A Sustainable Development Framework for India's Climate Policy

Interim Report

CSTEP
CENTER FOR STUDY OF SCIENCE, TECHNOLOGY & POLICY

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Center for Study of Science Technology and Policy
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Executive Summary

As a large developing country, India's challenge is to meet its development aspirations in a carbon-constrained world. This study, undertaken by the Centre for Study of Science Technology and Policy (CSTEP) uses Sustainable Development (SD) as the overarching framework and aims at equitable access to energy, clean air and water, food, health and livelihoods and economic growth. The study connects elements of SD in an integrated bottom-up approach to understand the implications for economy, energy trajectories, emissions and costs. Any reduction of CO_2 is treated as a co-benefit of the framework mentioned above.

The present study is an initial assessment of such an analysis and focuses on three objectives: (1) Energy security, meaning that the energy system should not be vulnerable to potential fuel supply disruptions, (2) Inclusivity, which ensures access to energy services for all and, (3) Environment, which implies that the pollutant emissions are within reasonable limits to avoid high risk of mortality and morbidity. The analysis develops two scenarios: Business-as-Usual (BAU) and Policy scenario, which achieves the objectives of SD mentioned above.

The results suggest that India's present energy demand of about 5,000 TWh is expected to increase to about 12,500 TWh in 2030 under BAU. This reduces to about 10,000 TWh under the Policy scenario, mostly through the adoption of energy efficient technologies and processes across all sectors. The share of fossil-free sources (excluding non-commercial biomass), which is presently about 4%, increases to 13% in the Policy scenario.

The electricity demand in 2030 is expected to be about 3,000 TWh. In the Policy scenario, fossil-free sources, (solar, wind, biomass, hydro and nuclear) contribute at least 40% of total generation by 2030 (this is 23% at present). Renewable sources contribute about 20% of electricity generated (6% at present). These results are available on the online portal (http://vedaviz.com/Portal/Playground.aspx?p=IMRT23Dec14&g=a24c44).

The Policy scenario in 2030 shows a significant increase in the deployment of fossil-free sources of energy. It's important to note that such a transition is driven by the objective of sustainable development, in particular ensuring energy security and improving air quality. In the process, the lowering of CO_2 emissions is achieved as a co-benefit.

Given these results, we believe that India has an opportunity to carve out a unique developmental trajectory that ensures quality of life for all its citizens when guided by the aspirations of energy security, clean air and a shift to sustainable development. These transformations take place without imposing any restrictions on CO_2 emissions, but nevertheless generate lower CO_2 emissions. This study's framework could serve as an alternative development paradigm for India and other developing countries. It could also be India's distinctive contribution at the Conference of Parties (COP-21) meeting in Paris in December 2015.

Acknowledgements

The authors of this report would like to thank CSTEP's two core funders, International Development Research Centre (IDRC) and OAK Foundation, for their continued support and encouragement.

Contents

Table of Figures

Table of Tables

Introduction

The forthcoming United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties (COP) meeting to be held in Paris, (COP-21) in December 2015 is expected to establish a new international agreement on climate change. As a prelude to COP-21, the recent COP-20 meeting in Lima highlighted the challenges that lie ahead in formulating such an agreement. The main issue lies in the differentiation and sharing of the remaining carbon space in order to avoid catastrophic warming. Several studies have estimated that to have more than a two third chance of keeping global warming within 2°Celsius, it will require the cumulative CO_2 emissions from all anthropogenic sources to stay below 1000 GtC and more than half this amount has already been released.

In an important development, China and the U.S., which are the world's largest CO_2 emitters, recently came to an agreement. The U.S. agreed to reduce its CO_2 emissions by 26-28% from the 2005 levels, by 2025. China offered to peak its emissions by 2030 and increase the share of non-fossil sources to about 20% by 2030. Based on these announcements, it appears that the U.S. and China's per capita CO_2 emissions are likely to converge to about 12-13 tonnes by 2030.

India is the third largest CO_2 emitter in the world with present emissions of about 2,000 million tonnes or 1.5 tonnes per capita. In the Copenhagen COP meeting, India committed to reduce the emissions intensity of its GDP by 20-25% by 2020 from 2005 levels. It also initiated a National Action Plan for Climate Change (NAPCC), which includes several National Missions.

The question now is what could be India's options in the forthcoming COP meeting in Paris? How can India meet its development aspirations, in particular, meeting the energy needs of the poor, in a carbon-constrained world?

Motivation for the Study

Developing countries, including India, have shown reluctance to accept targets for GHG emissions or to announce a peaking year. Developing countries feel the need for sufficient carbon space to improve the standards of living of its citizens. They also argue that industrialised countries should own the responsibility for historical emissions.

There is also wide recognition of the fact that climate change policy needs to be embedded within the broad framework and context of SD. This connection has also been acknowledged by the Government of India in the framework document for NAPCC, developed by the Prime Minister's Council (Ministry of Environment and Forests, 2008). At the same time, India being the 3rd largest emitter with a fast growing economy should take responsibility for being part of the solution. This is the reason India announced the NAPCC and made a commitment to reduce its carbon intensity.

However, this debate on emissions implicitly assumes that India's development aspirations go hand in hand with increasing CO_2 emissions. In other words, we are assuming that we are already committed to a carbon-intensive development pathway with the associated technological and institutional locks-ins. The institutions (policies, procedures and rules for engagement), technology and infrastructure investments compel the country into adopting specific development paths, which would be difficult to modify later. Such path dependencies in different sectors need to be identified and addressed since they adversely affect the poor and are generally unsustainable.

A co-benefits approach has been suggested to bring climate change under the umbrella of mainstream development. This is based on the assumption that several mitigation options also have 'co-benefits' for sustainable development. For example, public transport as a CO_2 mitigation option, also improves the overall efficiency of transportation in the economy. Yet, such an approach still focuses on carbon first, by using mitigation actions as the starting point for analysis.

Alternatively, what if the analysis concentrated primarily on SD; using it as a framework and assessing any reduction in carbon intensity as a co-benefit of the SD paradigm? How would the analysis and the results change if the debate is framed differently? A case in point is the air pollution in Chinese and Indian cities or water scarcity as other drivers for a carbon policy that embeds SD.

In this on-going project, we have assumed that the overall vision of the country is Sustainable Development. How can we achieve our vision of providing equitable access to energy, clean air and water, food, health and livelihoods, alongside economic growth? Specifically, we focus on the following attributes:

- Energy Access
- Water Access
- Energy Security
- Air and Water Quality
- Sanitation
- Housing Access
- Food Security
- Livelihoods
- Health Quality
- Biodiversity

The study attempts to connect these elements of SD in an integrated approach with rigorous bottom-up analytical tools to understand their implications for the economy, energy trajectories, emissions, and costs.

The present report is an initial assessment of the framework as described above. A more detailed report will be published in the latter half of 2015.

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Sustainable Development Framework

As mentioned in the previous section, CSTEP is undertaking a long-term effort to model India's development pathways using a framework, which includes several aspects of SD. The present report illustrates the interim results based on a subset of the assumptions. It focuses on energy and its linkages with economic, social and environmental aspects.

Energy is crucial for economic development and scarcity of energy imposes a constraint on output (Stern D. a., 2013) (Stern D. , 2010). Access to energy services, such as cooking, heating and lighting, is also important for human and social development (Modi, 2005). At the same time, energy also has a close nexus with the environment, thus affecting all the pillars of SD. Consequently, directly or indirectly, energy demand and supply will lie at the heart of India's aspiration for 'faster, more inclusive, and sustainable growth.'

Thus, this report focuses on the following linkages between energy and SD, as shown in Table 1.

Table 1: Energy and Sustainable Development Linkages

Economic	Social or Inclusivity	Environment
Energy Security	Access to services	Pollution
Livelihoods	Access to modern fuels	Land
	Health	Water

1. Energy Security: This implies that the energy system should not be vulnerable to potential fuel supply disruptions due to geo-political considerations. Net energy imports account for about 6% of the Gross Domestic Product (GDP). These are likely to double in value over the coming decade (The Indian Express, 2014). India imported about 80% of its crude oil requirement in 2013 (Chakraborty, 2014). Despite high coal reserves, the share of imported coal has grown rapidly because of challenges in domestic production, which may rise to over 30% in the next few years (MoSPI, 2014). The import of natural gas is likely to increase from about 25% to over 60% by 2035 to meet the four-fold increase in the demand for the fuel (CEEW, 2014).
2. Inclusivity: Per capita energy consumption in India is only about one-third of the world average (The Economist, 2012). About 300 million people in the country do not have access to electricity while 700 million rely on biomass and other traditional fuels for cooking (Banerjee, 2013). The disparity in access to energy has a regional as well as socio-economic dimension to it. Even those with access to electricity receive unreliable and erratic supply, and the country has both peak and average power deficits (MoSPI, 2013).
3. Environment: This refers to the fact that pollutant emissions from energy generation are within reasonable limits to avoid a high risk of mortality and morbidity. The country has a poor record in environmental performance, with high pollution and inefficient resource utilisation for energy production and use (The Economist, 2012). Indoor air pollution due to traditional cooking is believed to be responsible for over 500,000 deaths every year (Financial

Express, 2014) while emissions from thermal electricity generation result in over 8,000 premature deaths and 20 million cases of asthma annually (Guttikunda, 2014).

