

ENERGY SECURITY OUTLOOK

Defining a secure and sustainable energy future for India



The Energy and Resources Institute

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Foreword

The issue of energy security has multiple dimensions, some of which go back to the Energy Survey of India Committee set up by the Government of India in the early 1960s. This was the first major effort to comprehensively address the challenges faced by the energy sector and define approaches and directions required to ensure the supply and use of energy to promote balanced economic development in India. The Working Group on Energy Policy set up in the late 1970s gave further substance to the issue of energy security, particularly since this Committee was established in the wake of the first oil price shock of 1973–74 and was actually functioning during the second oil price shock triggered by certain political developments in Iran. A more recent definition was provided in the 12th Five-Year Plan which defined energy security as ensuring uninterrupted supply of energy to support economic and commercial activities necessary for sustained economic growth. However, in the Indian context, in particular, two important aspects of energy security also include the challenge of energy access for all sections of the population as well as a perception of risks, both economic as well as non-economic, associated with dependence on energy supply from external sources.

A sudden increase in oil prices is in general likely to be followed by a proportionate ratcheting of prices of other fossil fuels as well. In other words, a global increase in oil prices has a multiplier effect across all fossil fuels, and the time lag between this sequence of increases has reduced considerably in recent years. Earlier, India was not importing coal other than small quantities of coking coal for the steel industry. Now, however, coal imports have grown substantially, and TERI's projections using the MARKAL model indicate that on a business as usual basis in 2031–32 we could be importing a total quantity of 900 million tonnes. Hence, a price increase across all fossil fuels, which would be inevitable in case oil prices were to increase sharply, could have serious repercussions for the Indian economy. It would not be out of place to mention that when global oil prices quadrupled in 1973–74 this increase was more or less passed on completely to the Indian consumer. As a result, inflation shot up to an average level of over 28 per cent, which understandably had very serious political ramifications at that stage. Some would even link the agitation and protest movement led by Shri Jai Prakash Narayan and the subsequent imposition of the emergency as an outcome of the sudden and enormous price increase that occurred in the global oil market. If India had options to replace oil imports with indigenous sources in a short period of time then perhaps some of these implications would have been avoided. But clearly

once an economic system is locked into a particular form of energy supply and consumption changes in the short run would be limited.

Today India's vulnerability to sudden price increases of fossil fuel imports or possible physical restrictions for geopolitical or other reasons could leave the country far more vulnerable and its economy in a far more precarious state than was the case in 1974. Even more serious would be the situation in 2031 based on TERI's projections of import dependence on fossil fuels projected on the basis of the modeling exercises carried out by TERI.

Energy security is an important question which is to be answered through policy measures and strategies which would ensure stability and security for the Indian economy and access to secure energy supply for meeting basic energy needs. It was with this in view that colleagues at TERI agreed on mounting an effort to inform the public and decision makers in the country on the elements of our energy situation which has a direct impact on the security of supply. TERI brings out a brief newsletter called *Energy Security Insights* which provides a flavour of current issues of relevance in this field, but it was felt that a thorough and detailed publication brought out on an annual basis with considerable analysis and substance would serve the needs of the Indian population and decision-making community far more adequately than a regular publication in the nature of a news report. The publication *Energy Security Outlook* is the outcome of this decision, and the following pages contain the first issue of this new product. Energy decisions and strategies are becoming increasingly more complex because not only does the energy sector and the entire energy cycle have serious impacts on the environment throughout the energy cycle, but even more importantly it has major implications for climate change and how to deal with this challenge. One of the major co-benefits of mitigating emissions of greenhouse gases is the enhancement of energy security, because a move from the use of fossil fuels to higher levels of energy efficiency and greater use of renewable sources certainly contribute to increasing the level of security associated with energy supply.

While expressing my satisfaction at the launch of this new publication, I would like to thank the UK Department for International Development (DFID) for the support that they have provided in making this publication possible. However, TERI takes full responsibility for the contents in this publication, and would like to ensure that future issues of the *Energy Security Outlook* benefit from the feedback and opinions received from the readers of this issue.



R K Pachauri

Director-General, TERI

Acknowledgements

The first edition of the *Energy Security Outlook* is a product of collective effort put in by the TERI team. We are grateful to Dr R K Pachauri for the inception of this publication and providing guidance at every stage of the process. We would especially like to thank Mr Batra for his endless patience and support to help structure and shape the publication. We are also grateful to Department for International Development (DFID), United Kingdom, for their support. This publication is a part of the DFID–TERI Partnership for Clean Energy Access and Improved Policies for Sustainable Development. The publication could not have been possible without the detailed interactions carried out by the team with various government bodies, and sector experts from academia as well as industry.

We are extremely grateful to Shri Piyush Goyal, Hon'ble Minister of State with Independent Charge for Power, Coal, and New and Renewable Energy, Shri Venkiah Naidu, Hon'ble Union Minister for Urban Development, Housing and Urban Poverty Alleviation, and Parliamentary Affairs, and Shri Nitin Gadkari, Hon'ble Union Minister for Road Transport and Highways, and Shipping, for their valuable time and inputs which have helped this publication.

Last but not the least, we would like to thank the entire team for their perseverance in helping complete this publication.

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Executive Summary

The distinct and diverse energy realities that characterize India necessitate a more detailed examination of the country's energy situation. A multi-sector and multi-issue analysis that takes cognizance of the tugs and pulls that India's energy policy is subject to is essential. It is with this objective that the *Energy Security Outlook* examines issues pertinent to India's energy security. It takes a multi-dimensional view of energy and energy security in India and aims to touch upon all the key issues facing the country's energy and development agenda.

Energy Consumption and the Issue of Energy Security in India

The total energy consumption in India registered a CAGR of nearly 5% over the period from 2001 to 2011. As per existing estimates, in order to sustain an economic growth rate of 8%, the primary energy supply is expected to grow at 5% over the next 20 years. Energy supply in India is largely dominated by fossil fuels — coal, oil and gas — that form around three-fourths of the country's total primary energy supply (Figure E1). A significant share of energy is also supplied by traditional biomass-based sources such as firewood, dung-cakes

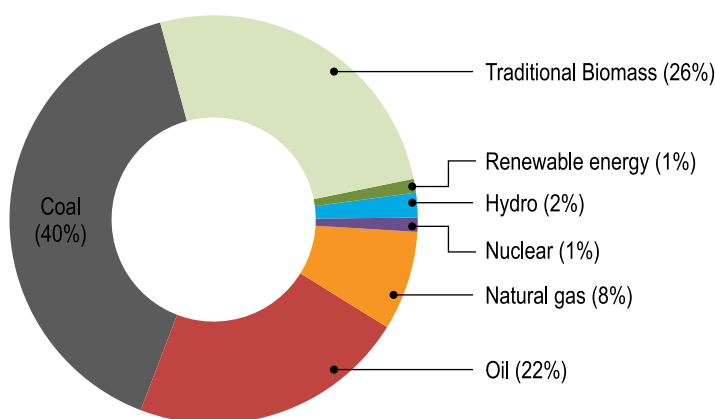


Figure E1: Primary energy supply mix in 2011

and crop residue among others, and this is reflected in the total primary energy supply mix.

