of coal-based Direct Reduced Iron (DRI) with gas-based DRI also helped attain reductions in final energy consumption. This shift in processes in the iron and steel sub-sector has had a significant impact on the energy efficiency and, thereby, energy intensity of steel production. The SEC can be further reduced through efforts such as deepening of PAT scheme in the second and third cycle[14]. Diffusion of more efficient technologies such as installation of Variable Frequency Drives (VFDs) for coke oven gas compressors, efficient ventilation fans along with increased Waste Heat Recovery (WHR) measures, etc. also help in reducing the SEC.

[14] PAT Scheme: It is a market-based trading scheme announced by the GoI under its NMEEE. It aims to improve energy efficiency in key industrial sectors (energy intensive) by mandating energy efficiency targets for select units (known as Designated Consumers). Four cycles have been notified until now—PAT-I (2012-15), PAT-II (2016-19), PAT-III (2017-20) and PAT IV (2019-21).

Cement

Indian cement industry is the second largest producer of cement in the world, after China. The total production grew at a CAGR of 7.3% from 2005 to 2015, almost doubling from the 2005 levels (Indian Bureau of Mines, 2017). The demand for cement is further expected to grow in the near future, led by growth in real estate and construction sectors. Though per capita consumption of cement has grown over the years and reached around 195 kg/capita in 2015, it still remains well below the global average per capita consumption of 520 kg/capita (Vishwanathan et al., 2017).

Indian cement industry comprises more than 165 large cement plants adding to a production share of 96% (CII, 2013). The industry produces a variety of cements such as Ordinary Portland Cement (OPC), blended cements[15] (PPC and PSC), white cement and specialised cement. The share of OPC, PPC and PSC in the total production is represented in Table 4.

Table 4: Cement production by type in 2011

OPC	PPC	PSC
32%	62%	6%

Source: (EMIS, 2014)

The share of blended cements such as PPC and PSC cements in the overall cement production has increased from 43% in 2005 to 68% in 2011 (CII, 2013; de la Rue du Can et al., 2009). These blended cements help in the reduction in overall energy and emissions from the cement industry, apart from other energy-efficiency measures (installation of vertical grinding mills, high recuperation efficiency hydraulic cooler, increasing the number of stages of preheaters, etc.). In 2012, India's cement sector consumed 158 TWh of energy, growing at a CAGR of 6.5% from 2005. Due to the stiff competition in the Indian cement market, this sector has been at the forefront of implementing energy-efficiency measures to reduce costs. Though the best and latest practices of this industry match global standards, there is still scope for improvement in the average performance of the Indian cement industry. The savings in energy due to adoption of efficiency measures are represented in Figure 6.

[15] Production of clinker uses the highest amount of energy in the entire cement manufacturing process. Substituting clinker with other materials (waste/by-products like fly ash from coal thermal power plants and slag from steel production) reduces the overall energy requirement for cement manufacture.

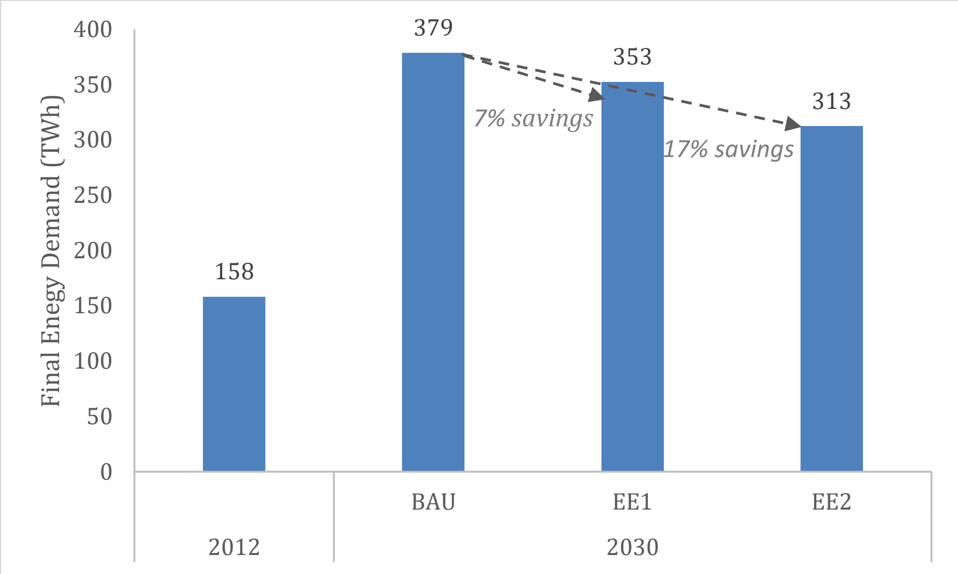

Figure 6: Final energy demand in the cement sector

Aluminium

India has the fifth largest bauxite (raw material used in aluminium production) reserves in the world (Indian Bureau of Mines, 2015). Owing to economic growth, demand for aluminium in automotive, railways, energy, defence and other sectors is expected to increase in the future. India's aluminium production in 2012 was 1.7 Mt, which grew at a CAGR of 9% from 2005 (de la Rue du Can et al., 2009, Indian Bureau of Mines, 2015). The total demand for aluminium is projected to increase to 6.4 Mt by 2030. In 2012, India's per capita consumption of aluminium was 1.4 kg and it is expected to reach 4.3 kg in 2030, indicating a good growth potential (IESS, 2015b), (Banerjee, 2017). Production of aluminium is a highly energy-intensive process where electricity accounts for 70% of energy requirement (Banerjee, 2017). It is typically carried out in two routes—primary production and recycling processes. Primary production involves production of alumina from bauxite and then production of aluminium through various routes, whereas secondary production involves recycling of aluminium scrap. The secondary process requires only 6% to 7% of the energy required for primary production (Trudeau et al., 2011). Hence, the production of aluminium from scrap has increased more rapidly across the world than primary production (ESMAP, 2011).

When compared with the most efficient primary producers in the world, India stands in a favourable range in terms of aluminium industry's energy efficiency. Close to 70% of India's primary aluminium production is through the modern point feed pre-baked anode technology (Trudeau et al., 2011). However, since most energy consumed is in the form of electricity, which in turn is produced from inefficient coal-fired power plants, its production is one of the most emission-intensive.

In 2012, the aluminium sector consumed about 50 TWh of energy (IESS, 2015b). The sector's energy consumption is projected to grow at a CAGR of 7.2% by 2030 in the BAU scenario. In the EE scenarios, due to shift in the primary production process of aluminium from the Soderberg process to a more efficient pre-baked anode technology, the growth in energy consumption reduced to 6.7%. In addition to the shift within primary production processes, aluminium produced from recycling scrap further reduced the energy footprint in the EE scenarios.

Other energy-intensive industries

Energy consumption of other energy-intensive sectors (chlor-alkali, pulp and paper, fertilisers and textiles) showed a reduction in the range of 4% to 27% across the three scenarios. This reduction was mainly driven by improvements in SEC levels. This is due to concerted efficiency-improvement measures such as increased use of Recycled Cellulose Fibre (RCF) in paper production, the application of WHR, installation of efficient motors in the textile industry (spinning mills) and use of VFDs for auxiliary equipment.

Savings

Table 5 provides the absolute and percentage savings from BAU, EE1 and EE2 in 2030 in all the energy-intensive subsectors. The iron and steel industry offered the highest amount of absolute savings in both EE1 and EE2 scenarios, followed by the pulp and paper industry.

Table 5: Savings in final energy demand across scenarios

Sub-sector	BAU final energy	EE1		EE2	
	TWh	TWh	% savings	TWh	% savings
Aluminium	133	11.0	8%	13.1	10%
Cement	379	26.1	7%	66.2	17%
Chlor-Akali	25	1.2	5%	1.7	7%
Fertilisers	177	21.1	12%	33.1	19%
Iron and Steel	1437	156.3	11%	241.5	17%
Pulp and Paper	307	55.6	18%	84.0	27%
Textiles	18	0.7	4%	2.3	13%
Total Savings		**271.9**		**441.9**	

With the adoption of emerging technologies in the manufacturing sector, productivity as well as savings in energy and emissions can be improved further. However, the acceptance of such technologies is often slow and entails market demonstration and associated risks (refer Table 6 to Table 8). It should also be noted that energy efficiency improvement is not solely dependent on technology; it is rather a combination of measures such as good maintenance and overall housekeeping, employing adequate control systems and integrating energy management into daily operations.

A significant portion of industrial processes across sectors employ motors. These motor-driven systems find applications in pumping, compressed air, fans, and various forms of mechanical handling and processing. Use of novel magnetic materials developed at Carnegie Mellon University (CMU) could lower losses and increase efficiency. Use of real-time data monitoring and process optimisation systems (industrial learning systems) enables manufacturers to improve energy efficiency (CMU, 2016).

The iron and steel sector is increasingly shifting its focus towards less energy-intensive manufacturing processes such as smelt reduction compared to the conventional blast furnace process. Some of the emerging technology options for energy efficiency improvement are described in Table 6:

Table 6: Emerging technology options in the iron and steel sector

Technology option	Description
Single chamber system coking reactors	These are large coke ovens without multi-chamber batteries. They improve thermal efficiency from 38 to 70 percent in the coking process.
Carbon Composite Agglomerates	These agglomerates (fine mixtures of iron ore, coke, coal, etc.) when added to the blast furnace improve its energy efficiency.
Inter-electrode insulation in electrolytic pickling line	The electrical efficiency of industrial steel pickling process can be improved by more than 20% by reducing the inter electrode short-circuit current through insulation.
Flameless burners	This technology uses diluted oxygen as the combustion agent with internal flue gas recirculation. Flameless oxy-fuel gives higher thermal efficiency compared with conventional oxy-fuel.
Airtight Electric Arc Furnace	An airtight EAF could provide an efficiency improvement of up to 78% compared with conventional EAF.
Production of steel using electrolysis	The most feasible routes for production are aqueous alkaline electrolysis and iron ore pyroelectrolysis. This process offers significant reduction in CO_2 emissions.
HIsarna	Based on bath-smelting, it combines coal preheating and partial pyrolysis in a reactor, a melting cyclone for ore melting and a smelter vessel for final ore reduction and iron production. It uses significantly less coal and thereby has lower emissions.

Source: (EPA, 2012; Fawkes, S., 2016)

In the cement sector, increased production of alternative cements can have a significant impact on energy and emissions. In addition, replacing carbon-intensive fuels with alternative fuels also help in reducing the emissions from this sector.

Table 7: Emerging technology options in the cement sector

Technology option	Description
Conversion of raw meal blending silo to gravity type homogenising	A gravity type homogenising silo helps in energy consumption reduction of up to 1.4–3.5 (kWh/t) of cement.
Improvements in kiln combustion system	With the incorporation of combustion optimisation methods, fuel savings of up to 2%–10% could be achieved.
Oxygen enriched combustion	With the introduction of oxygen enriched combustion, the energy requirements in the kiln could reduce between 84 and 167 MJ/t_{cement}.
Air mixing technology	By improving the combustion efficiency inside the kiln, significant reductions in emissions could be achieved.
Oxy-combustion	In the process of burning fuel in the presence of pure or nearly pure air, the requirement for fuel is significantly reduced.

Source: (EPA, 2012; Fawkes, S., 2016)

Table 8: Emerging technology options in the aluminium sector

Technology option	Description
Inert Anodes	Use of inert anodes in the production of alumina (through Hall-Héroult process) could yield up to 3 to 4% energy savings.
Wetted cathodes	Compared with conventional carbon cathodes, wetted cathodes could lead to an energy savings of up to 20% in the primary production of aluminium.
Carbothermic reduction	Non-electrolytic reaction based carbothermic reduction process for aluminium production could result in 20% to 30% reduction in energy consumption compared with conventional Hall-Héroult process.

Source:(Cecilia & Ali, 2016; Fawkes, S., 2016)

5.3 Transport

Commensurate to its geographical expanse, India's transport network is one of the largest in the world. It is the third largest energy consumer, after industries and buildings sector. In 2015, it accounted for more than 15% of the total energy demand (Vishwanathan et al., 2017). Road and rail continue to be the preferred mode of transport for both passenger and freight in India. Between 1990 and 2010, passenger transport demand grew at a CAGR of 7.4%. The share of passenger transport by road has seen an increase from 83% to 88% from 2000 to 2010, due to the growth in inter-city and intra-city transport (Vishwanathan et al., 2017). An increase in the share of private transport vehicles has also augmented this growth. However, vehicle ownership per capita is much lower in India than other developed economies in the world. In 2015, there were 167 vehicles (all types) per 1000 people and just 19 passenger cars per 1000 people in India[16]. On the other hand, the Organization for Economic Co-operation and Development (OECD) countries observed 500–700 vehicles and 300–400 cars per 1000 people for the same year. Not only has there been a significant and rapid growth in the number of private cars in the last decade, but the demand for both private vehicles and last mile connectivity is also likely to increase in the future. This can be attributed to rapid urbanisation and increase in disposable income.