The present report is an initial study using the framework mentioned above, where the primary focus lies in sustainable development opportunities in power, transportation, industry, buildings, and agriculture sectors. In the initial analysis toward such a long-term study, we have used inclusivity, energy security, efficiency, and air pollution (for the power sector) as the *cornerstones* of a future energy policy.

On the whole, the study will treat reduction of greenhouse gas emissions, improvements in climate resilience and improvements in equity as a co-benefit to the country's development along a low-carbon inclusive pathway. This initial analysis will cover the period until 2030 to help India to develop policies towards COP-21 in Paris.

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Methodology

Energy: IESS 2047

This report has taken a scenario-based approach relying largely on quantitative analysis to understand the long-term energy trajectory. It considers a timeframe from 2012 to 2030. This analysis used the India Energy Security Scenarios (IESS) 2047 tool developed by the Planning Commission of India as the overall framework to integrate the analyses across various sectors. IESS 2047 models plausible pathways for energy demand and supply across various sectors and illustrates their impact on energy security, land requirement, and greenhouse gas emissions.

The main reasons for using IESS 2047 for this analysis are: i) it is an open-source tool which has integrated inputs from several sources; ii) it allows the user to modify the assumptions used in any sector of the economy; iii) it permits calculation of the impact of changes in energy pathways on energy security of the country.

The primary sectors considered in this analysis were agriculture, buildings, industries, transport, and power supply. These sectors account for nearly 75% of India's carbon emissions and are the most significant contributors from the perspective of energy trajectories. (Cooking has not been analysed for this version and will be included subsequently.)

IESS 2047 specifies four levels, or trajectories, for each demand or supply sector, where Level 1 represents the most pessimistic (Least Effort) outcome in that sector while Level 4 represents the most optimistic outcome (Heroic Effort). In this report, we have defined two scenarios:

1. Business as Usual (BAU): This roughly corresponds to Level 2 (Determined Effort) of the IESS. We have defined this scenario as BAU for all energy demand and supply sectors. The scenario also takes into account any ongoing policy strategies of the government and assumes that these are reasonably accomplished.
2. Policy Scenario: The results of the BAU scenario are contrasted with the sustainable development policy scenario. This assumes greater policy effort towards sustainability objectives– energy security, inclusivity, and cleaner air – in the sectors of power, industry, transport, agriculture, and buildings.

The country's dependence on energy imports is taken as a measure of energy security. Inclusivity is somewhat simplistically measured as per capita electricity and energy consumption for this version. Emissions of Oxides of Nitrogen (NOx), Sulphur Dioxide (SO_2), and Particulate Matter (PM) were used to indicate the magnitude of air pollution.

While the impacts of this policy effort in agriculture, buildings, and industries were analysed by modifying the assumptions within IESS 2047, additional analytical models were employed to assess the impact of policy effort in the transport and power sectors – LEAP and TIMES, respectively. The complete methodological framework used for the purposes of this report is represented in Figure 1.

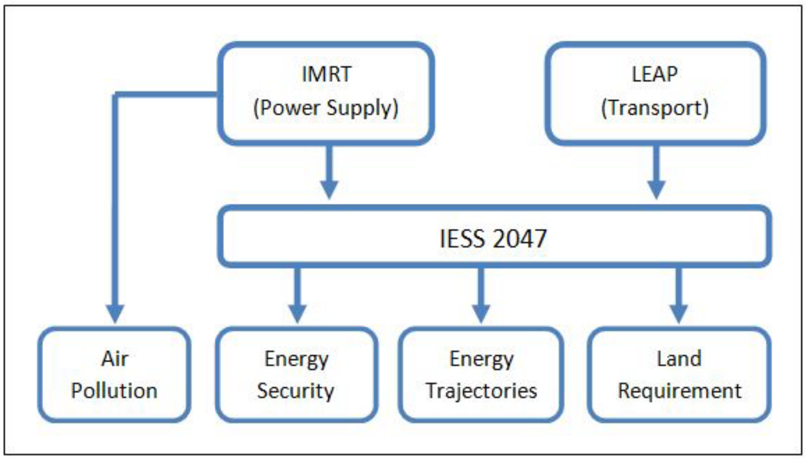

Figure 1: Methodology Framework

Power Sector: TIMES Model

The Power Sector model is a bottom-up, multi-sector model, which develops future trajectories up to 2030. Using inputs such as reference case estimates of end-use energy demand, existing stock of energy related equipment, as well as present and future sources and technologies of primary energy supply, the model generates energy scenarios at minimum cost. It also provides analyses of energy-environmental policies.

For the purpose of this study, data from 2012 was used as base and then projections for 2030 were simulated. The model explores possible energy futures based on contrasted scenarios consisting of a set of coherent assumptions. The scenarios generated are based on the following:

Supply Component

The model generates multi-stepped supply curves for electricity, each case representing a certain potential of the resource available at a particular cost. The assumed potential is based on factors such as resource base, manufacturing capacity, maximum extraction rates, announced government policies, etc. It also takes into consideration the impact of fuel prices (coal, natural gas, uranium).It develops a supply mix, which meets the overall energy demand, taking into consideration the balancing requirements of meeting the load curves, especially in the case of high penetration of renewable resources.

The assumptions for the constraints on potential of each supply source in the timeframe of 2030 are provided in Annexure A.1 Power Sector.

Policy Component

This component is an integral part of the scenario definition. For instance, a No-Policy scenario will ignore emissions of various pollutants and fuel import restrictions. However, under the Policy scenario, constraints are placed on the above and announced government policies are considered. The following section describes the various policy scenarios considered in the model.

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Techno-economic Component

This model uses a rich, well-developed set of technologies, both current and future. It considers present costs as well as likely future cost trajectories, especially for renewable sources. In addition, the incremental costs of various pollution reducing technologies are also specified in the model based on data from the IECM (Integrated Environmental Control Model) software developed by the Carnegie Mellon University. The assumptions for these costs are provided in Annexure A.1 Power Sector.

Scenarios for the Power Sector

The main drivers for the future shape of the Power Sector are the following:

1. Energy Access – India's aspiration is to ensure access to the entire population, rural and urban, as well as, 24x7 electricity supply to all. Based on these assumptions, the IESS spread sheet is used to obtain the energy demand of the Power Sector for 2030.
2. Energy Security – This implies that the electricity generation system ceases to be vulnerable to potential fuel supply disruptions due to geo-political considerations. At present, India imports a reasonable fraction of its coal, natural gas and uranium. The country's aspiration would be to keep the fuel imports in 2030 within reasonable limits to ensure energy security.
3. Pollutant Emissions – At present India has regulations imposed only on the emission of PM, however, there are no regulations for SO_2 and NO_X. Going forward, India may have to regulate the emissions of these pollutants, especially in the vicinity of thermal power plants, to ensure air quality standards. Coal power plants would then need to install more stringent systems for PM, SO2 and NOx removal.
4. Efficiency: The overall efficiency of the Power Sector needs to improve considerably, especially in generation, transmission and distribution. Future coal power plants should be based on Super Critical (SC) and Ultra Super Critical (USC) technologies. The generation of solar and wind energy require large tracts of land and therefore, should also be based on the most efficient technologies. Additionally, T&D losses in India are very high and need to be reduced to global best standards.
5. Cost of electricity: The cost of electricity should be affordable to all categories of consumers, while simultaneously, the subsidy burden on the government should also be reduced.

The model considers two scenarios, as described below:

1. BAU: In this case, we assume that there are no restrictions on pollutant emissions and fuel imports. In addition, the scenario is based on the assumption that the low price of coal (domestic and imported) is sustained till 2030, while the cost of renewable exhibits a moderate decline. This scenario also assumes that India's domestic coal production capacity does not increase significantly.
2. Policy Scenario: In this scenario, we assume that there are regulations for pollutant emissions and restrictions on fuel imports. For the cost of renewable

sources and domestic and imported coal prices, different scenarios are assumed. It further assumes different levels for domestic coal production capacity.

Annexure A.1 Power Sector provides the assumptions for the various scenarios described above.