In terms of consumption, the industry and transport sectors are the largest consumers of commercial energy in the country (Figure E2). Here again, if one considers the consumption of biomass-based energy sources, the share of residential sector increases to almost equal industrial consumption. Biomass is used primarily for cooking in households in rural areas and in a small percentage of households in urban areas.

Defining and Analysing Energy Security

Various definitions have been proposed and indicators suggested for measuring the level of energy security and computing the extent to which existing policy measures achieve the goal of ensuring and strengthening a country's energy security. Strong linkages can be found between energy and major policy issues

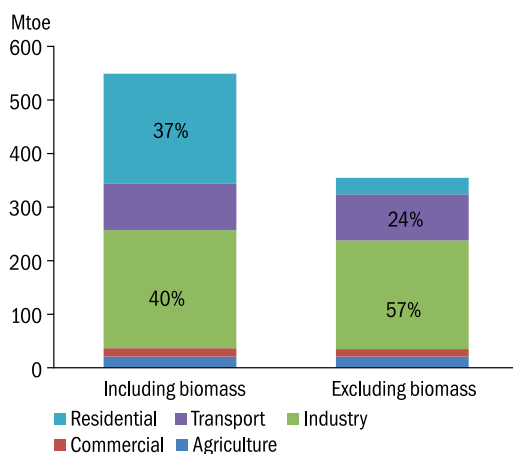


Figure E2: Final energy demand by sector in 2011

INDICATORS OF ENERGY SECURITY

- Share of fossil fuels in the primary energy supply energy mix
- Diversification of energy basket
- Import dependence of fossil fuels
- Diversification of import sources
- Energy intensity of economic output
- Average per capita commercial energy consumption
- Access to electricity
- Access to modern cooking energy fuels and technology

such as poverty, environment, and economic growth.

The definition for energy security in India's context was first provided in the report of the Expert Group on the Integrated Energy Policy. In a departure from the conventional analysis that tends to focus on international geopolitical risks and uncertainties, this definition gave due consideration to issues of access, pricing, and resilience to shocks. The more recent 12th Five-Year Plan defines energy security in the following manner:

"Energy security involves ensuring uninterrupted supply of energy to support the economic and commercial activities necessary for sustained economic growth."

It further goes on to state that "Energy security is obviously more difficult to ensure if there is a large dependence on imported energy."

This, in some sense, again narrows the definition used to analyse the concept. It is imperative to have a broader and more inclusive understanding of energy security. For this, it is important to envisage a forward

looking energy secure pathway given the limited domestic resources and the increasing pressure on global oil and coal resources, aggravated by increasing geopolitical tensions. A comprehensive energy plan would be based on moving away from fossil fuel dependency and opting for sustainable measures, and promoting resource efficiency (energy, water, and waste) and incentivizing energy efficient, and sustainable energy choices in the demand sectors. The complex linkages between energy and different sectors of the economy and their impacts on each other necessitate a synchronized and planned effort in all sectors. This requires comprehensive planning across the different sectors of the economy to ensure cohesion between them.

Much in line with Integrated Energy Policy, this publication takes a wide view of Energy Security and looks at supply and demand side, as well as micro and macro issues. Encompassed within the supply and demand side issues are the cross-sector aspects of the

role of government, infrastructure, and pricing (Figure E3).

Scenarios for Energy Pathways

This publication takes a long-term view of energy security and combines a modeling exercise with appropriate scenario frameworks. Three scenarios are considered to examine the future pathways for the energy sector in the country. These take into account the existing policies and the proposed measure that impact energy security in the country. The implications of these scenarios are incorporated into a long-term energy model that uses the energy systems modeling approach. The modeling exercise for this publication is based on the Market Allocation (MARKAL) model for India. MARKAL is a bottom-up dynamic linear programming model that depicts both the energy supply and demand sides of the energy system. It provides policy-makers and planners in the public and private sectors with extensive

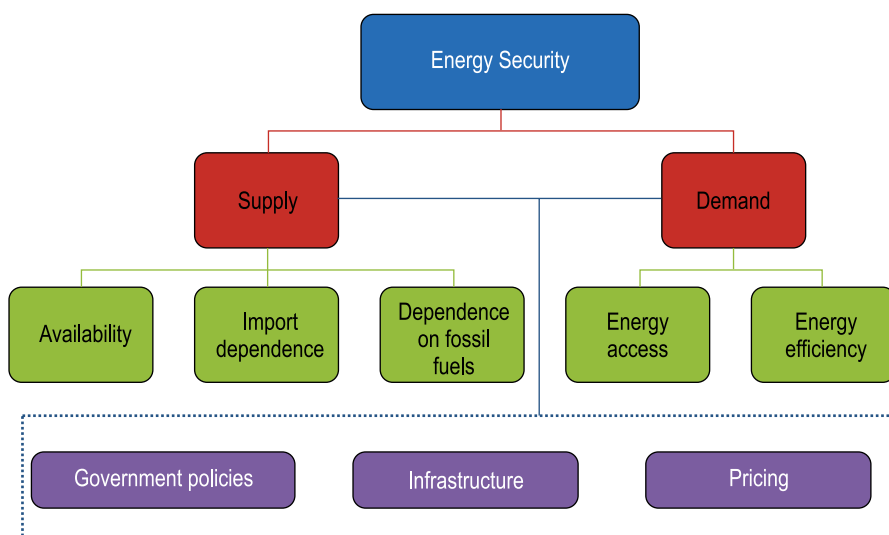


Figure E3: Framework for Energy Security

details on energy producing and consuming technologies, and an understanding of the interplay between the various fuel and technology choices for given sector-wise end-use demands. In the model, the Indian energy sector is disaggregated into five major energy consuming sectors, namely the agriculture, commercial, industry, residential, and transport sectors. Each of these sectors is further disaggregated to reflect the end-use demand in each sector.

The MARKAL database for this exercise has been set up over a 30-year period extending from 2001–31 at five-yearly intervals coinciding with the time period of Government of India's Five-Year plans. The year 2001/02 is chosen as the base year the data for 2001/02, 2006/07, and 2011/12 has been calibrated.

The Scenarios

This edition of the *Energy Security Outlook* provides three major scenarios that visualize alternative energy pathways for the country. The first is a **Reference Energy Scenario (RES)** that is structured to provide a trajectory that shows how the nation's energy pathway would evolve if current trends in energy demand and supply are not changed. It takes into account existing policy commitments and assumes that those recently announced are implemented. But, wherever necessary, a diversion from government projections and forecasts has been assumed.