The role of transport sector in emissions reduction and in addressing the challenges of global climate change is very important as it consumes about half of the oil produced globally, and results in almost a quarter of the total CO_2 emissions in the world (OECD, 2015). In India, the transport sector contributes close to 10% of the total national GHG emissions, with road transport contributing about 87% (MoEFCC, 2015). This has a direct impact on the local air quality and thereby public health.

Modelling Approach

In a top-down accounting framework, the transport module was set up to yield results on variables such as activity demand, final energy demand and primary energy requirement. Activity demand for passenger and freight was modelled based on calculated historic GDP

[16] These metrics offer averages across rural and urban areas and do not capture the regional or spatial variation.

elasticity of service demand. To determine the baseline energy demand (using the equation below where '*m*' represents the modes of transport), the following data was used (GoI, 2015):

- Activity share (passenger kilometres, tonne kilometres for freight)
- Share of different modes (including road and rail)
- Technology load factors
- Fuel efficiency by technology type (including engine and fuel-variants)
- Fuel emission factors (CO_2) (MoEF, GoI, 2010)

Equation 13

$$Energy\ Demand_{Transport} = Transport\ demand_{passeneger(BPKM)}/_{freight(BTKM)} * \sum_{m=1}^{3} Mode\ share\ (\%) * Fuel\ efficiency_{mode}\left({}^{Liters\ of\ fuel}/_{km}\right)$$

The base-year energy consumption was calibrated against fuel-wise totals reflected in the government estimation of retail fuel consumption for the transport sector. Key energy-efficiency strategies, such as electrification, improved fuel efficiency and fuel shift, were modelled by varying the exogenous inputs (percentage shares and improvements) to the model.

The transport sector in India is dominated by the use of fossil fuels. In 2012, 94% of the primary energy demand from the transport sector was petroleum-based, with electricity comprising a marginal 1% share. This sector consumed 70% of the total diesel and 99.6% of the petrol consumed in the country (PPAC, 2013). In 2015, out of the total of 185 Mt of petroleum products consumed, road transport consumed about 19 Mt of petrol and 47 Mt of diesel (Paladugula et al., 2018).

In the BAU scenario, the energy demand in this sector was projected to grow at a CAGR of 6% between 2012 and 2030. This increase in demand was driven by the overall growth in transport service demand and increase in private mode of transport, compared with public transport. The share of public transport in road passenger transport, in the BAU scenario, decreased from 73% in 2012 to 65% in 2030 (IESS, 2015a). Also, the share of rail transport in overall passenger transport decreased to 13% from 15%. Roadways are the preferred mode for freight transport as well. The share of road transport in total freight movement increased from 58% to 61% during this period, with the rest of the share catered to by rail (IESS, 2015a).

Passenger Transport

Increasing incomes across all strata of society are driving a shift from public to private transport; vehicle sales are increasing every year. Consequently, the share of public transport (which is the most efficient mode of transport in terms of passenger km) in the total passenger road transport is expected to decrease by 2030. Government initiatives such as the National Urban Transport Policy (MoUD, 2014) and the New Metro Rail Policy (Ministry of Housing and Urban Affairs, 2017) have strengthened the public transport services for inter-city and intra-city commute. Other interventions like compliance with stringent fuel norms and fuel economy standards are also underway to curb air pollution and fuel demand.

With the National Electricity Mobility Mission Plan 2020 (Ministry of Heavy Industries and Public Enterprises, 2012) and Faster Adoption and Manufacturing of Hybrid Electric Vehicles (FAME) programme (Ministry of Heavy Industry and Public Enterprises, 2015), the share of Electric Vehicles (EV) in the total vehicle fleet will grow.

Domestic crude oil production is currently only able to meet 17.9% of India's total crude oil requirement. A majority of petroleum products used in transport are imported. To reduce dependency of fuel imports, alternative fuels to substitute petroleum-based fuels are being explored. The National Biofuel Policy aims at promoting domestic feedstock utilisation for the production of biofuels. The policy has set a target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel, by 2030. In 2017, only 2% of the petrol sold was blended with ethanol, and only 0.1% diesel sold was blended with biodiesel.

Hence, these strategies—(i) increased public transport share, (ii) improvement in fuel economy standards, (iii) increased use of EVs for both public and private transport and (iv) use of blended fuels—were modelled. The assumptions on the levels specified for EE1 and EE2 are provided in (Table 17 in Appendix I). Results indicate a cumulative energy savings of 286 TWh and 483 TWh in EE1 and EE2 scenarios in 2030 (refer Figure 7). A shift towards public transport in cities and to rail for inter-city transport can have the highest impact in terms of reduction in energy consumption, followed by improvements in fuel efficiency, electrification of vehicle fleets and fuel blending. Improvements in fuel efficiency and blending can be induced by automobile manufacturing regulation and policy incentives to improve energy efficiency. These measures take effect in short to medium term. However, other infrastructure and cost-intensive measures such as increasing the share of public transport and EVs show significant effects in the longer term.

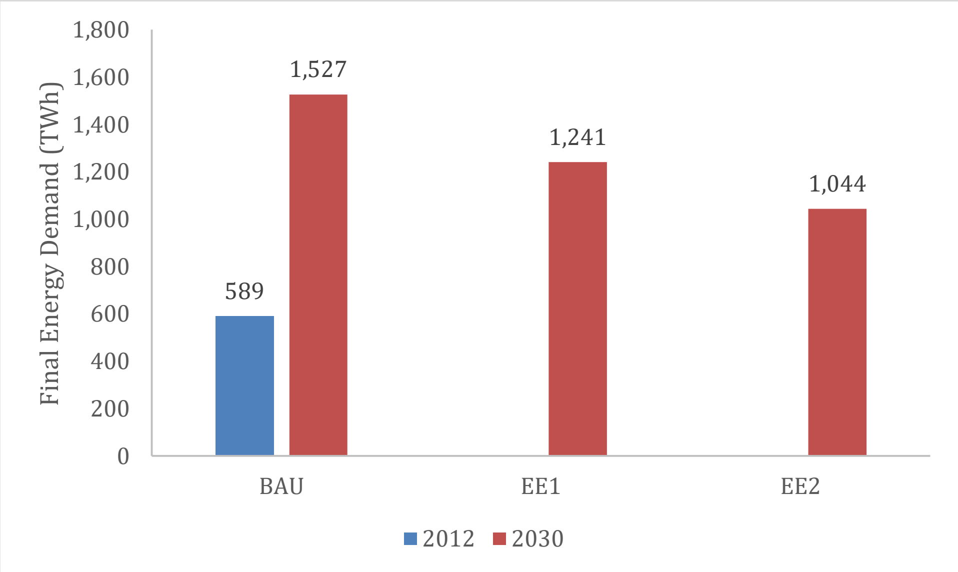

Figure 7: Final energy demand in passenger transport

Freight Transport

With a push for dedicated freight corridors, the share of rail in total freight transport in EE scenarios is assumed to increase from 39% (BAU) to 50% in 2030. This shift in demand is expected to ease the load on road freight, which is dependent on diesel-powered trucks. It is assumed that, in addition to the eastern and western freight corridors already in construction, additional rail linkage to industrial clusters will be provided. The shift in freight traffic from road to rail is coupled with increased electrification of rail. The share of electrified freight movement is assumed to increase from 39% in 2012 to 50% in 2030 (refer Table 17 in Appendix I). This shift, along with improvements in fuel efficiency and fuel blending, can result in cumulative energy savings of 123 TWh and 248 TWh in EE1 and EE2, respectively (refer

Figure 8). However, this reduction in energy savings cannot be translated to emission savings unless the electricity sector is decarbonised. This shift from road towards rail, apart from providing significant energy savings, also helps in shifting away from oil and strengthens energy security.

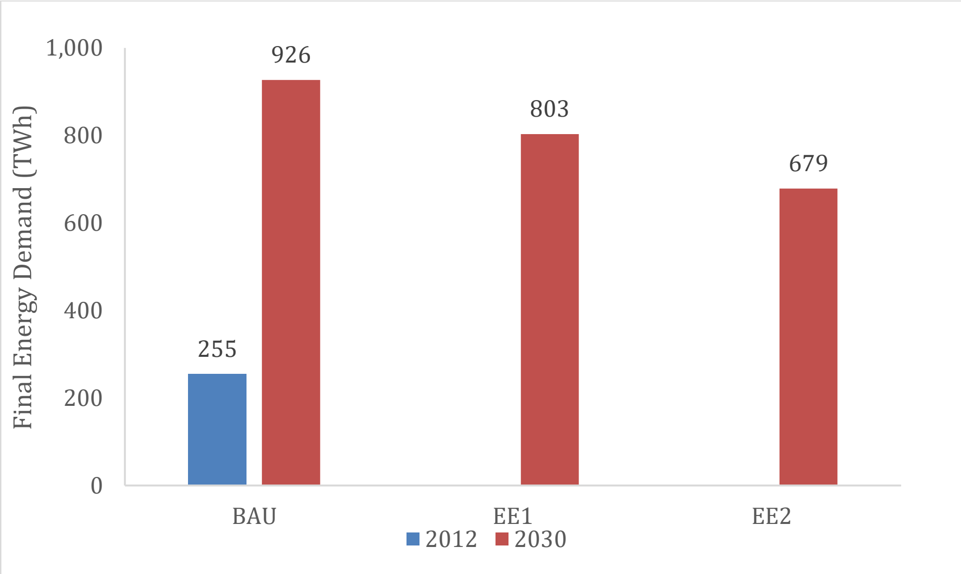

Figure 8: Final energy demand in freight transport

Savings

In all three scenarios, India's transport sector continued to be heavily dependent on oil in 2030 (refer Figure 9). However, the share of electricity in the energy mix in 2030 increased from 2% in the BAU scenario to 9% in EE2 on account of increased share of rail in passenger and freight and increased adoption of EVs. Across the transport sector, a cumulative energy savings of 409 TWh and 730 TWh can be achieved in 2030 in EE1 and EE2, respectively.

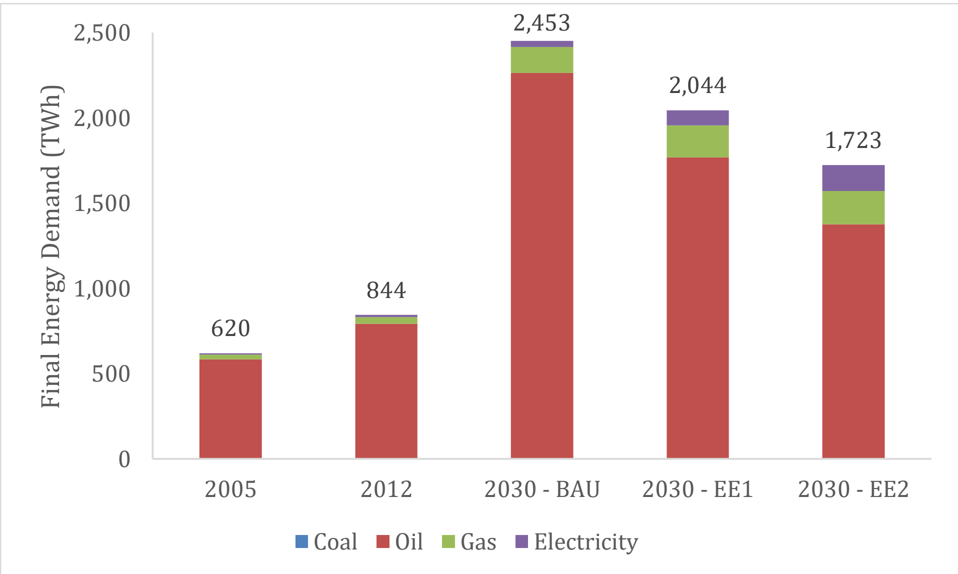

Figure 9: Energy fuel mix in transport sector

Emerging technologies have a significant role in energy and emissions reduction in the transport sector. The application of such technologies is complementary to improvements in existing transport infrastructure. Some of the emerging technologies in the transport sector are represented in Table 9.

Table 9: Emerging technologies in the transport sector

Technology option	Description
Autonomous vehicles	These vehicles show great promise for enhancing safety, decreasing congestion and reducing energy consumption.
EV battery and fuel cell technologies	Batteries with higher energy density and extended operating temperature range offer significant fuel savings.
Hybrid EV	Hybrid electric vehicles combine an electric drive with an internal combustion engine. Significant savings in energy consumption can be achieved on account of elimination of idling and engine downsizing.