Transport Sector: LEAP Model

LEAP (Long-range Energy Alternatives Planning System) is a software tool for creating energy scenarios using a bottom-up, end-use based modelling framework. It can specify demand and supply-side options at various levels of disaggregation as determined by the user and permits different operations including econometric and optimisation exercises, depending on the modelling approach used (for more details, see www.energycommunity.org).

For this exercise, LEAP was used to generate a model of transport demand and supply. The transport sector was segmented into passenger and freight segments. The passenger segment was further divided into urban and non-urban transport, each having different activities (passenger-kilometres) by mode (e.g., cycles, two-wheelers, three-wheelers, cars, utility vehicles, mini-bus, public & private bus, rail) and energy intensity by fuel/technology (e.g., petrol, diesel, CNG, hybrid, electric). The freight segment was similarly divided by mode (air, rail, road and water) and further subdivided by technology and fuel (e.g., Heavy-Duty diesel trucks; electric rail). An example of the transport data structure is shown in Figure 2 below:

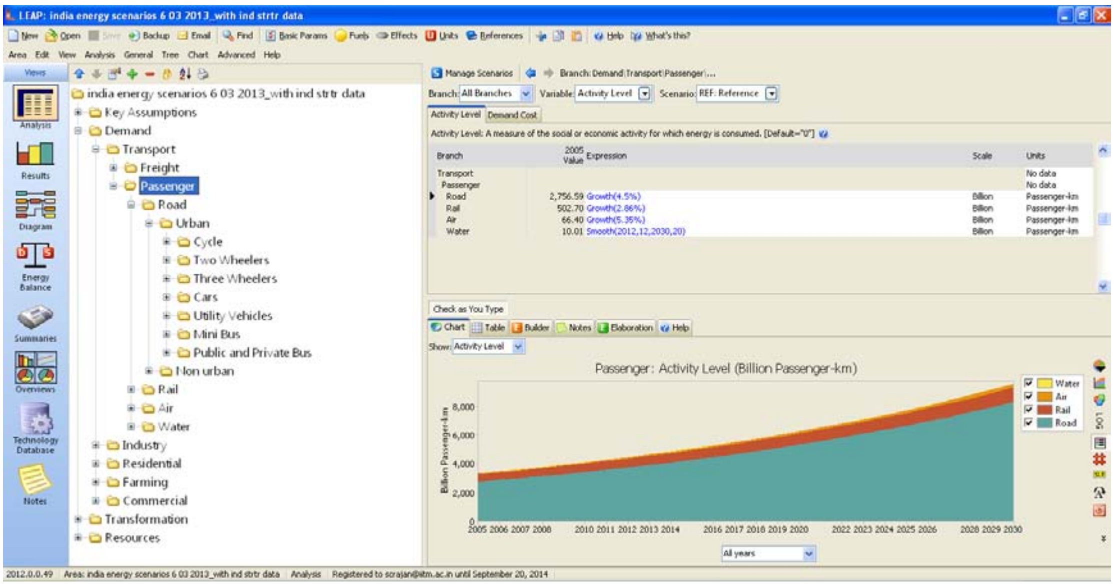

Figure 2: Example of Data Structure in LEAP

Two sets of transport scenarios were generated, each with the following assumptions:

1. BAU Scenario: In this scenario, existing trends of increased reliance on road-based urban transport and growing demand for personal motorised vehicles are expected to continue, with only modest changes because of the evolution of technology and gradual tightening of fuel economy standards for light-duty

vehicles. Access is expected to become increasingly difficult and walking, cycling and travel by other non-motorised vehicles because urban designs and planning tend to favour car-use leading to increasingly 'automobilised' cities and peri-urban regions. In freight, the growth of road-based transport continues to grow at high rates at the expense of rail.

2. Policy Scenario: This scenario assumes improved emissions regulations and fuel economy. Modest increase in access for non-motorised modes, including walking and cycling was assumed for passenger transport, but most importantly, the emphasis is expected to be on access rather than mobility. This implies a greater sensitivity to land-use and transport issues, mixed-use planning, transit-oriented development, transport demand management, and some changes in lifestyle to reduce the need for travel. This results in an expansion of public transport, walking and bicycling. For freight, fuel economy regulations for heavy-duty vehicles are expected to be ramped up modestly. In addition, a reversal in the falling mode share of rail is anticipated, through the development of freight corridors and more efficient routing and supply-chain management particularly for bulk users of freight goods.

For the Policy Scenario, the schematic below (Figure 3), illustrates for passenger transport but is similarly applicable for freight, provided a framework for considering policy interventions.

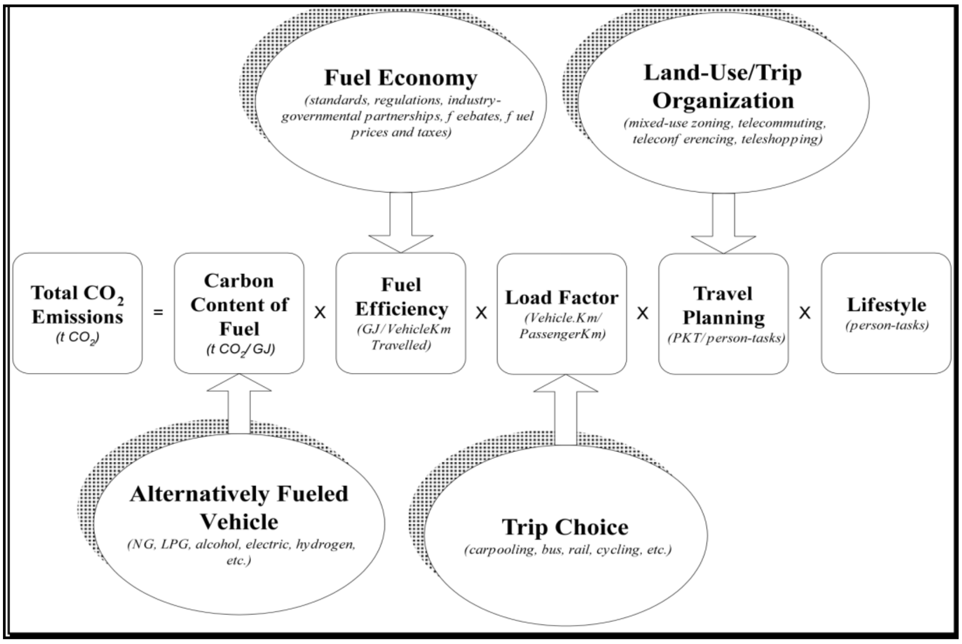

Figure 3: Drivers of CO_2 Emissions in Passenger Transport

Source: Tellus Institute, private communication

Limitations of the Current Study

This interim report seeks to indicate a feasible range of emissions intensity reduction and a feasible energy trajectory for the country. The limitations of this report include:

1. At present, only a small part of the sustainability framework described above has been applied to the analysis. The current version of the report does not assess impacts on livelihoods, energy access in cooking, impact on health, and water scarcity, biodiversity, etc.
2. The energy and economic trajectories are loosely coupled at the moment. The activities across various sectors may not reflect assumptions in GDP growth accurately and would need to be refined through a more systematic assessment.
3. This version of the report does not examine the costs of the scenarios described. Further, implications on subsidies, financial requirement, etc. will also be added subsequently.
4. Cooking has not been assessed beyond what is already present in IESS 2047. A more rigorous assessment here would be particularly important from the perspective of inclusivity and sustainability.
5. This version of the report does not analyse or recommend specific policies that can realise the sustainable energy trajectory. Only the broad levers to achieve this objective have been identified at this stage.

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Results

Figure 4 shows that India's present energy demand of about 5,000 TWh is expected to increase to about 12,500 TWh in 2030 under a BAU scenario. The Industry and Transportation Sectors account for the bulk of energy demand. Under a sustainable development scenario, energy demand is reduced to about 10,000 TWh by 2030. This is accomplished by the desire for energy security, which leads to adoption of energy efficiency across all sectors of the economy. Thus, there is scope to reduce energy demand by up to nearly 20% by 2030 as compared to BAU scenario.