The second is the **Moderate Energy Security Scenario (ESM)**. This scenario is

structured in a manner that enables one to envisage an energy trajectory of the nation that would ensure energy security in the future. This in broad terms implies that efforts are provided here for efficiency improvements both on the supply and demand sides. There is an accelerated push for diversifying the energy mix, fuel substitution, and penetration of new technologies. This is met with moderate reduction of imports.

Thus, the constraints that were assumed for domestic production of resources in the RES scenario are revised to more optimistic (but not over-ambitious) levels.

The third scenario is the **Ambitious Energy Security Scenario (ESA)** where concerns of energy security are paramount. The main objective being to drastically reduce the energy imports of the country by 2031. This entails faster implementation of efficiency measures, rapid penetration of new technologies, and increased electrification of the economy. The role of renewables is crucial in this scenario.

Primary energy supply¹

In the *Reference Energy Scenario*, the total primary energy supply increases from the current level of 717 Mtoe to 1,950 Mtoe in 2031. Fossil fuels are expected to maintain their share as the largest sources in the total energy mix (Figure E4).

Significant gains can be noted in terms of the total reduction in commercial energy required in the country by 2031 in the ESM. In 2031, the total primary

¹ As per the glossary of statistical terms of the OECD, primary energy consumption refers to the direct use at the source, or supply to users without transformation, of crude energy, i.e., energy that has not been subjected to any conversion or transformation process.

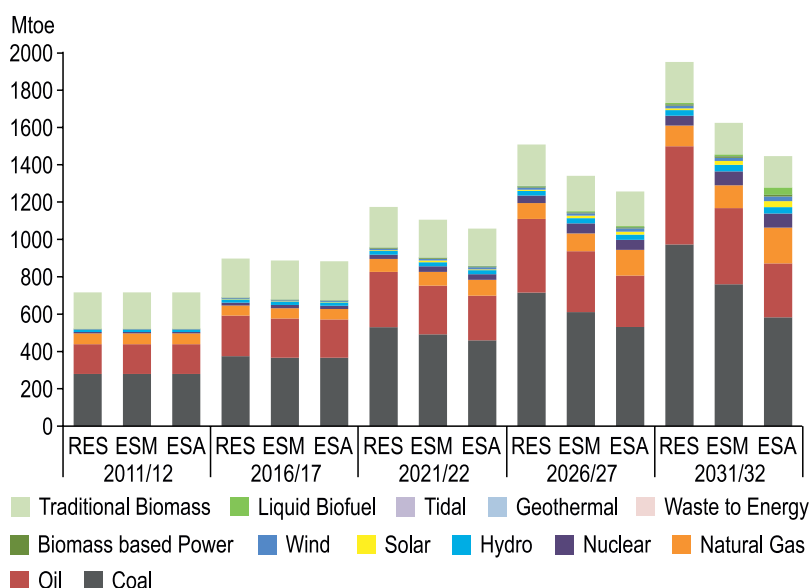


Figure E4: Primary energy supply

commercial energy supply in the ESM is 1,625 Mtoe, reflecting a saving of 17% when compared to the RES. While in the ESA, this further drops to 1,446 Mtoe in 2031, which is a saving of 26% from the RES.

On the demand side as well, the current trends are likely to continue and our energy demand in the RES grows from 549 Mtoe in 2011 to 1460 Mtoe, increasing by almost thrice over a period of 20 years. The industry and transport sectors are mostly responsible for this increase (Figure E5).

In the ESM, due to several demand management measures and fuel efficiency enhancements in the demand technologies, the final energy demand by 2031 is 1,252 Mtoe. This is a reduction of 17% from final demand in RES. This result helps us understand the

demand management aspect of achieving an 'energy secure' future and the important role that energy efficiency plays in achieving this.

In the ESA, the final energy demand by 2031 stands at 1,158 Mtoe, which is 21% lesser than the final demand in the RES and 8% lesser than the ESM.

Major Energy Security Indicators over the Projection Period

Table E1 summarizes the various indicators of energy security under the different scenarios. Overall import dependence in fossil fuels is expected to rise in all the scenarios but can be reduced if the recommendations are adopted with earnest effort. One improvement that

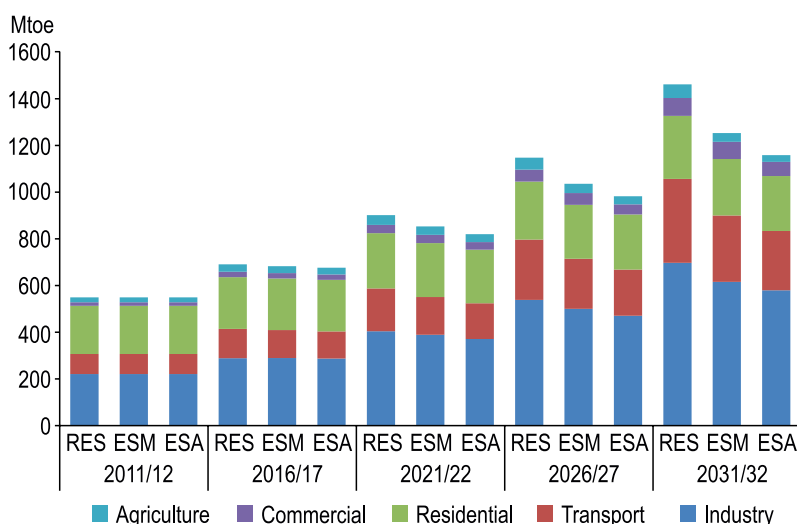


Figure E5: Final energy demand

can be noted is the reduction dependence of fossil fuels, i.e., the share of fossil fuels in the energy basket. On the demand side, the net energy intensity of the economy, as represented by the energy consumption per unit of output is also seen falling across all the scenarios in the projection period. This implies that more output can be generated using the same amount of energy and represents improvements in efficiency of energy usage in the country. Further, on the demand side, improvements are seen in access to improved lighting and cooking energy sources through universal access to electricity and higher penetration of improved cookstoves.

The Way Forward

This section outlines the way forward to ensure a secure and sustainable energy future for the country. Apart from sector-specific recommendations that emerge from the foregoing analysis, is the need for an integrated

energy policy with clarity on directional pathways for energy development. There are certain overarching issues that affect the energy system as a whole. These include lack of clarity and interdepartmental coordination among different agencies, structural issues, and dominance of few players in some of the major energy supply sectors.