Source: (Guerrero-Ibáñez, Flores-Cortés, Damián-Reyes, & Pulido, 2012; Jin, Fagnant, Hall, & Walton, 2015)

5.4 Agriculture

Agriculture plays a vital role in India's economy. About 55% of the population is engaged in agriculture and allied activities (Census 2011), and they contribute to 18.2% of the country's Gross Value Added (GVA)[17] in 2014–15 (Office of Economic Adviser, 2018). India's food grain demand is expected to grow at about 2% CAGR till 2030. The total geographical area of the country is 328.7 million hectares. Of this, 139.9 million hectares is the reported net sown area and 194.4 million hectares is the gross cropped area (GoI, 2015b), with a cropping intensity of 138.9%. The net irrigated area is 66.1 million hectares. Since cultivable land is limited while population is growing (and therefore the demand for food is also increasing), it is necessary to find ways of increasing the yield from the same cultivated area. The government intends to accomplish this by increasing the cropping intensity and farm mechanisation.

Rural India is mainly agrarian with traditional farming techniques. Traditionally, agriculture was mostly dependent on animate and non-commercial energy sources, but is now more dependent on commercial energy sources like diesel, electricity, etc. Additionally, the consumption of energy in agriculture is increasing due to increasing demand for food grains, fruits and vegetables. Energy use in the agricultural sector has registered a high growth rate of 10.4% from 1990 to 2015 (Alam & Chandra, 2015). Electricity has become the preferred source of energy for irrigation as electric motors are more efficient and economical than diesel engines. The agriculture sector accounted for 18.3% (MOSPI, 2018) of India's total electricity consumption in 2016–17; electricity consumption grew at 6.5% CAGR from 2006–07 to 2016–17 (MOSPI, 2018). As agriculture continues to be mechanised, the demand for energy from the sector is only likely to increase.

Modelling Approach

Farm mechanisation and irrigation are the main drivers of energy consumption in agriculture. The need for increased productivity and decline in farm labour availability has necessitated farm mechanisation. Thus, the demand for tractors and pump sets has increased over the past few decades. Yet, Indian agriculture lags behind developed countries in terms of farm power availability (kW/ha) and tractors per thousand hectares. These metrics have a direct impact

[17] At current prices

on crop productivity. For this study, the projection of energy demand from agriculture is based on diesel (for tractors and pumps) and electricity (for pumps) consumption.

Energy demand for tractors is based on the increased use of tractors and the corresponding fuel consumption. Successful mechanisation depends on carrying out farming operations with well-matched, energy-efficient farm implements/machine systems requiring less power, time and fuel (Alam & Chandra, 2015). In 2011–12, diesel consumption by tractors was 7.7% of the total diesel consumption of India. The tractor density of India per thousand hectares of net sown area is 33 (Mehta, Chandel, & Senthilkumar, 2014), which is much lower than agriculturally developed countries like Japan (461) or Italy (211). Non-agricultural usage of tractors for transport and haulage in construction will also boost tractor demand. Subsidies through government programmes like the Rashtriya Krishi Vikas Yojana, which also supports community renting of tractors for small landholdings, is another step towards increasing farm mechanisation.

The main intervention for energy efficiency in tractors is improvement in the fuel efficiency. This would involve savings in specific fuel consumption through imposition of Bureau of Indian Standards (BIS) norms and a tightening of emissions standards. At present, the tractor industry follows the Bharat Tractor Emission norms—Trem3A emission norms with Trem4 will come into force in 2020 (ETAuto, 2018). For enhancing energy efficiency in India, improvements in farm tillage implements and proper matching of equipment to the power source can result in efficiency improvements of about 7% (Vishwanathan et al., 2017).

Irrigation pumps may use diesel, electric or solar energy. In 2012, about 66% of the pumps were electric, 33% were diesel and 1% were solar (Alam & Chandra, 2015). Agricultural pumps consumed 3.3% of India's total diesel consumption in 2011–12. The average efficiency of existing irrigation pump sets is low, ranging from under 20% to 35%. Energy-efficient pump sets have an overall efficiency of 45% to 55% (BEE, 2015; Saini, 2011). Moreover, there is no incentive for farmers to use electricity or water efficiently because most states provide agricultural power either for free or at heavily subsidised prices. This provides a huge opportunity for efficiency improvements if pump replacement programmes are implemented across the country.

The Central Electricity Authority (CEA) provides historical values for electricity consumption in the agriculture sector from 2006-07 to 2015–16. The projections up to 2030 are based on the 19th Electric Power Survey of India (EPS) report, with an appropriate reduction by 5% because the 18th EPS overestimated electrical energy consumption. The National Solar Mission (NSM) pushes for existing diesel pump sets to be replaced with solar pump sets. The National Mission for Enhanced Energy Efficiency (NMEEE) promotes the replacement of existing inefficient pump sets with energy-efficient electric pump sets. Increasing the area under micro-irrigation would lead to an improvement in water-use efficiency, thus leading to an overall reduction in the pumping demand.

In the 2030 scenario, electricity consumption by pumps would increase due to the depleting water table and the need to pump ground water from greater depths. In line with the NSM's goal of moving towards cleaner forms of energy, there would also be a shift from diesel pump sets to energy-efficient electric pumps as well as solar pumps. Figure 10 shows final energy demand by sector.

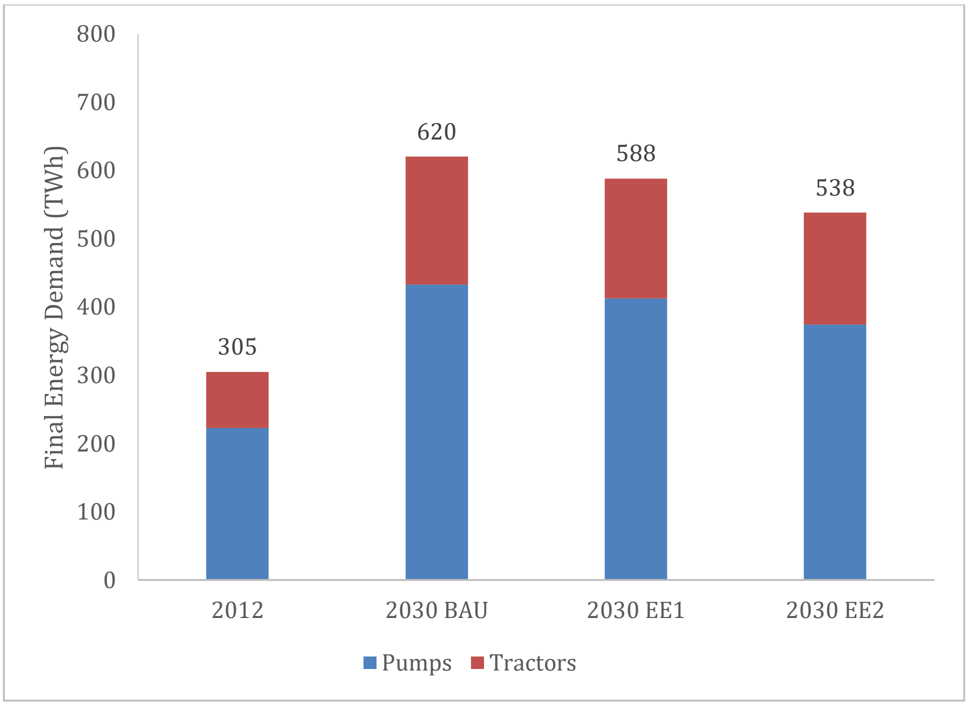

Figure 10: Final energy demand in agriculture

Total energy demand in BAU 2030 is estimated to be 620 TWh, in which the share of irrigation pumps is 70% and tractors is 30%. This share remains constant from 2012 through 2030, mainly because both the pumping demand and tractor demand are growing at similar rates. The energy demand grew at 6.4% CAGR from 2005 to 2012, and is projected to grow at 4% from 2012 to 2030.

In the EE1 scenario, energy demand is 5% less than the BAU scenario due to improvements in tractor fuel efficiency and the shift to cleaner energy like electric and solar for irrigation pumping. The more aggressive EE2 scenario indicates that about 13% of the BAU energy demand could be avoided. The main fuel shift observed in agricultural energy demand is due to a switch from diesel to electric pump sets. The projection indicates that the share of diesel in energy demand reduces from 50% to 35% in the BAU scenario, from 2012 to 2030. In this period, the share of grid electricity and solar increases from 49% to 63% (MoP, 2017) and 0.1% to about 2%, respectively. The remaining 51.9% and 35% will be fuelled by diesel.

5.5 Buildings

Energy services are very crucial for a country's economic development. According to the World Bank, India's poverty rate reduced to 12.4% in 2011–12. It identified rural electrification to be the driving factor for this reduction (IndiaSpend Team, 2015). As per the 2011 Census, there was a 12% increase in the number of rural households using electricity in 2011 compared to 2001 (Census of India, 2011). About 67% of households in India use electricity, while 31% of households use kerosene for lighting.

The electricity consumed in residential and commercial sector accounted for 45% of the electricity consumed in India in 2016 (MoP, 2017). The type of appliances used and the design of the building influence this. In this study, the energy demand from major appliances like lighting, Heating Ventilation and Air Conditioning (HVAC), television and refrigerators are studied in detail.

The main drivers for increase in residential and commercial demand are population growth, urbanisation and increasing GDP. With about 70-80% of India's 2030 building-stock yet to be built and with increase in purchasing power to buy domestic appliances, the energy demand from these sectors are likely to significantly rise in the future.

Modelling Approach

The energy demand from the building sector was calculated for residential and commercial sectors separately. This demand was further segregated into lighting and other appliances based on the type of building envelope.

The lighting sector saw a sharp drop in the use of incandescent lamps from 2005 to 2012; these were replaced by Compact Fluorescent Lamps (CFL) with the help of the Bachat Lamp Yojana (BLY) scheme (GoI, 2011). The use of incandescent lamps in residential sector reduced to 56% in 2012 from 94% in 2005(CEA, 2018). The BLY scheme was later replaced by the Unnat Jyoti by Affordable LEDs for All (UJALA) scheme in 2015. Under this scheme, the state electricity board distributes LED lamps to residential consumers at a subsidised rate (MoP, 2016). With the advent of LED lamps in the Indian market, it was seen that the CFL industry started declining and consumers started using LED lamps instead of CFL.

In the appliances sector, the cooling demand is likely to continue and further grow as a major share of the total energy demand. The demand from Air Conditioners (ACs) and fans is expected to increase in future due to rise in mean temperatures (GoI, 2017) as well as increasing purchasing power of people. The weighted average of Indian Seasonal Energy Efficiency Ratio (ISEER) in Indian ACs was assumed to be 2.71 in 2012, which is equivalent to a 2-star labelled AC, in the residential sector. In the BAU scenario, the ISEER was considered to be increasing by 1.5% every year, reaching ISEER of 3.82 by 2030. In the EE1 and EE2 scenarios, ISEER was considered to be increasing at 3% and 4% per annum, respectively. With the penetration of energy-efficient appliances in the market, the weighted average ISEER was estimated at 5.45 and 6.81 in 2030 for EE1 and EE2, respectively.

The other appliances that were considered in the analysis were fans, refrigerators, televisions, etc., as detailed in Table 24 to Table 27 in Appendix II.

Figure 11 shows the energy demand from the residential sector. It is evident that cooling demand contributes to about 40% of the demand from the residential sector and is projected to increase four times by 2030 (from 2012). The current policy of Standards and Labelling for appliances mandates energy-efficiency labelling of major appliances like ACs, refrigerators, televisions and lighting lamps (like LED and tubular fluorescent lamps) in the residential sector. Similarly, energy efficiency programmes in the lighting sector, like the UJALA scheme, will help in reducing the energy demand in this sector.

Smart buildings (such as ECBC-compliant buildings) also contribute to the reduction in energy demand. The use of construction materials with a higher U-factor for the roof, walls and windows will result in reduced heat loss from the building with temperature change. The use of energy-efficient appliances in combination with smart buildings can lead to significant energy savings from this sector. The U-factors for different types of buildings are provided in Table 28 in Appendix II.

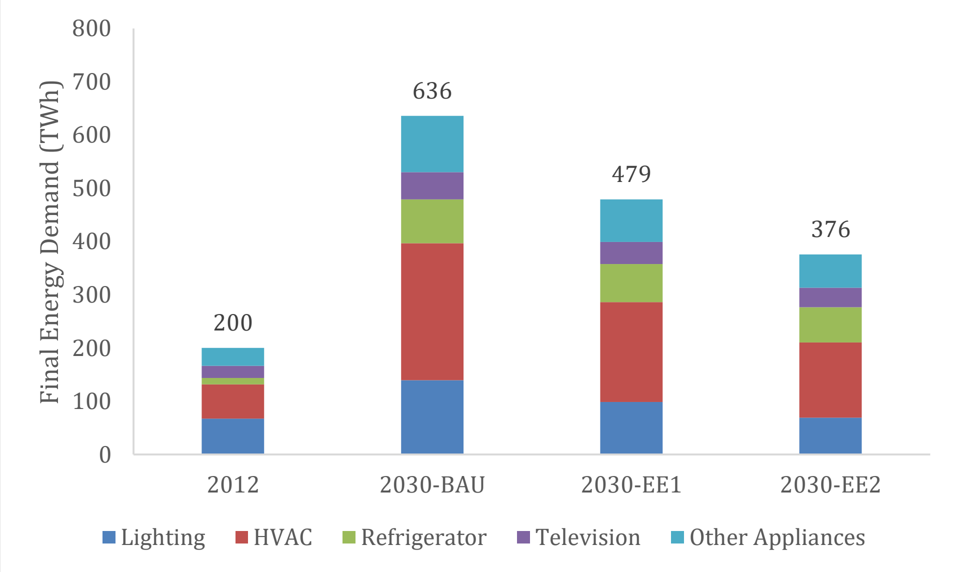

Figure 11: Final energy demand from residential sector

In the commercial sector, the demand is mainly divided into lighting, HVAC and other demands. The HVAC demand in 2012 was around 32%, which increased to 40% by 2030 in the BAU scenario. Figure 12 shows the energy demand for the commercial sector. The additional energy savings of EE1 and EE2 scenarios from BAU are just 3% and 8%, respectively. With mandatory introduction of Energy Conservation Building Code (ECBC) for commercial sector, the energy savings from this sector increases.