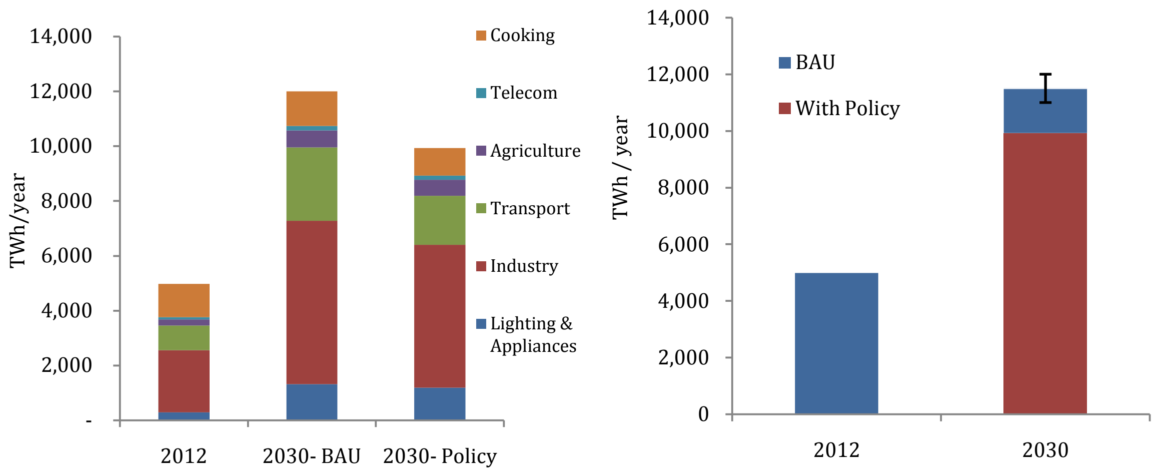

Figure 4: India's Energy Demand in 2012 and Projections for 2030

Figure 5 shows the present and future fuel-wise Total Primary Energy Supply (TPES) so as to achieve the energy demand by 2030, as mentioned above. This suggests that India will continue to be dependent on coal and oil even in 2030, as expected. However, to an extent, coal and oil consumption is reduced in the Policy scenario, and replaced with cleaner and sustainable supply of energy, such as nuclear, solar and wind power.

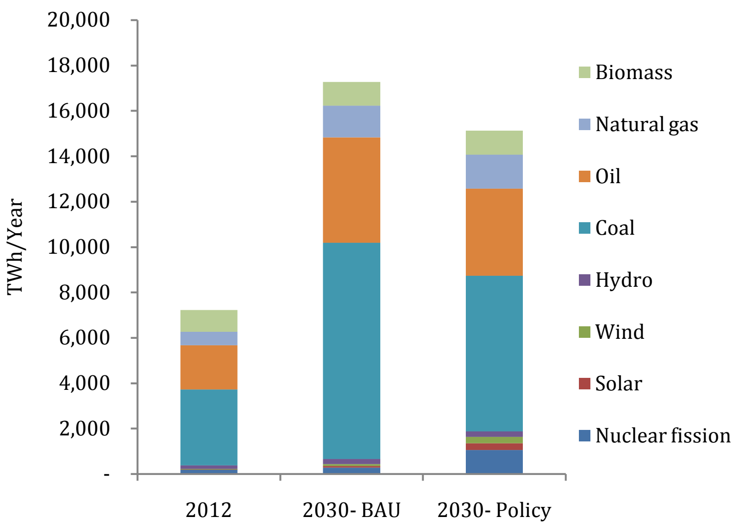

Figure 5: Fuel-wise TPES 2012 and 2030

The Figure also illustrates the growing share of fossil-free energy sources in total primary energy supply. In 2012, these sources contributed about 4% of the supply (excluding non-commercial biomass) and 18% (including non-commercial biomass). For 2030, under the Policy scenario, the share of fossil-free sources will increase to 13 – 15% (excluding non-commercial biomass). In other words, the share of fossil-free energy sources nearly triples in the next decade and a half. It is important to note that this transition is occurring because of SD objectives. Lowering of CO_2 emissions is a co-benefit of the above policy.

Figure 6 shows the energy flow Sankey diagram based on the results of energy demand and supply estimates.

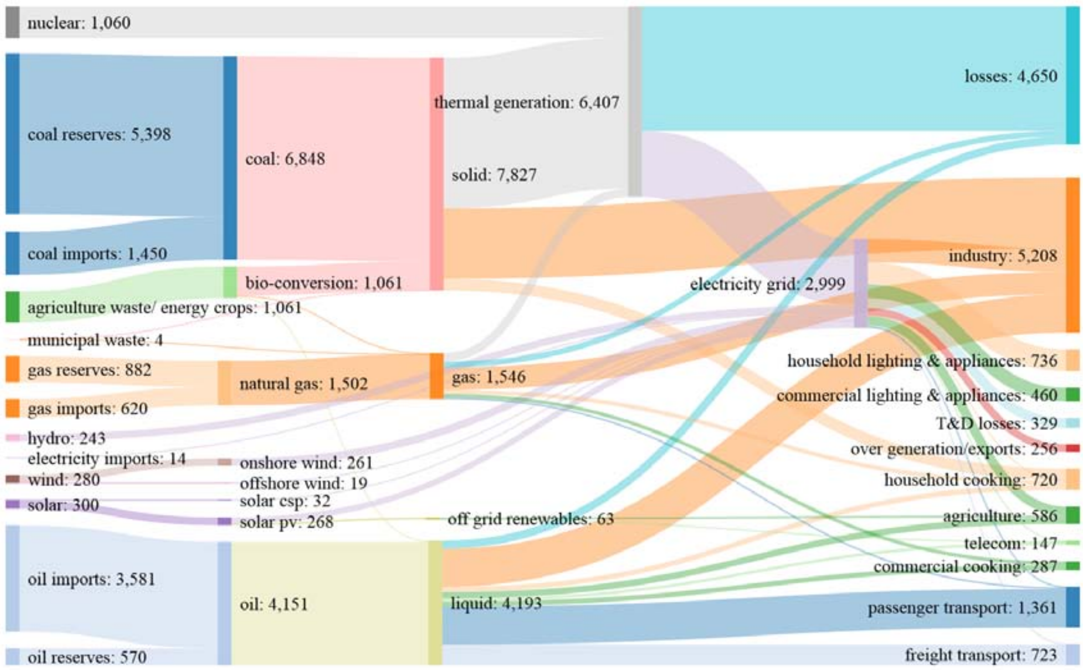

Figure 6: Sankey Diagram of Energy Demand and Supply in 2030, Policy Scenario

Note: Units in TWh

Power Sector

In the BAU case of power generation, as shown in Figure 7, there is electricity demand of about 3,000 TWh, which could reduce to about 2,700 TWh under a sustainable development scenario. In this report, we have used 3,000 TWh to plan for supply mix in 2030 considering a conservative estimate and also the likelihood of export to neighbouring countries. The power sector results are available in an online portal (http://vedaviz.com/Portal/Playground.aspx?p=IMRT23Dec14&g=a24c44). It explores the various trade-offs between the objectives of energy security, pollutant emissions, fuel cost, etc.

The energy supply mix, which is mainly dependent on coal in the BAU scenario, shows a significant share of solar, wind and nuclear power. These fossil-free sources contribute to about 40% of the total generation by 2030 (as against 23% at present) (Figure 8). Similarly, the renewables contribute about 20% of power generation in 2030 (as against

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6% at present). Both of these are significant accomplishments. Moreover, it is important to realise that the adoption of fossil-free sources is driven by the objectives of energy security, and lower pollutant emissions and *not* by targets for CO_2 reduction. Thus, lower CO_2 emissions are a co-benefit achieved from a sustainable development policy.

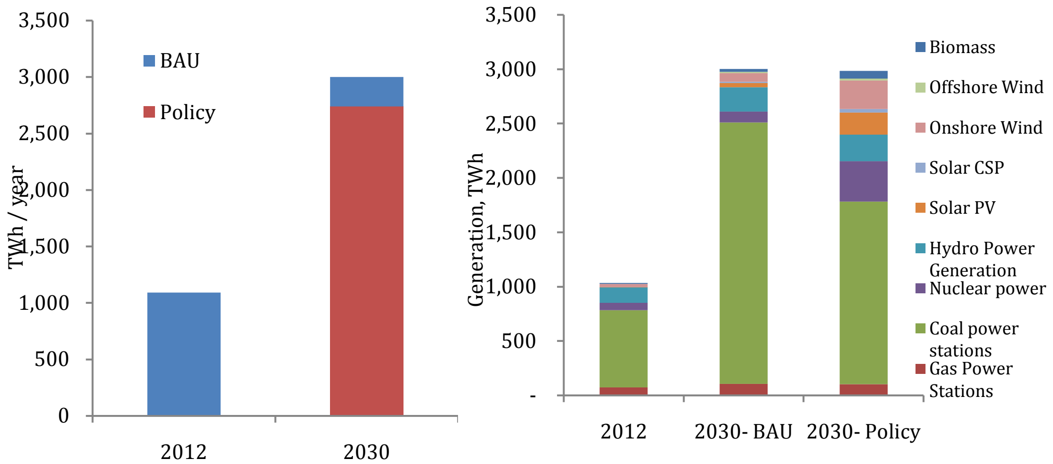

Figure 7: Electricity Demand and Supply Mix in India's Power Sector, 2012 and 2030