There is also a need to address the issues of inter-sector linkages. For example, a reform of pricing in the coal and natural gas sectors cannot be sustainable with a concomitant change in the policies in the power generation and industry sectors that are the largest consumers of these fuels. Together with the development of renewable sources of supply, there is a need to promote capacity in manufacturing of renewable energy technologies. These require a concerted effort to strengthen regulatory framework to ensure that it functions independently and takes into account long-term interests; developing

Table E1: Parameters for Energy Security

	Parameter	Current Status (2011)	2021			2031		
Supply side			RES	ESM	ESA	RES	ESM	ESA
	Import dependence — Oil	76%	86%	75%	73%	91%	84%	77%
	Import dependence — Coal	23%	42%	23%	18%	66%	40%	22%
	Import dependence — Natural Gas	21%	46%	17%	28%	60%	41%	63%
	Total energy import dependence for fossil fuels	40%	57%	39%	36%	74%	54%	44%
	Share of fossil fuels in the commercial energy supply energy mix	69%	76%	75%	74%	83%	79%	74%
Demand side	Net energy intensity (Ktoe/INR)	0.0120	0.0098	0.0093	0.0088	0.0082	0.0069	0.0060
	Average consumption of energy per capita (Ktoe/capita)	435	698	659	627	1137	956	840
	Access to electricity	67%	100%	100%	100%	100%	100%	100%
	Use of Improved Cookstoves	0%	1%	5%	5%	5%	20%	25%
	Access to modern cooking energy fuels — Rural	29%	30%	30%	30%	34%	34%	34%

pricing frameworks that are cohesive and meet energy security objectives.

On the energy supply front, high dependence on fossil fuels, the persistent dependence on imports, pricing of resources coupled with the regulatory issues pose major challenges to energy availability in the country. Accordingly, some of the recommendations provided below are aimed at addressing issues affecting energy supply and have resonance across major energy sources. These include addressing infrastructural constraints and removing bottlenecks, collection, and provision of accurate estimates of reserves and production potential. Further, initiating

pricing reforms in the coal and power sectors, and continuing the reform process in the petroleum sector is necessary. As the share of imports in the country's energy supply is rising, it will also be imperative to establish import infrastructure such as ports, storage facilities, and transportation infrastructure that link import facilities to processing and demand centres.

The major issues affecting energy security on the demand aspects include lack of access to energy, particularly in the rural areas where the dependence on traditional forms of energy is still very high. In urban areas too, issues of access manifest in the form irregular and poor

quality of energy supply. The other key issues include availability of technology and the lack of available data on energy consumption patterns in most of the consuming sectors. Further, increased mechanization, change in preferences and choices has also contributed to an increase in the demand for energy in the sectors such as transport and agriculture. In case of agriculture, the adoption of mechanized forms of agriculture has increased the demand for energy. In transport on the other hand, the modal shift towards private and road-based transport has also increased the fuel consumption in the country.

There is a need to encourage both supply as well as demand sector management to ensure that the sectors perform efficiently and optimally. This requires forward thinking and visionary planning that takes into account current technology advances and the possibilities they could hold for the future. This would also require manifold increase in R&D both at the technical and policy levels to support desired transitions. There is synergistic interdependence between different sectors and resources such as energy, food, water, health; developments in any one sector have a domino effect, affecting others. These need to be recognized to help undertake holistic planning. Setting up a committee to review options for phasing out obsolete, inefficient infrastructure; for preparing and planning for the future infrastructure; and for undertaking integrated management of energy should be considered.

We now look at specific recommendations for each of the sectors covered in this publication.

Coal

One of the critical issues facing the coal sector is the lack of uniformity of the estimates of extractable reserves based on an internationally acceptable basis. While estimation activities have been conducted by CMPDIL, it is necessary for all government agencies.

Enhancing domestic production of coal and, at the same time, facilitating the creation of import infrastructure and inter-connectivity will be important. As regards domestic production, fast tracking the clearance process, monitoring production from coal mines, and addressing bottlenecks to coal transportation infrastructure is critical. For this, the Coal and Rail Ministries have already moved forward to discuss the fast tracking of critical coal connectivity projects.² Continuing this momentum and expanding it to the rest of the country is critical.

It is also necessary to increase the investment in technology and for this, private participation and expertise needs to be invited in the sector. Restructuring the coal sector has already been proposed as one of the measures to be taken up by the government but the proposed new structure and its implications on the current energy industry need to be considered carefully.

² A meeting to address this was organized in June 2014.

Oil and Gas

One of the primary reasons for the lack of participation from international companies in the country's hydrocarbon sector is the uncertainty in policy and regulatory regime of the country. The slow process of granting clearances and in some cases, changing these after a block has been allocated, changes in taxation of crude oil and natural gas produced, uncertainty in the fiscal regimes have all led to international majors withdrawing from the Indian oil and gas sector.

To address this, it is necessary to first initiate a comprehensive review, and then put in place a stable mechanism. Fast tracking clearances should be a priority. To encourage participation in the sector, pricing policies and fiscal regimes need to be remunerative and stable.

Further, independent exercises on collection of seismic data need to be initiated in order to provide good quality data on the sedimentary basins across the country. Data collected for basins and blocks awarded under previous contracts also needs to be provided on a standardised platform. For this, fast tracking the work on creating the National Data Repository is also necessary.

Reforming the pricing mechanism, making efforts to provide estimates of reserves based on international standards, addressing infrastructure bottlenecks, providing a stable fiscal regime for market players and enhancing the level of technology employed in all energy sectors is necessary to make energy production feasible and sustainable

Power

As power generation has been constrained by the availability of fuel in the country, there is a strong need to develop a sustainable strategy to ensure coal and gas supply to power plants in the long term. Production of coal from the captive coal blocks allocated to power companies needs to be enhanced.

Strengthening of inter-state and inter-regional transmission capacity for optimum utilization of available power is necessary. It is essential to encourage use of modern project management tools complemented by timely monitoring and corrective actions to avoid delays and any consequential losses.

There is also a need to fast track the development of clean coal technologies with higher efficiencies and low emissions. In the transmission sector as well, higher deployment of advanced technologies, such as the Thyristor Controlled Series Compensation (TCSC), High Surge Impedance Loading (HSIL) lines, High temperature high capacity conductors, multi-circuit towers, mono pole towers etc. is essential. Further, in order to reduce the land required for establishment of networks, scaling up the Gas Insulated Substations (GIS) which requires less space (about 80% reduction) is necessary.

A financial restructuring of state-owned power distribution companies has been proposed in the Transitional Finance Mechanism notified by the Government of India. However, this is only a short-term mechanism. In the long term, measures such as elimination of the gap between revenues and cost of electricity supplied, reduction in distribution losses, and automatic pass-

through of fuel costs are needed to enhance the profitability of the companies and to increase the level of participation in the power distribution sector.

Key regulatory issues in the distribution sector also need to be addressed. Once such case is the provision of open access; although the introduction of open access has been mandated in the Electricity Act 2003, there has been reluctance on part of the states to give freedom to the customers having requirement of 1 MVA and above to choose their own sources of supply. This should be expedited so that power markets are broadened and developed.

Renewable energy

There is a need for the government to proactively formulate a comprehensive policy or action plan for all-round development of the sector, encompassing all the key aspects. An action plan must be prepared in consultation with the various state governments. The preparation of the umbrella renewable energy law which has been proposed by the Energy Coordination Committee needs to be completed in a time-bound manner.

Improvements and streamlining of the regulatory procedures is also necessary. For instance, in the case of establishing RPOs, there must be a standardized target formulation wherein standard procedures should be applied across states to determine these targets.