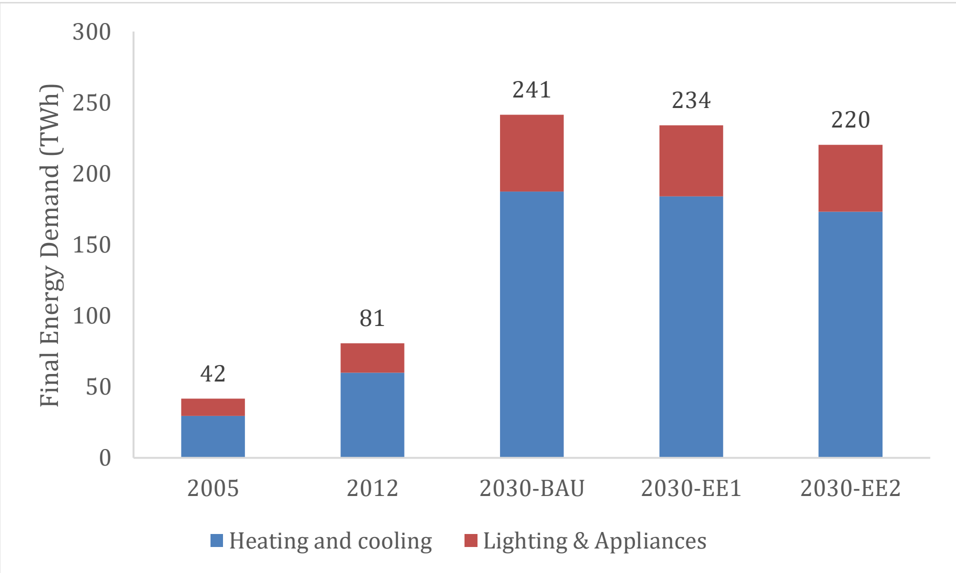

Figure 12: Final energy demand from the commercial sector

5.6 Cooking

The residential cooking sector contributes 10% of the total GHG emissions from the energy sector. Liquefied Petroleum Gas (LPG), firewood and chips, Piped Natural Gas (PNG), kerosene, coal, biogas and electricity are the fuels used in the sector. As of 2011, nearly 83% of households in rural areas and 26% in urban areas used firewood and chips for cooking. However, 66% of households in urban areas and 12% in rural areas used LPG as cooking fuel (Chandramouli, 2011). Since firewood and chips are considered to be carbon neutral, their CO_2

emission factor is zero, making the accounted emissions from the cooking sector low in the inventory.

However, while combustion of firewood and chips contribute towards lower GHG emissions, they are major contributors to household air pollution. Several studies have highlighted the harmful consequences of biomass used in cooking, especially on human health. Modern cooking fuel and efficient cooking stoves help in reducing the fuel demand, cooking time and indoor air pollution. The change in fuel type and efficient cooking technologies will however lead to higher GHGs due to the uptake of carbon-intensive fuels.

Modelling Approach

The average annual cooking energy requirement for each Indian household is considered to be around 2,727 MJ. Based on the climatic conditions, type of vessel and the food prepared, the cooking energy requirement changes with each household. The amount of fuel combusted to produce the required energy is mostly dependent on the energy content of the fuel and efficiency of the stove. With better technologies, push from current policies like the Pradhan Mantri Ujjwala Yojana (PMUY) scheme and improved cook stove programmes, there could be a considerable increase in users switching to modern fuel. The urban sector has slowly started switching to efficient technologies and fuels like electric stoves and PNG. The details of the cooking technologies and its future penetration are provided in Table 21 and Table 22 (in Appendix II), respectively.

With population growth and increased urbanisation, the energy demand for cooking is expected to increase in future. However, with the use of efficient cook stoves and shift in fuel type, the cooking energy demand in the residential sector could reduce by 40% in 2030. The increased access to improved cook stoves and higher penetration of PNG and electricity-based cooking will lead to a drastic reduction in the use of firewood (low calorific value fuel). In the BAU scenario, the energy demand from the cooking sector is expected to reduce by 2.4% every year. With more aggressive policies in place, the demand is expected to further reduce by 3.7% and 4.2% every year in EE1 and EE2 scenarios, respectively.

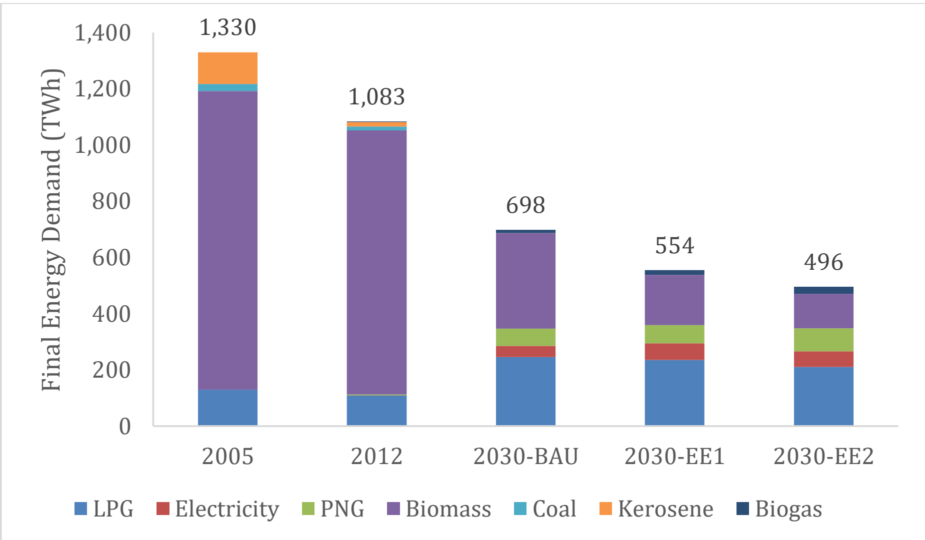

Figure 13: Final energy demand for cooking

6. Results and Discussion

This study estimated the total primary energy demand[18] in 2012 at 6,704 TWh, of which industries contributed the maximum (43%), followed by buildings (17%) and the cooking sector (16%). In the BAU scenario, this demand is expected to double by 2030. The share of industries and buildings is expected to increase to 47% and 20%, respectively, while cooking will reduce to 5%. The decrease in cooking energy demand is due to a switch to modern cooking fuels (biomass to LPG and electricity) and penetration of efficient cooking technologies. However, energy demand from buildings is expected to increase to two and a half times of the 2012 demand by 2030, on account of increased demand for space cooling.

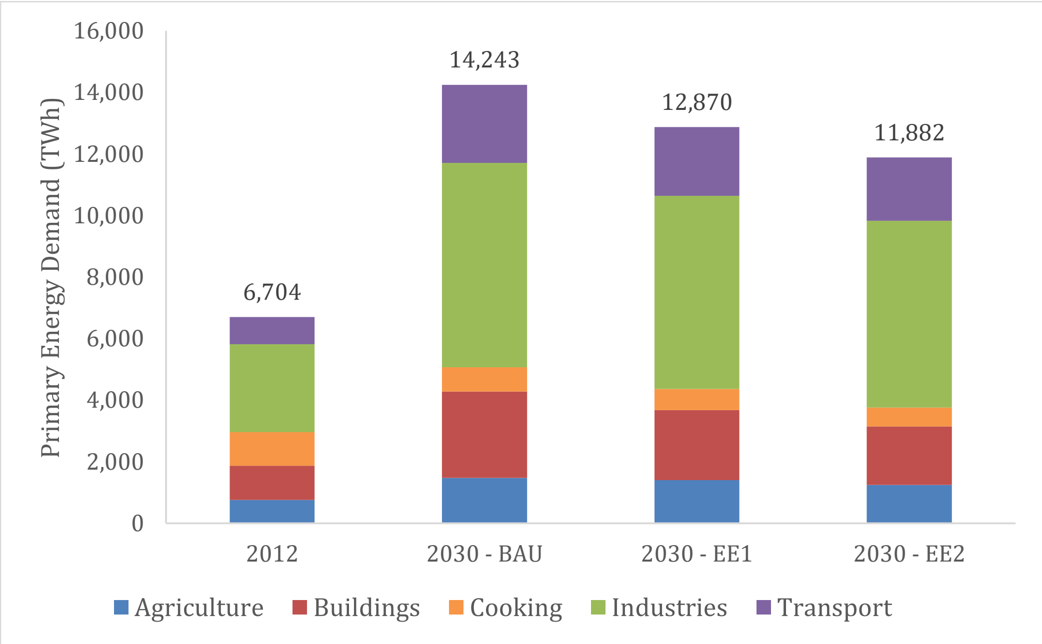

Figure 14: Primary energy demand for all sectors

Under the EE1 and EE2 scenarios, the total primary energy demand reduced by 10% and 17% respectively below BAU, in 2030.

In the EE1 scenario, the energy demand in the building sector (residential and commercial) reduced by 19%. Similarly, in the cooking and transport sectors, this reduction was 13% and 12%, respectively. However, energy demand in the industries sector reduced only by 6%, as the sector is already on a path for improved energy efficiency in the BAU scenario.

With more aggressive penetration of energy-efficiency measures across sectors, the energy demand avoided in the EE2 scenario was 17%. In the EE2 scenario, among the demand sectors, residential and commercial buildings showed the highest savings potential (32%), followed by transport (19%) and agriculture (16%). The industry sector showed a reduction of 9% in EE2.

[18] Conversion factor of final energy to primary energy is provided in the 'supply sector' discussion in Appendix II

6.1 Energy Intensity

India's energy intensity of GDP has shown a declining trend over the last two decades and is expected to reduce further. This reduction indicates the decoupling of GDP growth with growth in energy consumption. The Indian economy grew at a CAGR of 8% between 2005 and 2012, while energy consumption grew at a CAGR of 3% (GoI, 2015c; OECD, 2015).The energy intensity of GDP declined at a rate of 5% annually (2005–2012). As per our analysis, energy intensity of GDP is expected to reduce at the rate of 3% per annum between 2012 and 2030 (refer Figure 15), under the BAU scenario. This drop in energy intensity can be attributed to increased penetration of energy-efficient technologies and processes across all demand sectors and a growth in the share of the service sector. The change in energy intensity is quite evident in the cooking sector, with a shift from biomass-based cooking to cleaner and efficient fuels such as LPG and PNG. Similary, in the industry sector, a shift towards cleaner production processes contributed to this reduction.

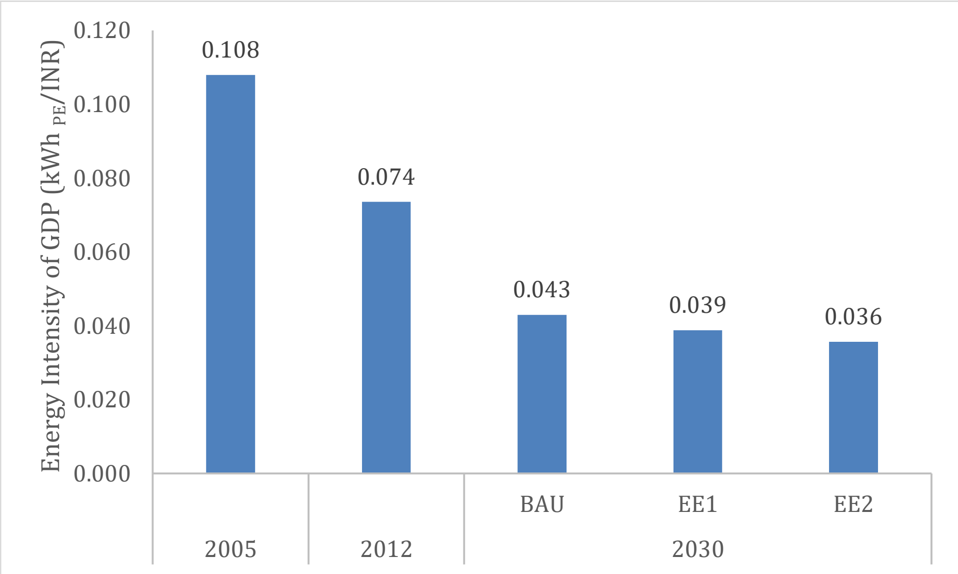

Figure 15: Energy Intensity of GDP

By decoding the NDCs, it was determined that in order to achieve the objective of reducing the emissions intensity of GDP by 33%–35% by 2030 from 2005 levels, the energy efficiency (EE) contribution should be 38%–45%.