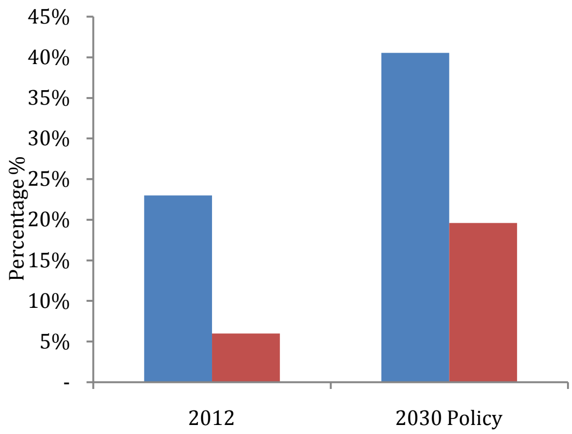

Figure 8: Share of Fossil-free and RE Sources in Power Generation, 2012 and 2030

The online portal explores various combinations of installed generation capacities to achieve the power generation subject to the societal objectives as described above. Broadly, the installed generation capacity is in the following range: Coal (240 - 250GW), Gas (40 – 45 GW), Nuclear (45 – 49 GW), Wind (120 – 140 GW), Solar (120 – 140GW), Hydro (80 – 85 GW) and Biomass (20 – 25 GW). Figure 9 shows one such scenario of installed capacities.

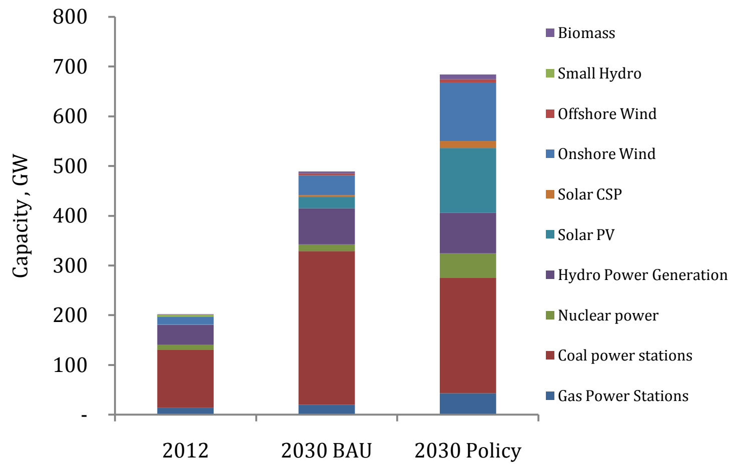

Figure 9: Installed Capacity, 2012 and 2030

Energy Security

Figure 10 shows the import dependence of the economy. At present, about 30% of India's total primary energy is supplied by imported fuels. Under a BAU scenario, this is likely to increase to about 50% by 2030. However, under a policy scenario, the share of imports could reduce to about 35%. This is an important factor and reduces India's vulnerability to the global geo-political environment.

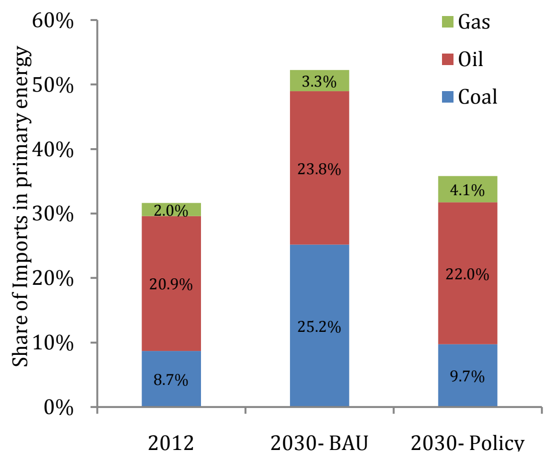

Figure 10: Share of Imported Fuels in Total Primary Energy Supply, 2012 and 2030

Industry

Figure 11 shows that the industry sector consumed about 2,000 TWh in 2012. Under BAU scenario this increases to nearly 6,200 TWh by 2030. Cement, and Iron and Steel account for most of the energy demand. It is also important to note the large share contributed by MSMEs in the total energy demand. In the policy scenario the total industrial energy demand can potentially reduce to about 5,000 TWh; a reduction of nearly 20% over BAU. This will be possible mainly through an aggressive adoption of energy efficient technology in the existing plants and also ensuring that all future plants will be state-of-the-art in energy efficiency.

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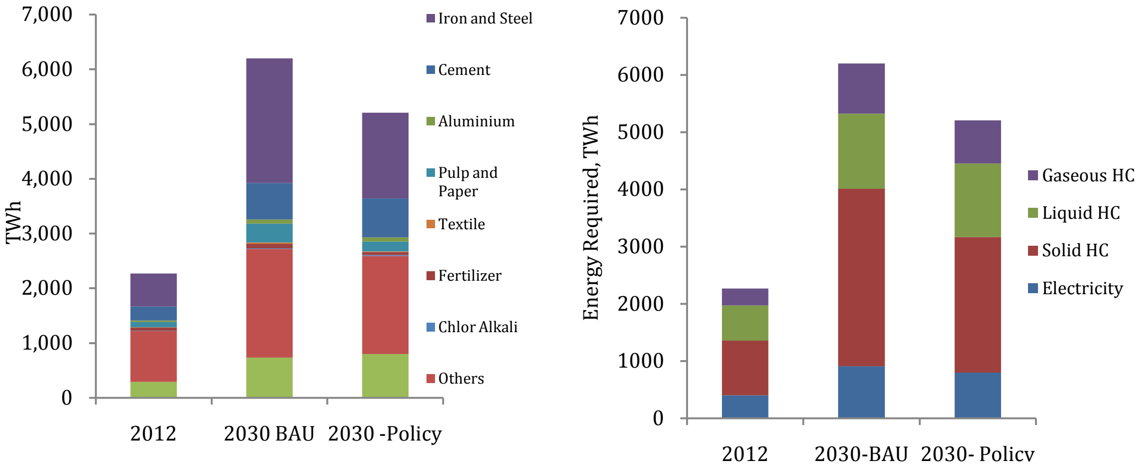

Figure 11: Energy Demand in Industries and Fuel Supply Mix, 2012 and 2030

Transport

Passenger Transport

Figure 12 the modal and technological shares that are likely to obtain under SD scenario. Given the population and income growth, demand of mobility and accessibility will grow almost three-fold. Public transport such as buses will continue to play a critical role, but its share increases in the SD scenario with the overall passenger demand reducing by 17%.Coupled with improved vehicular efficiency, this yields a saving about 26% in energy demand. The share of Railway continues to remain constant account about 15%, and overall share of private vehicles reduces. Figure 12 shows the passenger kilometre share by technology under the subjected levels.

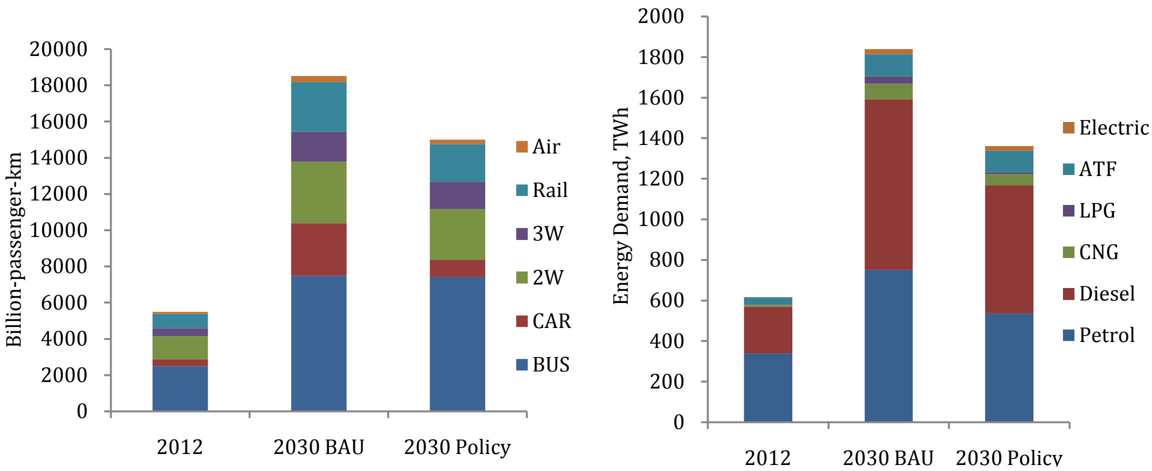

Figure 12: Technology and Modal Share in Transport, 2012 and 2030

Freight Transport

Figure 13 shows the impact of modal shift in freight transport to rail, as well as the shift from diesel to electric rail. Overall freight transport demand can reduce by about 20% in the SD scenario compared to BAU, primarily by avoidance of Heavy Commercial Vehicles (HCVs).