There needs to be a focus on developing appropriate energy storage solutions. Energy storage helps to accommodate large-scale

renewable energy injection by addressing issues, such as uncertainty of output and variability. To achieve low cost manufacturing and therefore lower capital costs, and to capitalize on its inherent advantages in the solar sector, India needs to consider revamping and upgrading its solar R&D and manufacturing capabilities. Reliable forecasting of renewable energy is also required for grid security especially in the case of wind and solar power, where it is critical for large-scale grid-integration of these sources. To enhance grid integration and to encourage the absorption of higher renewable energy, short-distance intra-state transmission network also needs to be strengthened. In order to address capacity constraints, there is an urgent need for technical assistance programmes, which increase the planning skills and understanding of renewable energy technologies by electricity utilities, regulators, local and municipal administrations, and other institutions involved.

Nuclear

In the nuclear energy sector, the social implications and response are perhaps the most significant areas that need to be addressed. Like in the case of fossil fuels, the regulatory policy in the sector needs to be addressed on an urgent basis. The draft Nuclear Safety Regulatory Authority Act that was tabled in the Parliament needs to be considered and implemented on an urgent basis. The level of transparency in the sector also needs to be enhanced in order to address concerns of stakeholder. Timely reviews through domestic and international organizations should be undertaken in a time-

bound manner. Further, in order to proactively manage eventualities in the sector, social impact assessments of nuclear energy projects need to be undertaken as a routine exercise in order to evaluate the extent of damage possible in the worst-case scenario.

Increasing the level of public engagement, debate and involvement of stakeholders is necessary, particularly in project sites. A comprehensive assessment of perceptions, needs and wants must be initiated in proposed sites in order to gauge the opinion of local residents.

As the nuclear power sector opens up, simultaneous reforms and strengthening of laws governing and affecting related industries also need to be initiated not only to promote investments but also to protect domestic interests.

Agriculture

Prudent use of resources and judicious application of technology has the capacity to significantly improve the long-term sustainability of food production. The adaptation of certain practices and modern technology such as minimum tillage, use of crop residue, use of micro irrigation technology, and better matching of tractor and attachments would help to conserve energy.

Also there is a definitive need to encourage research and development in use of alternative energy forms to petroleum and renewable energy sources such as biodiesel, biogas, producer gas, and solar operated pump sets, etc.

Metering of electricity, tariff revisions, restructuring MSP to promote crop

diversification, long-term agricultural mechanization policy at national and state levels, promoting farmers' machinery cooperatives to provide an efficient network of custom-hiring services should be promoted via appropriate policy and regulations.

Industry

In the industry sector, there is a need to improve the level of innovation in the technology implemented in the sector. The existing testing centres can be expanded into technology incubators and/or research centres. Technical assistance in the form of institutional capacity-building, expert training, equipment up-gradation, and business model development should be provided to these centres.

Minimum performance standards should be established for equipment and appliances and perhaps star rating can also be strengthened in this context. Intensive data collection exercises also need to be carried out. The extension of the Perform Achieve Trade mechanism will be useful for the large industries sector. There are sector-specific issues in the Micro Small and Medium Enterprise (MSME) Sectors. They are highly fragmented, and unifying the data collected for these presents serious challenges. Notwithstanding, including the data on energy parameters in the MSME census conducted by the Ministry of MSME provides a solution to this challenge.

Another area where interventions are necessary is enhancement of capacity-building and awareness provision. Awareness generation needs to be undertaken through

large campaigns, stakeholder training, and networking programmes. Efforts to increase sensitization regarding energy management at the entrepreneurial level training of experts to implement the performance standards need to be made on an urgent basis in order to ensure that development of manpower talent complements technology improvements. Work in this area offers immense scope for energy conservation in a sustainable manner.

Residential and commercial

There is a need to streamline all government initiatives on enhancing access to energy, and support the measures to improve efficiency in the commercial sector. A comprehensive review of the current schemes intended to enhance access to energy in rural areas is also needed.

There is also a need to comprehensively collect data on the energy consumption patterns of the commercial and urban residential buildings. This will help achieve the twin objectives of enabling regular monitoring of the sector, and, at the same time, increase awareness. In fact, for the later, it is also crucial to involve local stakeholders — Resident Welfare Associations (RWAs), local municipal bodies, and civil society organizations in order to effectively disseminate information on a large scale.

Financing a move to green building is also necessary in order to sustain a move towards green buildings. Financial institutions from both the banking and non-banking sectors need to work together to ensure that credit linked to

energy efficiency measures is provided on easy terms to the beneficiaries.

Transport

The greatest efficiencies in the national transport sector can only be achieved when there is an integrated mobility plan prepared for the country. The presence of different agencies that monitor and regulate different modes of transport, results in sub-optimal outcomes in terms of both operations as well as energy efficiencies.

At the sector-specific level, apart from using innovative financing mechanisms to encourage investments in the inter and intra-city mass passenger transportation mechanisms, these is also a need to provide a push towards providing better and more accessible modes of public transport.

In case of freight transport, encouraging and sustaining a movement to electric traction which is complemented by renewable energy-based power generation is necessary for ensuring long-term energy security in the transport systems in the country. There is also a need to create more dedicated freight corridors in addition to the WDFC and the EDFCs and support it with an integrated logistic planning of resources.

Capacity-building, technology enhancement, raising awareness, providing correct policy signals, and streamlining all efforts are necessary to ensure that demand for energy is met in the most efficient and sustainable manner

Introduction

Energy Security in India: An Introduction

The demand for energy in India has grown at a rapid rate during the past decade. Keeping pace with the growing economy, the total energy¹ consumption has increased at nearly 5% (CAGR from 2001–11) in the same period. The demand for energy is currently met largely from fossil fuels. Coal forms the largest source of primary energy, followed by crude oil and natural gas (48% coal, 39% oil, and 10% natural gas in 2010–11 in the primary commercial energy supply) (TERI 2014). Increasingly, wind energy, followed by solar power, is emerging as an important source in the electricity generation mix of the country. According to the Ministry of New and Renewable Energy (MNRE), in terms of generation capacity, the share of solar was 1% and wind stood at 9% as on January 31, 2014 (MNRE 2014).

The rising demand for energy is putting great pressure on the already limited domestic energy sources in the country. Adding to this is the pre-eminent need of providing access to a large segment of population that currently lacks dependable and modern sources of

energy will release a significant amount of suppressed demand. The import dependence to meet India's energy demand has increased significantly. In 2010–11, nearly 79% of crude oil requirement was met from imports. Import dependence for coal and natural gas was 18% and 15%, respectively. As per TERI projections, in the reference scenario, the dependence on imported fossil fuels is expected to rise in the future, putting greater pressure on the limited domestic resources. Further aggravating this rising demand–supply gap is the necessity of mitigating the adverse environmental implications of energy consuming and producing industries. Carbon Dioxide (CO₂) emissions from energy industries have the largest share in total emissions. To add to this, key consuming sectors such as transport and industry are also large sources of CO₂ emissions.