Based on sectoral analyses, it is observed that in comparison to 2005 levels, the energy intensity of GDP declined by 60% under the BAU scenario. In the EE1 scenario, this can be further reduced to 64% and 67% in the EE2 scenario.

Therefore, based on the current analysis, India could achieve its NDC obligations with a rigorous implementation of the current policy framework. However, this study shows that there is a significant potential for further improvement in EE across sectors. To realise this potential, additional policy goals need to be defined in the demand sectors, along with strong support at the state-level implementation. These additional policy instruments would presumably be associated with higher cost. This study has not explored the cost implications of EE1 and EE2 scenarios. These additional policy measures and state-level ownership of goals would help in creating a framework towards achieving these goals by 2030.

6.2 Limitations of the Study

Though the study attempted to estimate India's overall energy demand taking into account key activities in various demand sectors, it has the following limitations:

- Service demand in each sector was projected using key performance indicators such as GDP, per capita consumption of an industrial product, floor space area, population, etc. The sectors were modelled independently and the choice of indicator was contingent upon the nature of service offered by each sector.
- The cost implications of EE1 and EE2 scenarios have not been explored in this analysis.
- Energy demand from the buildings sector did not account for energy demand for hot water.
- Cooking energy demand from commercial establishments was not considered.
- In the industries sector, though energy demand from MSMEs was accounted for in the final energy demand estimates, the impact of energy-efficiency measures was examined only for the energy-intensive sectors.
- To estimate the energy demand in the transport sectors, only land-based transportation was taken into account.

7. Policy Gap Analysis

The central government has provided overall policy frameworks for the NDC targets. However, there exists a gap in understanding the implications of the NDCs for state governments. The level of percolation of sector-wide efficiency targets will manifest differently across sectors and states. This section examines the sufficiency of sectoral policies of eight states to contribute to achieving the NDC target of emissions intensity reduction by 33-35% by 2030.

7.1 Methodology

In order to conduct policy gap analysis, sector specific metrics were identified and quantified. This, in turn, was used to identify states with high energy savings potential (which was evaluated in Chapters 5 and 0). State policy documents and technical reports were reviewed to populate and assess policy maturity in a consistent framework. Policy maturity was qualitatively defined in an index based on the following criteria: policy targets are specified, the policies have been notified, and/or the extent to which policy has been implemented.

Sectoral Metrics for Identifying States

The identification of states in the industries sub-sector was based on the contribution of industries to the Gross State Domestic Product (GSDP) in 2005 and 2012. We estimated the contribution of each state's industrial GSDP to the national GVA. The top ten contributing states accounting to almost 80% of GVA from industries were chosen.

In the transport sector, Net State Value Add (NSVA) from road and rail transport for the year 2012 was used to identify the key states. In addition to the NSVA, rate of urbanisation and share of total registered vehicles (car, two wheelers and buses) by state, in 2005 and 2014, were the key metrics to identify the states.

Table 10: Identification of states

Sector	Metrics	States
Agriculture	Net sown area, sectoral value add to GDP, crop intensity (yield per hectare)	Andhra Pradesh, Maharashtra, Karnataka, Uttar Pradesh, Tamil Nadu, Gujarat, West Bengal, Rajasthan
Buildings and cooking	Population growth, Energy consumption by area (PJ/m^2), energy consumption per HH	
Industries	GSDP by industries, GVA by states to GDP and energy-efficiency rating	
Transport	GVA by transport to GDP/GSDP, registered vehicular growth	

Analytical framework

The framework for analysing states for energy-efficiency policy maturity index consisted of both qualitative and quantitative evidence indicators. The qualitative evidence indicators assessed whether a specific policy, mandate and financial incentive exists under each demand sector and broad energy-efficiency intervention proposed for that sector. They also considered the policy intentions of the state towards energy-efficiency improvement that can potentially translate to a policy. The quantitative evidence indicator captures whether the specific policy has a mandated target and the level of achievement against the target. This framework limits the evidence indicators to the data available only in the public domain. Also, this data has not been verified with state agencies.

Table 11 provides a list of broad energy-efficiency interventions by sector and qualitative and quantitative evidence indicators used for the development of the state policy maturity index.

Table 11: List of sectoral evidence indicators for energy-efficiency policy maturity

Sector	Energy-Efficiency Intervention	Qualitative	Quantitative
Industries	• Technology switch • Process switch • Use of Alternative Fuel and Raw material use (AFR)	Notification of a sector-specific policy or action plan	Quantified energy-efficiency targets and utilisation of hazardous raw material
Buildings	• Improved lighting efficiency • Improved appliance efficiency • Improved building design	• Mandate for use of energy-efficient appliances • Notification of building design code	• Targets for distribution of LEDs • Targets for implementation of ECBC codes
Cooking	• Penetration of energy-efficient cook stoves • Fuel Switch	Mandate for use of modern fuels	• Number of households with LPG connections
Transport	• Increased electrification • Modal shift to public transport and rail • Improved fuel efficiency • Increased fuel blending	• Notification of electric vehicle policy • Adoption of legislation for increased production of biofuels • Adoption of urban transport policy	• Targets for increased use of EVs in new vehicle sales • Targets for blending of biofuels
Agriculture	• Penetration of energy-efficient IP sets • Penetration of solar IP sets • Improved tractor fuel efficiency	• Mandate for use of energy-efficient IP sets • Subsidies on adoption of solar pump sets	• Implementation of pilot projects

Based on the data available for each evidence indicator, each state's policy has been ranked as high, medium and low depending on the level of maturity, as represented in Table 12. The policy maturity level in each state has been decided based on the mandated targets and level of achievement. While assigning the maturity against each policy, possible realistic achievement of the policy was determined.

Table 12: State Policy Maturity Index

States	Agriculture	Buildings	Cooking	Industries	Transport
Karnataka	Medium	Medium	Medium	Medium	Medium
Maharashtra	Medium	Low	Medium	Low	Medium
Uttar Pradesh	Medium	Medium	Medium	Low	Low
Tamil Nadu	Medium	Low	Medium	Low	Low
Gujarat	Medium	Medium	Medium	Low	Low
Andhra Pradesh	Medium	Medium	Medium	Low	Low
West Bengal	Low	Low	Medium	Low	Low
Rajasthan	Medium	Medium	Medium	Low	Low

Table 13 shows the national and state-level policies for the eight states identified in the previous section. In the case of industries, there are not many state-level industry-specific policies.

Table 13: State-level policies of the industries sector

<table>
<tr><th>National/ States</th><th>Policies</th><th>Targets and Achievements</th><th>Gaps</th></tr>
<tr><td rowspan="2">National</td><td>Perform Achieve and Trade (PAT)</td><td>Specifies targets for specific energy consumption reduction of key industrial sectors</td><td rowspan="6">• No mention of specific targets on adoption of energy-efficiency measures
• Sub-sector wise targets for energy efficiency improvements absent; policy not yet notified
• No targets for use of renewables for heat requirement (E.g. Low temperature solar process heat); policy not yet notified</td></tr>
<tr><td>National Steel Policy, New Urea Policy</td><td></td></tr>
<tr><td rowspan="3">Karnataka</td><td>Karnataka State Industrial Policy 2014</td><td>Mandates energy auditing and adopting energy-efficiency measures for all industrial units consuming 600 kVA and above</td></tr>
<tr><td>Karnataka Energy Efficiency and Energy Conservation Policy (Draft) 2015</td><td>Mandates targets for policy period (1%) as well as annual</td></tr>
<tr><td>Karnataka Renewable Energy Policy (Draft) 2014</td><td>Capacity addition targets for biomass, cogeneration and waste-to-energy measures have been proposed</td></tr>
<tr><td>Maharashtra</td><td>Save Energy Programme</td><td>Financial assistance of up to 50% of the cost for conducting energy audit</td></tr>
</table>

	Comprehensive Policy for Grid connected Power Projects based on New and Renewable (Nonconventional) Energy Sources - 2015	Target to set up 200 MW industrial waste based power projects	
Gujarat	Scheme of financial assistance for Energy & Water Conservation.	75% cost (Max INR 50,000) of energy/water audit conducted in a unit	
		25% of cost of equipment subject to maximum INR 20 lakhs per project.	
Uttar Pradesh	Uttar Pradesh State Energy Conservation Award	To promote energy efficiency and conservation	
Andhra Pradesh	No specific state policies targeted towards industries	74% DC has met PAT I SEC target	
West Bengal		50% DC has met PAT I SEC target	
Rajasthan		71% DC has met PAT I SEC target	
Tamil Nadu		58% DC has met PAT I SEC target	

Table 14: State-level transport policies

National/ State	Policies	Targets and Achievements	Gaps
National	National Urban Transport Policy 2014	Encourages the growth of urban transport on a path of low carbon growth; Promotes non-motorised transport	• Efficient operation in terms of punctuality and last mile connectivity is not given enough impetus in public transport • Integrated planning of transport system in relation to urban housing and infrastructure is absent • Incentives for production and supply chain for biofuels are non-existent
	National Biofuel Policy 2018	Provides an indicative target for fuel blending of 10- 20% using bio ethanol and biodiesel	
	National Electricity Mobility Mission Plan 2013	Targets the sale of EVs to reach 15 - 16 million	
	National Auto Policy (Draft) 2018 and CAFE	Mandates Bharat Stage VI fuel efficiency standards and improvement in fuel consumption efficiency	
Karnataka	Karnataka State Biofuel Policy 2009	Specifies targets for bio fuel blending for petrol (20%) and diesel (10%); However, only 4-5% blending has been achieved.	
	State EV and Battery Charging Policy 2017	Sets a target to introduce 1000 EV buses; Electrify 100% of 3W, taxis and school bus fleet in Bangalore; Investment promotion subsidy of up to INR 50 lakh for promotion of EV manufacturing; Exemption from road tax for private EV; 0.081% penetration of hybrid and electric passenger vehicles	
Maharashtra	Maharashtra's Electric Vehicle Policy - 2018	Increase the number registered EVs to 5 lakh; 25% capital subsidy on first 250 commercial charging stations for 2W, 3W, cars and buses; 15% capital subsidy on 2W, 3W, 4W private vehicles and exception from road tax; 0.107 % penetration of hybrid and electric passenger vehicles	
	Maharashtra State Urban Transport Policy - 2017	Encourage public transport by increasing the number of buses to 50 and Mass Rapid Transit system to 3 km per 1 lakh population; Encourage sustainable modes of transport by spending 1% of cities' transport budget for awareness campaigns	
Gujarat		0.156% penetration of hybrid and electric passenger vehicles	
Uttar Pradesh	UP Biofuel Policy	Policy to address the issue of burning of crop residue	

Andhra Pradesh	AP Electric Mobility Policy 2018	All state road transport buses and government vehicles to be made electric in top four cities by 2024; 1 lakh EV charging stations to be built by 2024; Exemption from road tax on purchase of all EV	
West Bengal	-	0.148% penetration of hybrid and electric passenger vehicles	
Rajasthan	-	0.101% penetration of hybrid and electric passenger vehicles	
Tamil Nadu	Tamil Nadu Transport Policy -2017	Plans to revamp public transport system to increase share from 20% to 50% by 2036; Encourages shift from road to rail transport system through metro 0.053% penetration of hybrid and electric passenger vehicles	

Table 15: State-level policies in buildings and cooking sector

State	Policy	Targets and Achievements	Gaps
National	UJALA Scheme	Target: Replace 77 crore incandescent bulbs with LEDs (9W) by 2019 Achievement: 30.31 crore LEDs sold by July 2018	• ECBC code to be enforced at local government level in all states • PNG infrastructure to be improved in all cities • Installation of biogas plants and improved cook stoves to be increased
	Energy Conservation Building Code	No targets	
	Energy Efficient Buildings Programme	Target: More than 10,000 large government/private buildings to be retrofitted with 1 crore LED lights, 15 lakh energy efficient ceiling fans and 1.5 lakh energy efficient ACs by 2020 Achievement: Completed retrofitting in 8,983 buildings and project ongoing in 2,566 buildings	
	Pradhan Mantri UJJWALA Yojana	Target: 8 crore LPG connections to be given to BPL households by 2020 Achievement: 4.71 crore LPG connections released (as on July 2018)	