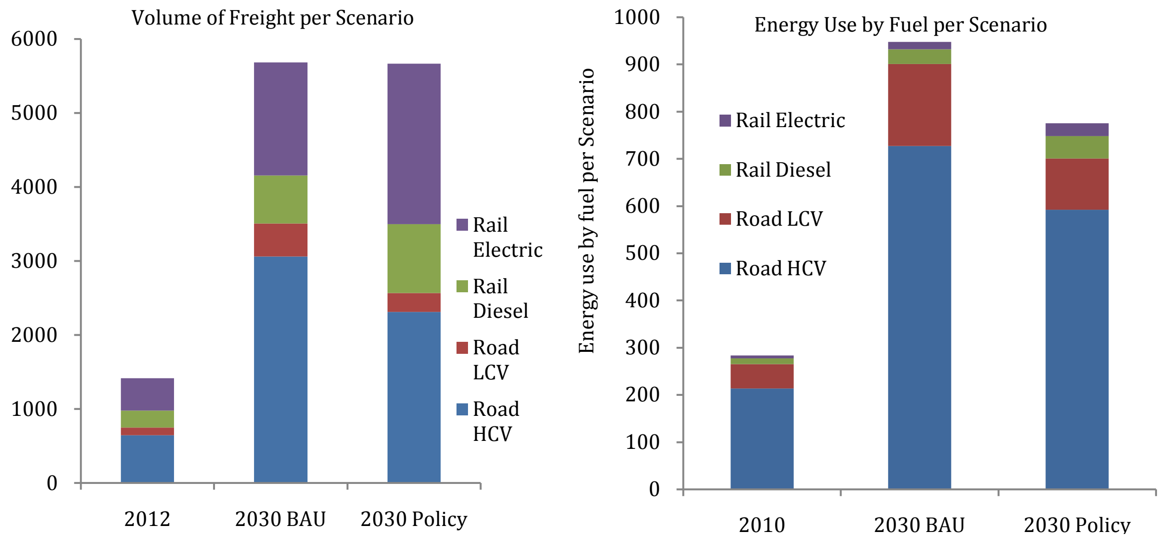

Figure 13: Volume and Energy Use per Fuel Type of Freight in 2012 and 2030

CO_2 Emissions

Figure 14 shows that India's present CO_2 emissions are about 1,800 million tonnes. Under a BAU scenario, the emissions are expected to reach 5,600 million tonnes by 2030. Under the Policy scenario, the emissions are likely to be about 4,500 million tonnes. This is about 1,000 million tonnes lower than the BAU scenario. This reduction in CO_2 is achieved as a co-benefit of the SD pathway.

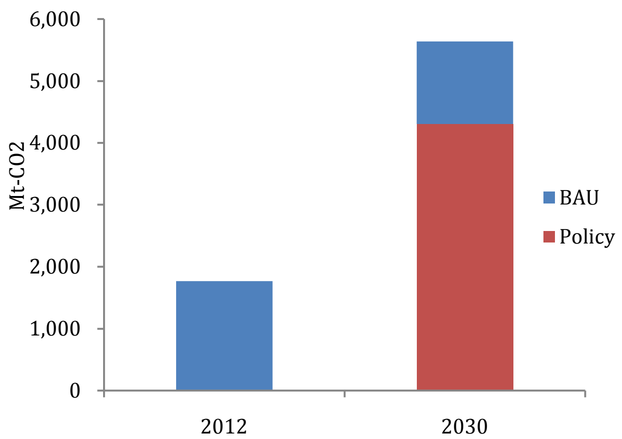

Figure 14: CO_2 Emission in 2012 and 2030

At present, the power sector emits about 0.76 kg CO_2 per kWh of electricity, as seen in Figure 15. This reduces to 0.55 kg CO_2 per kWh by 2030 because of the significant adoption of fossil-free sources.

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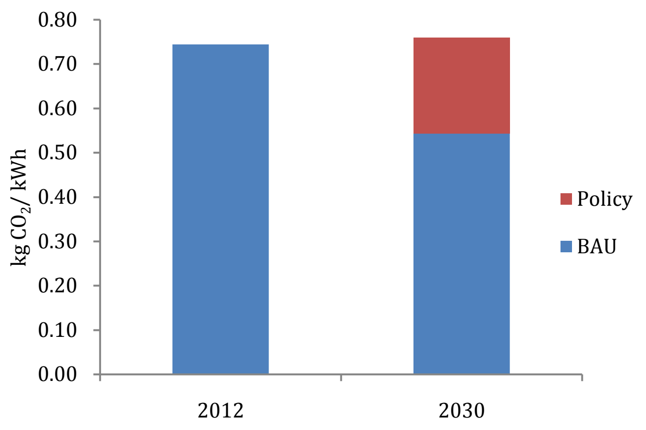

Figure 15: CO_2 Emission Intensity of Electricity Generation in 2012 and 2030

Figure 16 shows the historic trend in CO_2 intensity to GDP of India, US and China. India's CO_2 intensity is already lower than that of China. Moreover, the CO_2 intensity is gradually declining over the last decade. This is mainly attributed to the adoption of energy efficiency in various economic sectors, which leads to lowering the energy intensity of the GDP (kWh per GDP). This report does not consider future GDP projections and therefore, it is difficult to project a future trend in CO_2 intensity. However, the analysis does suggest that there is further potential to reduce the CO_2 intensity to GDP by 2030. This is mainly because of two reasons, namely reduction in primary energy demand and increase in deployment of fossil-free energy.

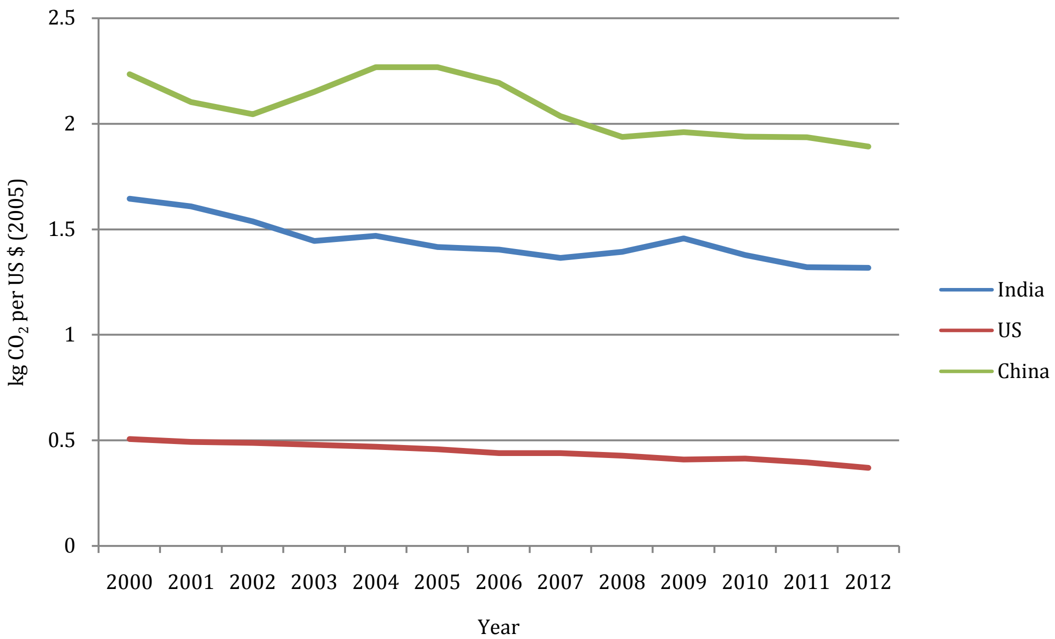

Figure 16: Historic Trend in CO_2 Intensity to GDP

Conclusion

This report is based on a sustainable development framework to develop India's future energy trajectories for 2030. This framework is based on the principles of equitable access to energy, clean air and water, food, health and livelihoods, and economic growth. It is also based on intensive use of energy efficiency as a means to accomplish the above objectives mentioned above. The report estimates CO_2 emissions as an output of the above framework and therefore lowering of CO_2 is treated as a climate co-benefit.

The present report is an interim application of the above framework, mainly considering energy security, energy access, and air pollution as the main drivers. The results suggest that there is potential to reduce future energy demand by at least 20% through the adoption of energy efficient technologies and processes across all sectors. The share of fossil-free sources (excluding non-commercial biomass), which is presently about 4%, increases to 13% in the Policy scenario.