Motivation for this Publication

The current scenario of rising domestic energy demand, driven by a combination of increased economic activity and the need to improve living standards, warrants an assessment of the available options to meet the demand.

¹ Here energy demand refers to demand for commercial as well as non-commercial fuels

On the supply side, India is currently at a crucial juncture where dwindling domestic reserves of conventional energy sources necessitate that alternative sources of supply, both in the form of imports as well as domestic sources, be proactively explored and developed. At the same time, however, the rising supply and demand for energy should not be met at the cost of the environmental and social well-being.

These multiple aspects affecting the state and trends of the energy scenario in India necessitate an assessment of the complexities generated due to the interaction among these themes. Comprehensive energy documents, driven by robust methodologies, are produced periodically the world over. Notable among these are the *BPEnergyOutlook2030* released by British Petroleum (BP), the *World Energy Outlook* (WEO) published by the International Energy Agency (IEA), and the energy scenarios created by Shell Corporation. The Energy Information Administration (EIA) of the Department of Energy of the US Government also publishes the *International Energy Outlook* (IEO).

Each of these documents takes into account various scenarios laying emphasis on different aspects of the global energy landscape. India, as a significant energy consumer, finds coverage across these publications. However, the distinct and diverse energy realities that characterize India necessitate a more detailed examination of the country's energy situation. The country's policy-making ought to draw from a multi-sector and multi-issue analysis that takes cognizance of the tugs and pulls that India's energy policy is subject to. It is with this objective that the present publication, the *Energy Security Outlook*, examines issues

pertinent to India's energy security. It takes a multi-dimensional view of energy and energy security in India and aims to touch upon all the key issues facing the country's energy and development agenda.

Defining Energy Security

Contextualizing energy security and its parameters

Energy security has been defined, debated, and discussed widely, in both policy discourse and literature. Various dimensions have been associated with the concept of energy security and accordingly, different definitions have been propounded to contextualize the issue. Some of these dimensions include equity, efficiency, environmental sustainability, and geopolitics. In a review of literature and research interviews, Sovacool (2011) has listed more than 45 definitions for energy security. A myriad set of conceptual frameworks and analyses that look at the concept of energy security can be found throughout literature and policy analysis—from the International Energy Agency's (IEA) *Model of Short Term Energy Security* (MOSES), that uses a framework of *Risk* and *Resilience* to the four 'A's (Availability, Accessibility, Affordability, and Acceptability) (APERC 2007) and the five 'S's (Supply, Sufficiency, Surety, Survivability, and Sustainability) (Sovacool 2011). As stated by Luft, Korin, & Gupta (2011), energy security as a concept has different implications for different countries depending on their level of development, geographical location, natural endowments, political systems, and international relations.

Several indicators have also been developed to quantify this concept. These range from

simple measures, such as energy intensity and import dependence to more complex and composite ones, such as diversity indices or the supply–demand index (Scheepers, Seebregts, de Jong, & Maters, 2007). Another emerging dimension of energy security is ensuring demand-side efficiency across all consuming sectors. A sustained and conscious move towards this can also be noted for India in the recent policies that have been introduced on energy efficiency.

The need to examine the climate implications and long-term sustainability of energy policies is also increasingly gaining importance. The linkage between climate policies and energy security has also been analysed widely in literature (IEA 2007), (Brown & Dworkin 2011). While many recognize energy security and climate-related policies as meeting similar objectives, Luft, Korin, & Gupta (2011) have insisted on a more nuanced approach to the two issues. They state, “If there is an inconvenient truth relating to our energy systems, it is that we may not be able to address both climate change and energy security in one strike.”

Often, the objectives outlined under these different dimensions imply that working towards ensuring energy security in one aspect or dimension conflicts with the objective of achieving another (Bazillian, Sovacool, & Miller, 2013). One such example is the recent emergence of unconventional hydrocarbons that is forcing countries to reconsider their energy strategies. While the emergence of these new sources adds to the overall security of energy supply, the extraction of these sources has adverse environmental implications associated with it.

Attaining the objective of energy security may also have varying implications across geographies. While for one country, energy independence might imply a move towards renewable energy, for another it could be seen in the form of increasing domestic fossil fuel production. In the case of developing countries, energy security encompasses issues related to access and equity since security of energy at household and individual levels is inextricably linked to overall human development. As has been recognized by the United Nations Development Programme (UNDP), “none of the Millennium Development Goals (MDGs) can be met without major improvement in the quality and quantity of energy services in Developing Countries (DCs)”.

Energy security in the Indian context

The most comprehensive definition for energy security in India is the one provided by the Planning Commission in the report of the *Expert Group on Integrated Energy Policy in India* (hereafter, *Integrated Energy Policy*) (Planning Commission, 2006) which states:

“We are energy secure when we can supply lifeline energy to all our citizens irrespective of their ability to pay for it as well as meet their effective demand for safe and convenient energy to satisfy their various needs at competitive prices, at all times and with a prescribed confidence level considering shocks and disruptions that can be reasonably expected.”

The *Integrated Energy Policy* provides a comprehensive definition for energy security and includes the dimensions of ‘energy access’ and ‘ability to pay’ in the traditional supply and

demand themes of the issue. For India, as in the case of other developing countries, the issues of energy poverty and access to affordable energy services assume significance. Also included in this definition are the aspects of 'safety', 'convenience', and 'shocks and disruptions'.

Given the diverging views on energy security and the varying imperatives of countries at different stages of development, energy security for India has three sets of linkages (TERI, 2010). These are:

- *Energy and growth*: Where energy is needed to meet the growth objectives of the economy
- *Energy and poverty*: Meeting the basic energy needs and providing access to all sections in order to facilitate overall development and growth
- *Energy and the environment*: Addressing the adverse environmental implications of energy generation and consumption

Defining Energy Security for the Energy Security Outlook

This publication takes a comprehensive view of India's energy security. A long-term view of supply of all energy sources, both conventional and non-conventional, is taken into account. However, the approach is not just limited to analysing the supply side. Factors affecting the demand for energy and energy efficiency in key consuming sectors are also accounted for, and policies on demand-side efficiency are analysed. This also helps in assessing the economy-wide implications of evolution in consumption and production of energy. This analysis is carried out using the Market Allocation (MARKAL) model for India which entails a bottom-up analysis of all energy demand and supply sectors, following an energy systems approach.