	Unnat Chulha Abhiyan	Target: 2.75 million improved cook stoves to be installed by 2016-17 Achievement: 37,789 improved cook stove distributed as on March 2018	
	National Biogas and Manure Management Programme	Target: Set up 65,180 biogas plants in the year 2017-18 A total of 49.6 lakh family type biomass plants installed as on March 2018	
	Saubhagya Scheme	Target: 100% household electrification by 2019 (i.e., 3.55 crore households to be electrified) Achievement: 86 lakh households electrified (as on July 2018)	
Andhra Pradesh	Energy Conservation of Building Code	Building code incorporated in municipal building bye-law; Financial incentives provided for ECBC compliant construction	• ECBC code to be implemented at the local level • Disincentivise non-energy efficient appliances
	UJALA scheme	Achievements: 2.18 crore LED bulbs distributed	
Maharashtra	UJALA scheme	Achievements: 2.18 crore LED bulbs and 5 lakh LED tubelights sold	
	Save Energy	Provide funds for conducting energy audits	
	Energy Efficient Buildings Programme	Target: Retrofit around 7,000 energy efficient ACs, 110 million LED lights, 60 million energy efficient ceiling fans, and 14,000 streetlights in about 1500 buildings Achievement: Completed retrofitting in 1,302 buildings and project ongoing in 332 buildings	
Karnataka	Hosa Belaku (UJALA scheme)	Target: Replace 6 crore incandescent bulbs with LEDs (9W) and 12 lakh street lights Achievements: 2 crore LED bulbs and 2 lakh LED tube lights sold	

	Karnataka Energy Conservation Building Code (ECBC) 2014	ECBC code notified and incorporated in municipal building bye-law	
	Anila Bhagya	Target: About 1 crore families in the state (whether eligible for Ujjwala Yojana or not) would get free LPG connection	
Uttar Pradesh	Energy Conservation of Building Code	ECBC code notified	
	UJALA scheme	Achievements: 2.47 crore LED bulbs and 4.5 lakh LED tube lights sold	
Tamil Nadu	Energy Conservation of Building Code	ECBC code not yet notified	
	UJALA scheme	Targets: 3 crore LED bulb, 35 lakh LED tube lights and 10 lakh energy efficient fans Achievements: 31 lakh LED bulbs and 5.38 lakh LED tube lights and 1.1 lakh fans sold	
Gujarat	Energy Conservation of Building Code	ECBC code notified, but not yet incorporated in municipal building bye-laws	
	UJALA scheme	Achievements: 3.95 crore LED bulbs and 11.8 lakh LED tube lights sold	
West Bengal	Energy Conservation of Building Code	ECBC code not yet notified	
	UJALA scheme	Achievements: 89 lakh LED bulbs and 6.67 lakh LED tube lights sold	
Rajasthan	Energy Conservation of Building Code	ECBC building code incorporated at municipal bye-law	
	Mandatory use of Energy Efficient Lamps in all new buildings constructed in Government sector/Government aided sector, Board and Corporation	No information available	

	/Autonomous bodies		
	Mandatory use of Solar Water Heating Systems		
	Promotion of Energy Efficient Air Conditioners		
	UJALA scheme	Achievements: 1.54 crore LED bulbs and 3.12 lakh LED tube lights sold	

Table 16: State-level policies in agriculture sector

National/ State	Policy	Targets and Achievements	Gaps
National	Rashtriya Krishi Vikas Yojana (RKVY)	Central assistance plan for states to achieve 4% growth in agriculture	Replace existing inefficient IP sets with at least 4 star rated pump sets Reduce or stop manufacturing of inefficient pump sets
	National Energy Efficient Agricultural Pumps Programme	2,00,000 BEE star rated smart pumps to be distributed to farmers free of cost	
	Sub-Mission on Agricultural Mechanization (SMAM)	Promotion of farm mechanisation and ensuring adequate farm power	
	Prime Minister's Krishi Sinchai Yojana (PMKSY)	Promotion of efficient water conveyance and ensuring precision water application devices like drips, sprinklers, pivots, rain-guns in the farm	
	Kisan Urja Suraksha evam Utthaan Mahabhiyan (KUSUM)	Distribution of 17.5 lakh solar pump sets; Eventually, every agricultural pump set should be solar	
Maharashtra	Replacement of inefficient IP sets	Mandatory usage of energy efficient IP sets for new consumers Pilot project in Solapur for 590 pumps	Replace existing inefficient IP sets with at least 4 star rated pump sets
	Nanaji Deshmukh Krishi Sanjivani Yojana for Climate Based Agriculture	Promote climate flexible agriculture and help small and medium farmers Make areas drought-free, promote sustainable development, improve soil quality, adopt different cropping patterns	

	National Micro Irrigation Mission	Procurement of drip irrigation system, up to 5 hectares subsidised at 50–60% of the cost; Lift irrigation system at INR 10,000 per farm or family	
Tamil Nadu	Agriculture Mechanisation Programme	Subsidy assistance is provided to farmers for procuring agricultural machinery and implements such as tractors and power tillers; 25% of the cost of machinery/implements or the ceiling limit prescribed by Government of India for each piece of machinery/implement, whichever is lower	Replace existing inefficient IP sets with at least 4 star rated pump sets
	Replacement of old pump sets with new pump sets	Replacement of old, inefficient electrical pump sets with new BIS pump sets and renewal of electrical accessories. For pump sets below 5 HP—subsidy of INR 2,500 or 25% of the cost, whichever is lower Pump sets of 5 HP and above—subsidy of INR 5,000 or 25% of the cost, whichever is lower	
	Subsidy for solar-powered pump	The State government will give 1,000 solar-powered irrigation pump sets of 5, 7.5 and 10 HP, under a model programme, to farmers across the state. To avail themselves of this benefit, farmers will have to apply for irrigation pump sets under the seniority scheme 40% state government subsidy; 20% central government subsidy; 30% Tamil Nadu Generation and Distribution Corporation; 10% farmers' share	
	Micro-Irrigation	Installation of Drip and Sprinkler Irrigation systems 50% subsidy to farmers, subject to the ceiling fixed by Government of India	
Gujarat	Solar Pumps	2,300 3HP and 5HP solar pumps to be distributed	Replace existing inefficient IP sets with at least 4 star rated pump sets
	Drip irrigation	Gujrat Green Revolution Company (GGRC) aims to promote Micro Irrigation System (MIS) among farmers in Gujarat; GGRC acts as an	

		implementing agency on behalf of the Government of Gujarat Many villages in Gujarat have adopted 100% drip and sprinkler irrigation systems. In June 2009, more than 93,000 farmers in Gujarat adopted drip irrigation for 1.51 lakh hectares	
West Bengal	Farm mechanization and technology dissemination	Distribution of equipment, including training and demonstration Rate of Assistance: 40 HP Tractor: INR 4.5 lakh Power Tiller: INR 0.45 lakh Power Reaper: INR 0.3 lakh Rotavator: INR 0.30 lakh	Replace existing inefficient IP sets with at least 4 star rated pump sets
	Drip Irrigation	Promote drip irrigation system as an effective measure for water conservation in dry areas	
Karnataka	Replacement of inefficient IP sets	New connections have to install 5-star energy efficient pump set Pilot projects have been implemented in Dodballapur, Mandya, Nippani, Byadgi (35% energy savings achieved) by EESL.	Replace existing inefficient IP sets with at least 4 star rated pump sets
	Surya Raitha Scheme	90% subsidy on solar pumps and government will buy excess power from farmers 310 pump sets under the scheme as on Jan 2018	
Andhra Pradesh	Replacement of inefficient IP sets	Replacement of 1 lakh inefficient IP sets EESL has replaced 25,000 out of 1 lakh pumps so far Pilot project in Rajanagaram (2,500 pump sets)	Replace existing inefficient IP sets with at least 4 star rated pump sets
	Solar PV Water pumping programme by NREDCAP through MNRE	Installation of 6,725 solar pumps in AP	
Rajasthan	Replacement of inefficient IP sets	Financial incentive for adoption of efficient pump sets: The farmers will only be given 20 HP connection if they set up five-star rated pump set certified by the Bureau of Energy Efficiency.	Replace existing inefficient IP sets with at least 4 star rated pump sets

	Installation of solar pumps	10,000 pumps targeted in 2018-19; 28,493 pumps installed in total	
Uttar Pradesh	Kisan Uday Yojana	Replacement of 10 lakh pump sets by 2022	Replace existing inefficient IP sets with at least 4 star rated pump sets
	Solar Pump Yojana	Up to 90% subsidy on solar pumps	

7.2 Discussion on Policy Gaps

The states are responsible for the co-ordination, regulation and enforcement of the Energy Conservation Act, 2001. They are required to take all measures necessary to regulate energy consumption standards in various demand sectors and create awareness for the efficient use of energy. Energy efficiency on the demand side is mainly governed by the states, unlike the supply side, which is governed by both the centre and the states. Table 13 to Table 16 examine the energy efficiency policies for the demand sectors in each of the chosen states.

In the industries sector, Karnataka has the highest policy maturity with mandated energy-efficiency targets. The state's policies provide financial incentives for adoption of low carbon technologies (generation from waste and renewables), apart from encouraging savings. Among the other states, while some (such as Maharashtra) have mentioned energy savings and clean energy generation targets, others have not set any targets while providing financial assistance for energy audits or adoption of energy conservation technologies. Though creating awareness by constituting the energy efficiency awards is a welcome measure, it is inadequate considering the potential for energy efficiency in industries. The lack of sub-sectorial targets is a hindrance for effective implementation of targets mentioned in the policies.

The energy-efficiency improvement landscape in each state is different, and it is thus important for states to formulate specific policies and targets to this effect.

- Policies should mandate detailed energy audits for all industrial units to identify energy-efficiency improvement opportunities along with the corresponding investment requirements.
- Industrial units should be mandated to publish the amount of energy savings achieved and the corresponding measures adopted for the same, in the public domain. This will allow knowledge transfer and display tangible benefits to other players in the market.

In the case of buildings and cooking sector, most of the EE measures are implemented at the central government level. Very few states have implemented the ECBC codes at the local level or in the state bye-laws. Currently, ECBC codes are mandatory only for the commercial sector. Since urbanisation is expected to increase in future, it is important for the codes to be enforced at residential sector also. Similarly, in the cooking sector, all the policies are implemented at the central level and are on track towards meeting their goals.

As in other key sectors, energy-efficiency measures in the transport sector are driven by the central government, and implementation of certain policy aspects is a state responsibility. Given the energy savings potential in the transport sector, some states (Karnataka and Maharashtra) have notified polices with targets (EV policy and Urban Transport policy). These expedite the realisation of policy goals formulated at the national level. However, hardly any states have mandated fuel economy improvement standards through state transport corporations in public transportation systems. The lack of policy goal alignment at the national and state levels is a hindrance to improving energy-efficiency in the transport sector. Hence, at the state-level, it is necessary to

- Mandate state road transport corporations to include vehicle fuel-efficiency norms as part of the procurement policy.
- Include eco-driving in driving licence examinations to instil the message of efficiency among drivers.

In the agriculture sector, most of the EE measures are initiated by the central government. Even though the Centre has announced many schemes, implementation (which is the responsibility of the states) needs improvement. Maharashtra, Gujarat and Andhra Pradesh are at medium levels of policy maturity, with their AgDSM pump replacement programmes and solar pump subsidies. For example, Maharashtra announced in 2017 that all sugarcane would be cultivated through drip irrigation. This would improve water-use efficiency and reduce pumping energy demand. Other states lag in terms of concrete EE efforts. States need to set specific targets and ensure implementation in order to improve the agricultural energy efficiency of India.

8. Conclusion and Policy Recommendations

By analysing historical emission trends and using an intuitive analytical framework to decode the NDCs, we determined that to achieve a reduction of 33%–35% in emission intensity by 2030 over 2005 levels, about 38–45% reduction in the energy intensity of GDP will be required. This would primarily be driven by efficiency improvements in demand sectors (industries, buildings, cooking, transport and agriculture). In our scenario analysis, we assessed that about 60%–67% reduction in energy intensity was possible with accelerated adoption of technologies and implementation of existing national policies.

In order to achieve the NDC pledge, ongoing efforts in EE (along with efforts in alternate fuels and renewables) need to be complemented with rigorous policy implementation at the state level. Further, given the likely growth in energy demands (and thereby savings opportunity) in select sectors, a more concerted focus is needed on sectors where maximum efficiency gains are possible. This study indicates that these sectors are cooking, transportation and space cooling (HVAC). The buildings and transport sectors offer the highest potential for reduction in India's energy footprint. In the buildings sector, around 526 TWh was saved in the EE1 scenario and 900 TWh in EE2. In cooking, energy savings of 101 TWh and 166 TWh were demonstrated in EE1 and EE2, respectively. End-use appliances (star rated) and adoption of ECBC are two key interventions that can bring about energy reductions in the buildings sector. The cooking sector is expected to transition towards more efficient cooking processes driven by fuel and technology switch (from biomass to LPG), especially in the rural economy. In the transport sector, a gradual reduction in energy demand can lead to a saving of 299 TWh and 477 TWh in EE1 and EE2, respectively. These savings were mainly due to modal shift in passenger to public transport and in freight to rail based movement. Further, adoption of stringent fuel-efficiency standards in the vehicle fleet along with planned deployment of electric vehicles can also reduce demand for petroleum-based fuels. The overall share of petroleum based-fuels in 2030 in the transportation fuel-mix reduced to 88% and 76% in EE1 and EE2, respectively, from 95% in BAU.