Similarly, the share of fossil-free sources in electricity generation increases to about 40% in 2030, from the present 23%. Renewable sources are expected to contribute about 20% of electricity generated in 2030 as against 6% at present.

The Policy scenario in 2030 shows a significant increase in the deployment of fossil-free sources of energy. It is important to note that such a transition is driven by the objective of sustainable development, in particular ensuring energy security and improving air quality. In the process, the lowering of CO_2 emissions is achieved as a co-benefit.

Given these results, we believe that India has the opportunity to carve a unique developmental trajectory that ensures quality of life for all its citizens when guided by the aspirations of energy security, clean air and a shift to sustainable development. These transformations take place without imposing any restrictions on CO_2 emissions, but still generate lower CO_2 emissions. This study's framework could serve as an alternative development paradigm for India and other developing countries. This could be India's distinctive contribution at the Conference of Parties (COP-21) meeting in Paris in December 2015.

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Annexure

A.1 Power Sector

Context

India's present electric power installed capacity is about 255 GW. This consists of thermal (177 GW), Hydro (40 GW), Renewables (31 GW) and Nuclear (5 GW). In addition, there is a captive generation capacity of 39 GW. About 56,000 MW of new generation capacity was added during the 11thFive Year Plan. The generation during 2013 – 14 was about 960 Billion Units. Moreover, about 93% of Indian villages have been connected to the grid.

Despite the impressive growth, power supply shortages continue to persist in the country, which constrain the growth of the economy, in particular industries. During 2013 – 14, the country faced an energy shortage of about 10% and peak shortage of about 15 %. Moreover, the per capita electricity consumption continues to be only about 900 kWh, which is very low by any standards.

The Government of India has recently declared that 24x7 power supply is one of its most important policy objectives for reviving economic growth. As part of this, the government's targets are: (1) Provide reliable 24x7 power supply to domestic, industrial and commercial consumers within five years, (2) Provide 8 – 10 hours of power supply for irrigation pump sets and (3) Provide access to all un-electrified households in the next five years.

Drivers:

Future growth of power sector should take into consideration a few important driving forces as outlined below.

- Inclusivity and electricity access to all – This implies providing electricity access to all households in both rural and urban areas. In addition to access, the policy objective also includes a minimum threshold supply to all households.
- Energy Security: This implies that the electricity generation in the country should not be vulnerable to possible disruptions in fuel supply. At present, India imports some amount of coal, uranium and natural gas. While it may not be possible to eliminate imports, it would be prudent to keep these within limits.
- Pollutant emissions: Thermal power generation, in particular from coal leads to emissions of PM, SO2 and NOx. At present, India has standards for regulating PM emissions. However, there are no standards for SO2 and NOx. Several studies have established the link between emissions of these pollutants and mortality and morbidity. It would be desirable to restrict the emissions of these pollutants.
- Efficiency: The overall efficiency of power sector needs to improve considerably. This includes efficiency in generation, transmission and distribution. Future coal power plants should be based on super-critical and ultra-super critical technologies. Solar and wind require large tracts of land and therefore, should also be based on the most efficient technologies. The T&D losses in India are very high and need to be reduced to global best standards.

- Cost of electricity: The cost of electricity should be affordable to all categories of consumers and should also minimise the subsidy burden on the government.

Assumptions:

Cost of Technologies:

Table 2: Cost of Various Power Generating Technologies

Technology	Rs. in crore (per MW)	Technology	Rs. in crore (per MW)
Coal (Sub Critical)	4.7	Wind (Offshore)	13-15
Coal (Super Critical)	4.3-5.0	Nuclear (PHWR)	10.0
Gas	3.0	Nuclear (LWR)	15.0-20.0
Solar PV	6.7-7.0	Nuclear (FBR)	10.0-15.0
Solar Thermal	15.0	Hydro	5.0-8.0
Wind (On shore)	5.9-6.5	Biomass	4.5

Cost of Pollution Reducing Technologies:
Various pollution reducing technologies such as Flue Gas Desulphurisation (FGD), Selective Catalytic Reduction (SCR) for NO_X control, and Electrostatic Precipitators (ESP) have been considered for the analysis in the power sector. The incremental costs of these technologies over the base coal plant (either Sub Critical or Super Critical) have been estimated using the IECM (Integrated Environmental Control Model) software and are shown in Table 3.

Table 3: Cost of Various Pollution Reducing Technologies

Plant Configuration	% Increase in Capital Cost (Over Base Coal Plant)	% Increase in O&M Cost (Over Base Coal Plant)	Removal Efficiency		
			PM	NOx	SO_2
Base Coal Plant + Wet FGD +Cold Side ESP	19%	18%	99%	0%	95%
Base Coal Plant + Wet FGD + Hot Side SCR	20%	18%	0%	73%	95%
Base Coal Plant + Hot Side SCR + Cold Side ESP	7%	5%	99%	73%	0%
Base Coal Plant + Wet FGD + Hot Side SCR + Cold Side ESP	22%	21%	99%	73%	95%

Cost Trends (by 2030):

Table 4: Cost Trends of Various Power Generating Technologies by 2030

Technology Cost	High	Low
Solar	Decreases by 20%	Decreases by 40%
Wind	Decreases by 10%	Decreases by 20%
Coal price (domestic)	Increase by 20%	Remains constant at 2012 levels
Coal price (imported)	Increase by 40%	Remains constant at 2012 levels
Gas prices (domestic)	Increase by 20%	Remains constant at 2012 levels
Gas price (imported)	Increase by 40%	Remains constant at 2012 levels

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Other Drivers:

Table 5: Drivers of Power Sector Performance in 2030 (Excluding Technology Costs)

Drivers	High	Medium	Low
Pollutant Emissions (PM, SO2 and NOx)	No control on emission of pollutants	Emissions allowed to double to present levels	Emissions restricted at present levels
Share of Imported Fuels in Electricity	No limit	Limited to 15%	Limited to 10%
Domestic Coal production capacity	2000 million tonnes per annum	1500 million tonnes per annum	1000 million tonnes per annum

A.2 Transport

Context

Transport sector is one of the economic drivers with the service sector in India, predominately observed under passenger and freight categories and distinctive mode are broadly under road, rail and air. Railways and roads dominate the transportation system to about 87% as of 2007-08 (National Transport Development Policy Committee). As of 2011-12, the growth in transport is about 9% (GoI, 2013-14). Overall the transport sector demands about 18-20% of the primary energy.

Some of the active and supportive policies in this space to highlight are from the Ministry of Heavy Industry; nodal agency for automobile sector, through its 'automotive mission plan' had envisioned facilitating more technology to the ground. *Emerge as destination of choice in the world for design and manufacture of automobiles and auto components, adding 10% to the GDP and create man power* (Department of Heavy Industries, 2006). Secondly, evolution of clean transport options such as electric vehicles has been commercialised, through National Electric Mobility Mission Plan 2020 and it is expected to have faster adoption of EVs (both hybrid and electric vehicles) and indigenous manufacturing in the country (Department of Heavy Industries, 2012).

Drivers

- Ensuring an safe and sustainable mobility options across the country
- Expansion of transport infrastructure (road, railway route) and associated facility (New Station, Building, Inventory handling)
- Indigenous manufacturing and employment generations
- Call for efficient, low carbon technologies in both domestic passenger and freight transports

Assumptions

The roadmap to sustainability in transport sector in the model has ensured to see through the vision and mission in the automotive sector. Improve the access to transport to a largest extent, increase more passengers on quick and rapid transportation system. Table 6 indicates the scenario of demand in the reference year till 2030.

Table 6: Transport Demand in 2012 and 2030

Category	2012	2030 Policy
Passenger (BP-km)	5500	15000
Freight (BT-km)	1422	5684

Passenger Transport

The conventional technologies in the system are by means of Car, Two Wheelers and Three Wheelers (Autos). Table 7 shows the assumed percentage share of various modes of transport used by passengers in 2012 and 2030.

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Table 7: Percentage Share of Various Modes of Transport Used in 2012 and 2030

Description	2012	2030		
Road	84%	84%	Bus	53%
			Omni-bus	6%
			Car	7%
			2W	22%
			3W	12%
Rail	14%	14%		
Air	2%	2%		

Freight Transport

Similarly, in the freight transport, inland roadways dominate by 45% and railways by 55% respectively, as seen in Table 8. The use of heavy and light motorised vehicles is overarching in the freight. There is shift towards electric railways in transporting freights.