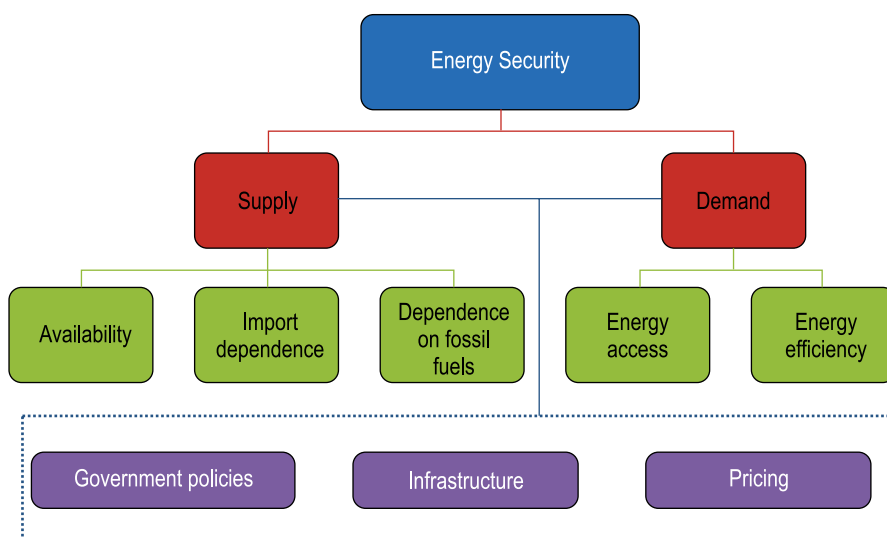


Figure 1: A framework for energy security

As stated previously, there are several dimensions to energy security and each of these can be analysed through multiple lenses. In order to account for these dimensions, this publication uses a matrix or dashboard of parameters for measuring energy security (Figure 1). Key supply- and demand-side factors have been identified for this edition. These are presented in Table 1. An incremental approach in each of the subsequent editions of this publication will be followed to broaden the scope and horizon. More indices and parameters will be added and scenarios developed therein.

Table 1: Measures for Energy Security (in 2011)	
Import dependence: Oil	76%
Import dependence: Coal	23%
Import dependence: Natural Gas	21%
Total energy import dependence for fossil fuels	40%
Share of fossil fuels in the primary energy supply energy mix	69%
Net energy intensity (ktoe/INR)	0.0120
Average consumption of energy per capita (ktoe/capita)	435
Access to electricity	67%
Access to modern cooking energy fuels	29%
<i>Source: TERI Compilation</i>	

Structure of the Publication

The publication is divided into three major parts, viz. Part I, Part II, and Part III. Part I carries an analysis of the current energy security situation in India. The existing situation in each of the supply and demand sectors has been examined in detail to explore the key areas of intervention. Part

II provides the long-term projections made under the aforementioned TERI's MARKAL model for India. The assumptions made for the model and the detailed results for each supply and demand sections are then provided.

In Part I, the chapters provide a detailed analysis of the current energy security situation of the country. The supply-side analysis includes sections on all commercial sources of energy—petroleum and natural gas, coal, nuclear energy, hydropower, renewable energy sources, and the power sector. Each of these sections further provides a brief overview of the respective energy sectors followed by key challenges and recommendations for reform. An analysis of the demand side where the major sectors covered are industry, residential and commercial, transport, and agriculture is also provided. These sections contain an overview of the sector followed by a discussion on key drivers of demand, issues and challenges, and major recommendations. For issues that cannot be assessed directly within the MARKAL modeling framework, a detailed qualitative analysis has been carried out, also covered in Part I.

The current edition of this publication focuses on commercial production and consumption of energy. Assumptions on improvement in access to modern forms of energy have been incorporated in the modeling exercise. To that extent, any increase in the costs due to expansion of networks has been built into the modeling framework. However, a more detailed assessment of the implications of reduction in energy poverty and improvement in access will be

incorporated in the forthcoming issues of the *Energy Security Outlook*.

Finally, the model framework, assumptions, and results are provided in the two chapters in Part II. Chapter 10 in this section provides a description of the model framework and the key macro-economic assumptions used in the modeling exercise. This is followed by the

chapter on the model results that present the key findings of the modeling exercise.

Part III summarizes key recommendations based on the analysis in the supply and demand chapters and the scenarios presented therein. It also outlines a pathway for policy making in the energy security space for each of the sectors.



PART I

Energy Security Analysis



SECTION I

Energy Supply Sectors

Supply of energy forms a critical component of the nation's energy security. India's energy basket comprises fossil fuels — coal, petroleum and natural gas; nuclear energy; hydropower and renewable sources of energy. The current energy mix is presented in Figure 2.

As can be noted, fossil fuels have the largest share in the total commercial energy basket of the country. In addition to the primary sources of energy, transformation of primary energy into final sources of energy takes place through power generation and crude oil refining.

The reserves and production potential play an important role in determining the level to which the generation of each source of energy supply will rise to meet growing demand. Domestic reserves for fossil fuels, particularly oil

and gas are limited. In case of coal also, there is significant concern regarding the extent to which available resources can be accessed and converted to reserves in the current price and technology scenario.

The domestic production of fossil fuels has not increased in-step with the sharp increase in demand for most energy sources leading to an increase in the dependence on imports to meet domestic demand. This also has implications on the total import spending and trade balance of the country, and on the physical as well as the economic security of energy imports in the country.

In case of renewable energy sources, India holds large potential of wind-, solar-, and biomass-based energy which, if harnessed

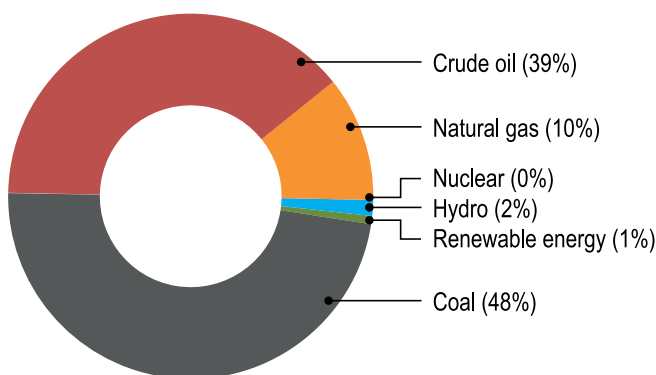


Figure 2: Primary Commercial Energy Supply Mix, 2010–11
Source: TERI Compilation

effectively, can play a major role in meeting the growing energy demand.

Issues in regulation of energy supply and market structures also affect the development of these sources and unless the bottlenecks in clearances, investments, and market structures are addressed, there will be significant difficulties in enhancing domestic production of the energy sources. These issues are highlighted

in detail in the following chapters in this section that look at specific energy sources covering coal, oil and gas, renewables, nuclear energy, hydropower, and power generation.

Each of these chapters begins by providing an overview of the sector, followed by a discussion of key issues that affect the security of supply of the fuel source, and a summary of key recommendations for the sector.

Chapter 1

Coal

KEY ISSUES

Inadequate domestic coal reserves

When calculated on the basis of techno-economic feasibility of extraction, total coal reserves held in India are considerably lower than the official resource figure. The adoption of the United Nations Framework Classification (UNFC), which was proposed in 2001, is still under review.