8.1 Policy Recommendations

Policy lacunae exist in these high savings potential sectors when evaluated at the state level. Here, EE standards need to be stringently implemented with periodic upgrades keeping pace with technological change and appropriate penalty and incentive mechanisms should be enforced. The study suggests that the strong national policy initiative on cleaning India's energy supply and increasing the efficiency of demand sectors needs to be complemented with an increased capacity, policy support, rigorous adoption and implementation at the state level.

To realise the energy savings estimated in the various demand sectors, the following measures are suggested:

Transport sector

- Similar to star rated appliances, it is necessary to adopt mandatory performance labelling for vehicles and crucial spare parts.
- Measures to reduce the negative impacts of vehicle components, such as tyres and air conditioning systems, need to be introduced.

- It is necessary to mandate institutional mechanisms (tax levies) to encourage the purchase of fuel-efficient vehicles.
- Continuous shift to public transportation systems (such as metros with feeder bus services) needs to be integrated in urban planning and development.

Industries sector

- Targeted financial incentives can be introduced to encourage investment in energy-efficient industrial equipment and processes.
- Through a resource purchase obligation, demand side management measures can be stipulated.
- Time-stipulated and achievable energy savings targets should be adopted.
- It is necessary to increase the scope and depth of energy-efficiency mechanisms such as PAT and increase focus and priority at state levels

Buildings and cooking sector

- It is necessary to adopt and periodically update mandatory labelling programmes across the full spectrum of appliances and technologies.
- Focus on efficiency norms for HVAC systems is crucial.
- National Lighting Code should be mandated for residential and commercial sectors.
- ECBC should be mandated for the residential sector.
- Resources should be allocated for monitoring ECBC compliance and verifying the accuracy of claimed performance.
- It is important to ensure faster implementation of infrastructure for PNG.

Agriculture sector

- The government should consider replacing existing inefficient pump sets with at least BEE 4 star rated EE pumps, including a 5 year warranty.
- Manufacturing of non–star rated pumps should be curtailed.
- Solar pump initiatives should be combined with micro-irrigation schemes to optimise both energy efficiency and water-use efficiency in agriculture.
- Farmers should be educated on the nuances of using energy-efficient IP sets, water-use optimisation and suitable cropping patterns specific to their farming conditions.

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Appendix I: Key Interventions

Table 17: Sectoral interventions

Interventions	BAU	EE1 Scenario	EE2 Scenario
Industries			
Energy-efficiency improvements in subsectors	4% to 13% improvement in SECs	8% to 18% improvement in SECs	10% to 23% improvement in SECs
Shift in production processes	Steel: Increase in Gas DRI (5% to 9%) and COREX process (3%-5%) Aluminium: Shift to pre-baked method (70%-75%) Fertilisers: Shift to natural gas feedstock (80%)	Steel: Increase in Gas DRI (5% to 11%) and COREX process (3%-9%) Aluminium: Shift to secondary process (20%-40%) Fertilisers: Shift to natural gas feedstock (100%)	Steel: Increase in Gas DRI (5% to 12%) and COREX process (3%-12%) Aluminium: Shift to secondary process (20%-40%) Fertilisers: Shift to natural gas feedstock (100%)
Use of waste and recycling	Thermal substitution rate in cement (4%) 32% scrap use in steel 20% scrap use in aluminium 43% recycled fibre use in paper	Thermal substitution rate in cement (19%) 35% scrap use in steel 20% scrap use in aluminium 43% recycled fibre use in paper	Thermal substitution rate in cement (40%) 37% scrap use in steel 20% scrap use in aluminium 43% recycled fibre use in paper
Transport			
Electrification of road and rail transport	2% of Cars, 9% of 2W	10% of cars and 3W, 30% of 2W and 3% in buses	20% of cars and 3W, 50% of 2W and 10% in buses

	5% - 70% rail electrification (Passenger and Freight)	70%-80% of rail electrification (Passenger and Freight)	70%-80% of rail electrification (Passenger and Freight)
Increased share of public road transport in passenger kilometres (PKM) travelled Increased share of rail in PKM	Share of public transport 65% Share of rail in overall passenger transport 14%	Share of public transport 80% Share of rail in overall passenger transport 15%	Share of public transport 90% Share of rail in overall passenger transport 20%
Increased share of blended fuels	2%-5% blending of biofuels	5%-10% blending of biofuels	5%-20% blending of biofuels
Improvement in fuel efficiency	9% improvement in cars, 1% improvement in buses and trucks	15% improvement in cars, 25% improvement in buses and trucks	25% improvement in cars, 30% improvement in buses and trucks
Buildings			
Improvement in lighting efficiency	Residential: 40% LED penetration in point and linear lighting Commercial: 30% penetration of LEDs; 50% penetration of high-efficiency CFLs	Residential: 50% LED penetration in point and linear lighting Commercial: 50% penetration of LEDs; 40% penetration of high-efficiency CFLs	Residential: 80% LED penetration in point and linear lighting Commercial: 80% penetration of LEDs; 20% penetration of high efficiency CFLs
Improvement in appliance efficiency	Residential: 10% penetration of highly efficient appliances	Residential: 30% penetration of highly efficient appliances	Residential: 50% penetration of highly efficient appliances
	Commercial: 30% penetration of highly efficient appliances	Commercial: 50% penetration of highly efficient appliances	Commercial: 80% penetration of highly efficient appliances
Improvement in building design	Residential: 30% of the high rise buildings in the urban sector are smart (ECBC code compliant)	Residential: 30% of the high rise buildings in the urban sector are smart (ECBC code compliant)	Residential: 30% of the high rise buildings in the urban sector are smart (ECBC code compliant)

	Commercial: 23% of floor space area (FSA) are part of ECBC buildings	Commercial: 27% of FSA are part of ECBC buildings	Commercial: 32% of FSA are part of super-efficient ECBC buildings
Cooking			
Transition to ICS	36% of rural and 8% of urban households use ICS	33% of rural and 4% urban households use ICS	32% of rural and no urban households use ICS
Improved access of PNG	24% of urban households use PNG	27% of urban households use PNG	36% of urban households use PNG
Biogas plant implementation	4% of rural households use biogas	6% of rural households use biogas	10% of rural households use biogas
Increased use of electric cooking access	9% of urban and 12% of rural households use electricity for cooking	14% of urban and 17% of rural households use electricity for cooking	14% of urban and 17% of rural households use electricity for cooking
Improved access of LPG to rural areas	57% of urban and 36% of rural households use LPG as a primary cooking fuel	54% of urban and 40% of rural households use LPG as a primary cooking fuel	50% of urban and 40% of rural households use LPG as a primary cooking fuel
Agriculture			
Improvement in fuel efficiency of tractors	Diesel consumption at 4.5 litres per hour	Diesel consumption at 4 litres per hour	Diesel consumption at 3 litres per hour
Improvement in efficiency of pump sets	Diesel – 6% improvement by 2030 Electric – 5% improvement by 2030	Diesel – 8% improvement by 2030 Electric – 10% improvement by 2030	Diesel – 10% improvement by 2030 Electric – 20% improvement by 2030
Increase in share of solar pump sets	2.6% by 2030	5% by 2030	10% by 2030

Appendix II: Data and Assumptions

Table 18: Macroeconomic assumptions

Variable	2012	2030
Real GDP growth till 2030	6.8%	
GDP (INR Million)	91.1	297.7
Population (Billion)	1.216	1.552
Urbanisation	32%	41%
Urban Household size	4.60	4.13
Rural Household size	4.90	4.83

Table 19: Baseline emissions for 2005

Sector	Emissions in 2005 ($MtCO_2e$)
Agriculture	374
Energy	1,269
IPPU	108
Waste	51
Total	**1,802**

Source: (MoEFCC, 2015) (Data extracted using Data Digitiser)

Historical Trends in Non-Energy (Emissions) Sectors

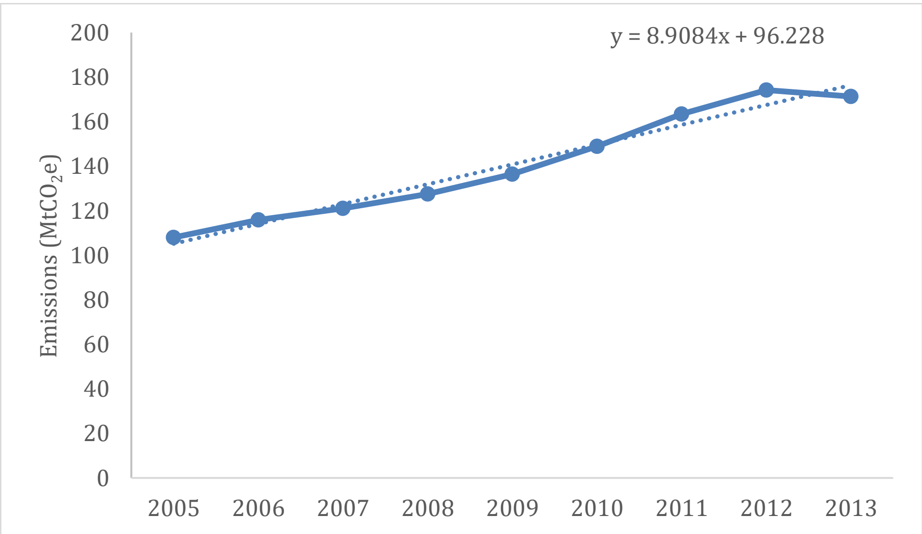

Figure 16: Historical IPPU emissions

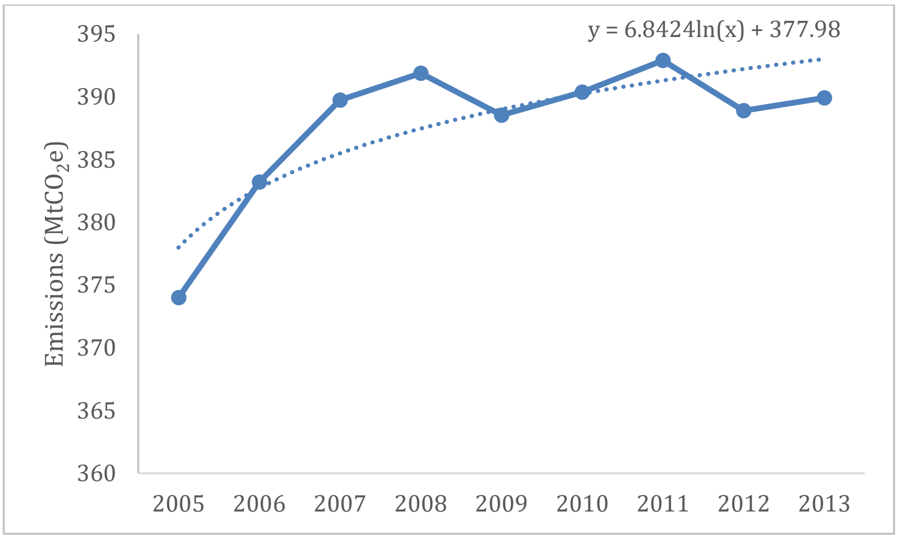

Figure 17: Historical agricultural sector emissions

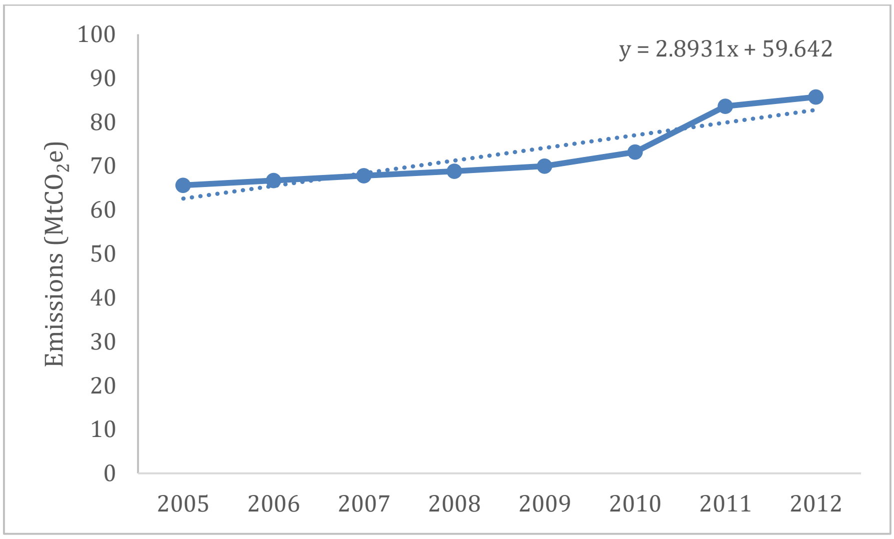

Figure 18: Historical waste sector emissions

Table 20: Comparison of different CO_2 (LULUCF) sink target and land implication

BUR 2010	$MtCO_2$	Basis	Future Value	% of India's land area under forests *
Estimate of LULUCF Emissions	-315	NDC Ultimate Goal (33% of geographical area forested)	-434	33%
		NDC target of 2.5 Gt CO_2 capacity in 2030	-345	24%
		NDC target of 3 Gt CO_2 capacity in 2030	-352	23%
		Projected Value using historic trends (Gov. GHG Inventories INCCA (2007), BUR (2010))in 2030	-764	52%

* A CO_2 sink to Forest Land Area Ratio of 4.5 tCO_2/ha was calculated using data from the Directorate of Statistics and Economics, Ministry of Agriculture for 2010. This value was assumed to continue in the future to estimate land area for projected sink value.