Table 8: Modal Share in Freight, Overall and Technology-wise

Overall Modal Share		Modal Share by Technology			
Mode		Type	Technology	2012	2030
Road	45%	HCV	Diesel	86%	90%
		LCV	Diesel	14%	10%
Rail	55%	Diesel	Diesel	34%	30%
		Electric	Electric	66%	70%

A.3 Industry

Context

The Industrial Sector is one of the key economic drivers in India. The sector contributes about 27.3% to the GDP, which includes global competitive sectors such as Cement and Iron and Steel. As of 2011-12, the growth in the Manufacturing Sector was about 7.4% and it included 24.3% of the country's workforce. The Micro, Small and Medium Enterprise (MSME) Sector plays a key role within industry in terms of employment and skill development. .

The Indian Industrial Sector accounts for 47% of the total energy consumption in India, out of which, 21% is consumed by the Iron and Steel Sector. The Sector envisions sustainable and equitable growth pathways by addressing the challenging issues of energy demand, clean energy options, raw material procurement and process efficiency improvement.

The National Mission on Enhanced Energy Efficiency (NMEEE) envisages aggressive energy efficiency targets through the Perform Achieve and Trade (PAT) Scheme. The Mission has also ensured appropriate financing platforms for efficient technology options to the Industrial Sector.

Drivers:

- Sustainable manufacturing options, producing adequate output to meet domestic and trade requirements
- Access to reliable and clean energy options
- A mandate on energy efficiency improvements from maximum number of industries by bringing them under a common compliance mechanism.

Assumptions

Table 9 shows the current production levels and future growth of various sectors by2030.

Table 9: Production Levels of Various Industrial Sectors, 2012 and 2030

Sector	Production (Mt) Level at 2012	Growth Rate (%) 2012	Growth Rate (%) 2030
Cement	246.7	8	6
Fertilizer	16.4	1.4	0.6
Aluminium	1.6	7.2	5.0
Iron and Steel	79.9	8.0	6.0
Pulp and Paper	10.9	8.0	4.0
Textile	3.1	1.9	2.2
Chlor- Alkali	2.3	3.8	4.5
Others	590	21.8	7.8

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Table 10 shows the extent of penetration of energy efficiency in the various sectors by 2030.

Table 10: Penetration Extent of Energy Efficient Technologies in Industry

Sector	Sector Production from EE	Present Average SEC of Existing units (TWh/t)	Target average SEC (TWh/t)
Cement	80%	0.99	0.94
Fertilizer	99%	4.58	3.93
Aluminium	78%	23.26	13.96
Iron and Steel	89%	7.33	5.12
Pulp and Paper	45%	7.79	5.30
Textile	93%	1.93	1.65
Chlor- Alkali	97%	3.84	3.61

A.4 Commercial Buildings

Context

Commercial Sector comprises all non-residential and non-industrial buildings such as offices, hospitals, hotels, retail outlets, education institutions, public services, etc. These account for approximately 9% of electricity consumption through utilities growing at 11% percent in the last decade (MoSPI, 2013). With the commercial floor-space growth projected at over 8% in the next 20 years (Planning Commission, 2011, p. 86), electricity demand from commercial sector will grow at a substantial rate.

The energy consuming equipments in the commercial sector are lighting (25%), heating, ventilation and air conditioning (HVAC) (55%), and other office related equipment (20%) (Bureau of Energy Efficiency, 2013). In contrast to the domestic sector, commercial buildings often rely on central AC, chillers and luminaires (complete lighting portfolio) for their end-use needs than stand-alone equipments. It is generally true that the commercial sector is more mindful of life-cycle costs and benefits of efficient appliances and invests more in these appliances than the residential sector.

Under the NMEEE, BEE is responsible for coordinating Energy Conservation and Building Code (ECBC) and Standard and Labelling (S&L) programs, both of which are expected to have significant impact on the aggregate energy demand from the commercial sector in the future. It is planned that ECBC shall be mandatory for commercial buildings or building complexes with a connected load of 100 kW or more. Apart from the usual star/green rating of these buildings, BEE has a retrofitting programme based on performance contracting model of Energy Service Companies (ESCOs) for existing buildings.

Drivers

- Urbanisation (Smart Cities Programme)
- Augmentation of Grid Supply (RGGVY, 24x7 Electricity Supply)
- Growth of commercial floor-space (> 8% till 2032)
- Implementation of Energy Conservation Building Code, etc.
- *Energy Efficiency*
    - Improvements in the service efficiency of appliances
    - Ability to pay for more efficient technologies
    - Updation and stricter implementation of Standards and Labelling
    - Operating costs of appliances and equipment (Commercial Tariffs)
    - Innovative financing mechanisms under NMEEE

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Assumptions

Table 11: Representative Technologies in the Commercial Sector

Efficiency	Lighting		HVAC		Others	
	Wattage	Life (hours)	Wattage	Life (hours)	Savings	Life (hours)
Low	15	12,000	1,870	10,000		10,000
Med	11	17,000	1,570	10,000	21%	15,000
High	6	40,000	1,400	18,000	43%	25,000

Table 12: Share of Technology in Commercial Sector

	High	Med	Low
2012	0%	50%	50%
2030-BAU	20%	50%	30%
2030-Policy	40%	50%	10%

A.6 Agriculture

Context

India supports around 17% of world's human population and 15% of world's livestock, while accounting for 2.4% of world's geographical area and 4% of its water resources (Ministry of Agriculture, 2013, p. 1). Agriculture accounts for 14% of nation's GDP, and 11% of its exports, and provides employment to about half our workforce and raw materials for various applications in the industrial sector.

The sector accounts for about 17% (Planning Commission, 2011, p. 86) of the total electricity and about 12% of the total diesel (Business Standard, 2012)consumption in the country. Irrigation pump-sets and tractors account for most of the energy requirement in the sector, with other farm machinery contributing only a small portion.

Pumping is primarily done through electricity. The number of electrified pump-sets has increased to over 16 million in 2009 from 12 million in 1999 (Planning Commission, 2011). Diesel pump-sets are estimated to meet about 17% of the total pumping energy demand (CSTEP analysis). Electricity consumption in the sector grew at a CAGR of about 7% between 2006 and 2012, from 90 TWh to 136 TWh. The average efficiency of pump-sets remains low at 30-35%% and offers significant scope for savings (TUV SUD, 2010, p. 34)

The number of tractors in the country was about 5.3 million in 2011 and has been growing at 6% annually. This trend is expected to continue as only 18% of the potential market has been exploited (Ministry of Road Transport and Highways, 2012). Total annual demand for diesel from tractors is estimated to be about 6 million tonnes.

Drivers

Irrigation Pumping

- Population Growth- Demand for agricultural production
- Availability of other sources of irrigation
- Water Table
- Water efficiency- micro irrigation and protected cultivation
- Cropping patterns- intensive/off-season cultivation
- *Policies*
    - Ag DSM
    - State solar irrigation / pump-replacement schemes
    - Electricity Tariffs
    - Major and Minor Irrigation Schemes; micro-irrigation schemes
- *Pumping Efficiency*
    - Quality of power supply
    - Technological improvements
    - Capital costs of pumps
    - Fuel Substitution
- *Choice of Fuel*

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- o Electrification (DDUGJY, 24x7 Electricity Supply)
- o Operating Costs (Policy on Diesel Subsidy)
- o Technological breakthroughs (cost of solar panels- Make in India)

Farm Mechanisation

- Rural demographics- landholding sizes and patterns
- Economics of mechanised versus manual/animal labour
- Intensive cultivation and multiple cropping
- *Policies*
    - o Rashtriya Krishi Vikas Yojana
    - o Macro-Management of Agriculture, etc.
- Improvements in fuel efficiency

Assumptions

Table 13: Representative Technologies for Irrigation Pumping

Year	Electric		Diesel		Solar **
	Input (kW)*	Life (Hours)	Input (lph)	Life (Hours)	Life (Hours)
2012	6.00	7,000	1.20	5,000	25,000
2030- BAU	5.00	7,000	1.10	5,000	25,000
2030- Policy	4.50	7,000	0.95	5,000	30,000

* For a standard 5 HP pump-set
**Input for 3 HP solar pump-sets at current efficiencies (~40%)

Table 14: Fuel-Choice for Irrigation Pumping

Fuel	2012	2030-BAU	2030- Policy
Diesel	20%	15%	5%
Electricity	80%	80%	85%
Solar	-	5%	10%

Table 15: Activity in Farm Mechanisation

Year	#Tractors*	% in use	Hours/year	Input (lph)	Diesel Consumption (Mt)
2012	5,310,705	60%	500	4.5	6.09

*Tractor population assumed to grow at 6%, with saturation expected at 16.5 million (Goel & Kumar, 2013).

Table 16: Fuel-Efficiency in Tractors

Year	Input (lph)
2012	4.5
2030- BAU	4.25
2030- Policy	3.75

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