Sector-wise Data and Assumptions

Cooking

Table 21: Fuel use for cooking

Fuel	% Household by Type of Primary Fuel Used for Cooking			
URBAN	**2012**	**BAU (2030)**	**EE1 (2030)**	**EE2(2030)**
LPG	63%	57%	54%	50%
Electricity	0%	9%	14%	14%
PNG	2%	24%	27%	36%
Biomass	23%	10%	5%	-
Coal	3%	-	-	-
Kerosene	8%	-	-	-
Biogas	0%	-	-	-
RURAL				
LPG	11%	36%	40%	40%
Electricity	0%	12%	17%	17%
PNG	0%	-	-	-
Biomass	86%	48%	37%	33%
Coal	1%	-	-	-
Kerosene	1%	-	-	-
Biogas	0%	4%	6%	10%

Table 22: Cooking technologies efficiency

Technology	Efficiency			
	2012	**BAU (2030)**	**EE1 (2030)**	**EE2(2030)**
LPG	50%	56%	59%	63%
Electricity	75%	79%	80%	82%
PNG	50%	56%	59%	63%
Biomass	30%	40%	45%	48%
Coal	20%	22%	24%	25%
Kerosene	35%	39%	41%	44%
Biogas	50%	56%	59%	63%

Building appliances and envelope

Table 23: Penetration of efficient lighting technologies

Type of appliance	2012	BAU (2030)	EE1 (2030)	EE2 (2030)
Bulb	56%	25%	10%	5%
Tube light	15%	20%	25%	10%
CFL	30%	15%	10%	5%
LED	-	40%	50%	80%

Table 24: Wattage of AC technologies

ACs	Efficiency level	2012	BAU (2030)	EE1 (2030)	EE2 (2030)
	Low	1926	1473	1131	951
	Medium	1733	1326	1018	856
	High	1576	1205	926	778

Table 25: Types of refrigerators

Types of refrigerator	Efficiency level	Power consumption (kWh)
Direct Cool	Low	400
	Medium	260
	High	130
Frost Free	Low	519
	Medium	415
	High	332

Table 26: Penetration of efficient refrigeration technologies

Refrigerators	Efficiency level	2012	BAU (2030)	EE1 (2030)	EE2 (2030)
Direct Cool	Low	16%	10%	0%	0%
	Medium	82%	10%	0%	0%
	High	2%	80%	0%	0%
Frost Free	Low	16%	10%	10%	0%
	Medium	82%	50%	30%	20%
	High	2%	40%	60%	80%

Table 27: Penetration of energy-efficient appliances

Efficiency level	2012	BAU (2030)	EE1 (2030)	EE2 (2030)
Low	98%	60%	20%	10%
Medium	1%	30%	50%	40%
High	1%	10%	30%	50%

Table 28: U factors for buildings (W/m²/° C)

Type of building		All building except hotels, business and schools	Hotels	Business (<10,000 m²)	School
ECBC Building	Wall	0.4	0.63	0.63	0.85
	Roof	0.33	0.2	0.2	0.47
	Window	3	3	3	3
ECBC+ Building	Wall	0.34	0.44	-	0.63
	Roof	-	0.2	0.26	0.26
	Window	2.2	2.2	2.2	2.2
Super-Efficient ECBC Building	Wall	0.22	0.22	0.22	0.22
	Roof	0.2	0.2	0.2	0.2
	Window	2.2	2.2	2.2	2.2

Agriculture sector

Table 29: Penetration of pump sets

Type of Pump	Base year (2012)	BAU (2030)	EE1 (2030)	EE2 (2030)
Diesel	32%	7%	5%	2%
Electric	68%	90%	90%	88%
Solar	0.1%	3%	5%	10%

Table 30: Key assumptions for efficiency improvements

Parameters	Base year (2012)	BAU (2030)	EE1 (2030)	EE2 (2030)
Number of tractors	56,29,347	Saturates at ~16 million	Saturates at ~16 million	Saturates at ~16 million
Annual hours of usage	500	500	500	500
Fuel efficiency	4.5 litres per hour	11% improvement	16% improvement	22% improvement
Efficiency of electric pump sets	-	5% improvement	10% improvement	20% improvement

Industry

Table 31: Key industrial output projections

Sector	2012	2030	CAGR
Cement	235	605	5.4%
Steel	77	249	6.7%
Aluminium	2	6	7.6%
Paper and Pulp	11	36	7.0%
Cholr-Alkali	5	8	2.7%
Textiles	3	5	3.0%
Fertilisers	26	31	1.0%

Table 32: Technology process share in steel sector

Technology	Production (% of total)	SEC (GJ/t)
BF-BOF	42%	26.75
EAF DRI-Gas	5%	26.46
EAF DRI-Coal	20%	24.56
IF	30%	26.00
COREX-BOF	3%	12.85

Table 33: Technology process share in aluminium sector

Technology	Production (% of total)	SEC (GJ/t)
Pre-baked	70%	82.02
Soderberg	10%	91.91
Blended	20%	67.99

Table 34: Technology process share in paper and pulp sector

Technology	Production (% of total)	SEC (GJ/t)
Integrated kraft (wood/bamboo/agro waste)	57%	41.17
RCF based (includes market pulp)	43%	19.76

Table 35: Technology process share in cement sector for base year

Type of cement	Production (% of total)
Ordinary Portland Cement	32%
Portland Pozzolana Cement	61%
Portland Slag Cement	7%

Table 36: Specific energy consumption in cement sector for base year

Thermal (kcal/kg $_{\text{clinker}}$)	732
Electrical (kWh/t $_{\text{cement}}$)	84

Table 37: Technology process share in fertilizer sector

Type	Technology	Production (% of total)	SEC (GJ/t)
Urea	Natural Gas based	80%	19.25
	Naphtha based	10%	22.84
	Fuel Oil based	10%	28.83
Ammonia	Natural Gas based	80%	25.79
	Naphtha based	10%	35.00
	Fuel Oil based	10%	44.11

Table 38: Process share in textiles sector

Process	Production (% of total)	SEC (GJ/t)
Integrated Textile Mills	100%	12.60

Table 39: Process share in chemicals sector

	Process	Production (% of total)	SEC (GJ/t)
Soda Ash	Solvay	40%	16.95
	Modified Solvay	20%	15.41
	Akzo dry lime	40%	11.50
Caustic Soda	Mercury cell	5%	11.88
	Membrane cell	95%	10.25
	Oxygen Depolarised Cathode	0%	8.51

Transport

Passenger Transport

Table 40: Passenger service demand projections

Service Demand (BPKM)	2012	2030-BAU	CAGR
Passenger transport demand	7,286	18,444	5%

Table 41: Share of various passenger transport modes and technologies

Mode share	2012	2030-BAU	2030-EE1	2030-EE2
Road	85%	84%	-	-
Rail	14%	15%	-	-
Air	1%	1%	-	-
Sub-mode share				

BUS	63%	55%	62%	67%
ONMI-BUS	3%	1%	1%	1%
CAR	10%	16%	8%	3%
2W	18%	19%	12%	7%
3W	4%	5%	13%	18%
TAXI	4%	4%	4%	4%
Public transport share				
Public	73%	65%	80%	90%
Private	27%	35%	20%	10%
Percentage Blending				
Petrol	-	5%	10%	13%
Diesel	-	2%	5%	5%
Electric Vehicles Share				
CAR	-	-	15%	20%
2W	-	-	40%	50%
BUS	-	-	5%	10%
3W	-	-	15%	20%
Rail	51%	55%	70%	90%

Freight Transport

Table 42: Freight service demand projections

Service Demand (BTKM)	2012	2030-BAU
Total freight demand	1,415	5,987

Table 43: Freight modal shares

Modal share	2012	2030-BAU	2030-EE1	2030-EE1
Road	58%	61%	55%	50%
Rail	42%	39%	45%	50%

Supply Sector

Trends in Power Generation in India

The power generation sector grew at a CAGR of 6.2% since 1990. As of 2017, over 77% (194 GW out of 358 GW) of the electricity generated used coal as the primary resource (MoP, 2017). This has led to a substantial increase in GHG emissions from the supply side. Around 74% of GHG emissions in the country are from the power sector (Ananthakumar Murali R et al., 2017).

To meet the NDC target, India has committed to increasing the share of fossil-free fuel mix in the power sector by 2030. Based on this, MNRE has planned to add 175 GW of Renewable Energy (RE) by 2022 (NITI Aayog, 2015).

Estimation of Future Electricity Generation Trajectories

CSTEP's IMRT model was used to estimate the electricity generation trajectories for the time period of 2016–2030 (Loulou, Remne, Kanudia, & Goldstein, 2005). The key inputs to the TIMES model are power plant database for coal and other power projects, including their plant characteristics such as historic plant efficiency, plant load factor and resource linkages (coal, natural gas, water, etc.). The other inputs to the model are future electricity demand projections (till 2030), national installed capacity addition plans and region-wise renewable energy potential. This data was collected from various ministries and government sources (CEA, 2015, 2018; CoalSwarm, 2016; IEA, 2014; MNRE, 2014; MoC, 2016; MoM, 2015; MoP, 2017).

For new coal plants, efficiency of 36%, 38% and 41% were considered for sub-critical, super-critical and ultra-super-critical plants, respectively.

The IMRT modelling was then carried out to generate a power generation profile till 2030. The total installed capacity in 2030 is expected to reach 650 GW. Out of this, around 334 GW (51%) is from fossil-free power plants, with 36% from renewables alone. The total electricity generation in 2030 is expected to be 2,855 TWh with 62% from coal TPPs and around 30% (845 TWh) being fossil-free. This implies that fossil-based TPPs, specifically coal TPPs, are likely to dominate the power sector for at least the next 15 years (as shown in Figure 19).

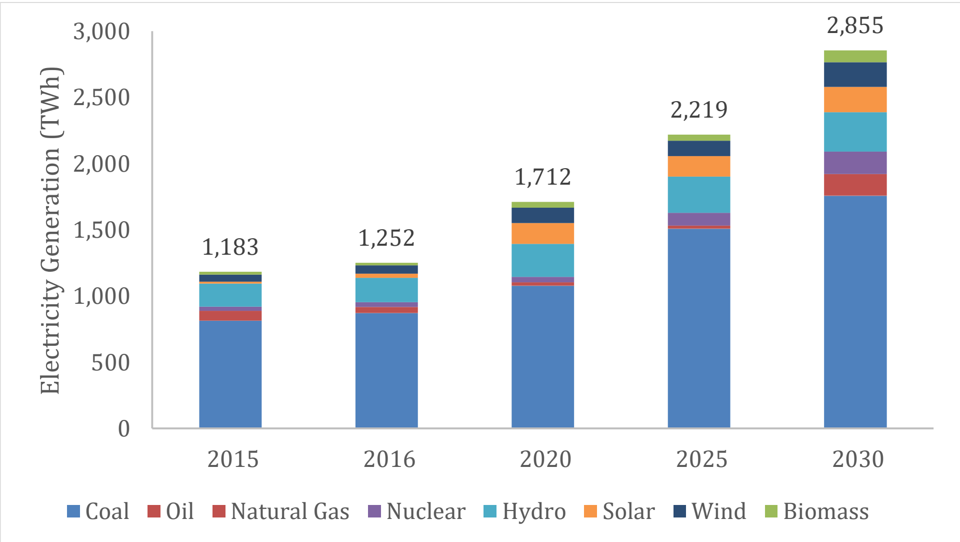

Figure 19: Electricity generation profile in 2015-2030

Based on the results of the IMRT model, the primary energy factor is estimated, which indicates the efficiency of the power supply sector. It represents the quantity of primary energy used in the generation of one unit of electricity. With the advent of super-critical and ultra-super critical power generation technologies in India, this factor is expected to reduce from 3.24 in 2015 to 2.78 in 2030. Since the demand for electricity is accounted for at the substation level, Transmission and Distribution (T&D) losses are also added to the primary energy factor. These losses are expected to reduce from 21% in 2015 to 15% in 2030[19].

[19] Deen Dayal Upadhyaya Gram Jyoti Yojana focuses on feeder separation (rural households and agricultural) and strengthening of sub-transmission and distribution infrastructure to reduce T&D losses.

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