Technology-related issues

Dependence on open cast mining which forms nearly 90% of total mining and the slow pace of development of underground mining have impacted the extent to which coal reserves at greater depths can be accessed.

Issues related to clearances

Lack of environmental and forestry clearances and issues faced in Rehabilitation and Resettlement (R&R) activities have affected the development of mines in the country. As of April 2013, a total of 49 proposals of Coal India Limited (CIL) were awaiting clearance from the Ministry of Environment and Forests (MoEF) and 138 proposals were awaiting clearances at the state level.

Rising dependence on imports

- In order to bridge the gap between stagnating domestic supply and rising demand, imports of coal in the country have increased substantially.
- Volatile international prices and changing policies in exporting countries can be seen. Rising dependence on imports exposes the domestic markets to this international volatility. Further, changes in the pricing and export policies in major exporting countries—Australia and Indonesia—also affect the global coal markets and prices at which coal can be imported.

- Shortage of coal handling infrastructure at domestic ports—jetties, barges, total capacity, and rail links—will also affect the extent to which rising imports can be managed.
- Investment by Indian players in equity coal overseas is useful in addressing the uncertainty of import availability. Indian companies have discovered coal in countries as far as Mozambique and Australia. Prospects of developing these resources add to the availability of coal for meeting the country's demand. However, the success of this mechanism for meeting domestic demand will depend on the Government policies of the host countries and any changes therein.

Infrastructure bottlenecks

- Transportation and evacuation bottlenecks are constraining the ability to supply coal from mines to power stations.
- This is also a mismatch between the stocks available at pitheads and power plants at different times during the year. This is reflected in the increase in the closing stocks at the mine pitheads.
- There has been limited addition to the washery capacity during the period of the XIth Five Year Plan. The current capacity of just over 100 Mt is far lower than the total coal produced in the country.

Regulatory and structural issues

- CIL and its subsidiaries dominate coal production. This skewed market structure has affected the level of competition and overall efficiency in the sector.
- Absence of an independent pricing policy and continued involvement of the Government in the sector has led to a lack of transparency in determining the prices. As of May 2013, pooling of prices of imported and domestic coal is also under consideration but is yet to be finalized.
- The absence of an authority to monitor and regulate the sector has also had ramifications in the form of alleged irregularities in allotment of coal mines for captive usage, an issue that has been widely reported on and discussed.
- Allocation of coal through Fuel Supply Agreements and Letters of Agreement has led to a mismatch between coal produced by CIL and the demand that it is expected to meet.

Overview

Coal forms the largest source of energy in the country in terms of its share in both the total commercial primary energy supplied as well as the installed power generation capacity. Although India holds large reserves of coal, enhancement of production capacity has been limited, thereby leading to a widening gap between demand and supply of coal. This chapter provides a brief overview of the sector followed by a detailed description of the key issues affecting the sector.

Consumption and supply

Coal continues to form the largest source of primary energy supply in India and its consumption has increased significantly over the past few years. Among the different sectors that consume coal, the largest proportion of coal consumption is for the power generation

sector which accounts for nearly three-fourths of the total coal consumed in the country in 2011–12² (Table 2). The sectors that consume coal include steel and coke manufacturing, cement, sponge iron, and the others category.

Allocation of coal is determined by the New Coal Distribution Policy (NCDP) of 2007, which provides for the signing of the Fuel Supply Agreements (FSAs) between the consumers and suppliers. Other forms of allocation include captive mining and e-auctions. Under captive mining, coal mines are allocated to public and private industrial consumers of coal. In e-auctions, 10% of the coal produced by Coal India Limited (CIL) is sold through both spot and forward contracts.

The rising demand of coal has primarily been met from domestic production which increased by nearly 200 Mt in the past decade (Figure 3). Coal is produced primarily by CIL and its subsidiaries Bharat Coking Coal Limited

Table 2: Consumption of coal across sectors (in Mt)

Sector	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12 ²
Steel and Coke	35.17	39.02	37.66	41.14	45.83	46.67
Power (Utilities)	307.92	332.4	362.08	364.6	383.98	460
Power (Captive)	28.13	29.31	32.74	51.33	28.99	40
Cement	19.67	21.27	20.09	21.61	27.58	28.89
Sponge Iron	17.47	20.92	19.78	23.1	18.76	30.47
Others	55.51	61.37	76.67	86.03	110.98	90
Total	463.87	504.29	549.02	587.81	616.12	696.03

Note: 2011–12 figures are based on the Annual Plan of 2011–12

Source: Report of the Working Group on Coal & Lignite for Formulation of the 12th Five Year Plan (2012–17), Government of India

² This includes both Utility and Captive power production

(BCCL), Central Coalfields Limited (CCL), Eastern Coalfields Limited (ECL), Western Coalfields Limited (WCL), South Eastern Coalfields Limited (SECL), Northern Coalfields Limited (NCL), and Mahanadi Coalfields Limited (MCL). The Singareni Coking Coal Limited (SCCL) is also engaged in mining coking coal in the country. In addition to these, the Neyveli Lignite Corporation (NLC) mines lignite and is engaged in power generation from it. Under the captive mining route, private companies also produce coal but this is not for sale in the market.

Primarily, non-coking coal is produced in India and is considered to be low quality with high ash content but is low in sulphur. In the past few years, however, the production of domestic coal has stagnated on account of several infrastructural and regulatory issues; these are discussed in detail in the section on key issues.

As a result of this stagnation in domestic availability, dependence on imports is rising to meet the demand for coal (Figure 4). While earlier, primarily coking coal was imported for

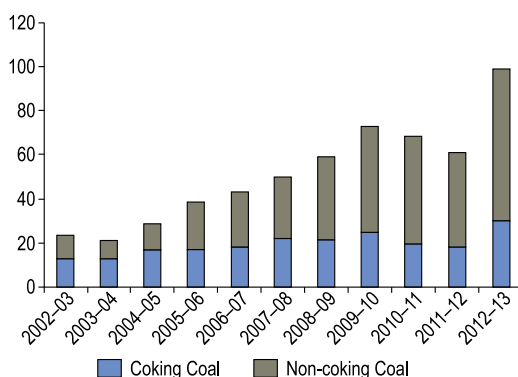


Figure 4: Imports of coal in India

Source: TERI (2013)

meeting the requirements of industry, the rising demand–supply gap has also led to an increase in imports of non-coking coal. Coal is imported from several countries but the key suppliers to India include Indonesia, Australia, and South Africa. The coal imports for 2012–13 stood at 137.56 Mt (CCO 2013),³ registering a 34% increase from 102.85 Mt imported in 2011–12.

Support infrastructure

As is the case with most energy sources, production and supply of coal requires significant infrastructure support ranging from rakes to railway lines and road transport and port facilities for importing coal.

Forty seven per cent of the total transportation of coal takes place through the railways which is the single largest mode of transport for the fuel source. This is followed by transport through road and Merry-Go-Round (MGR) systems. With the increase in import of coal, requisite coal movement and infrastructure facilities need to be created.

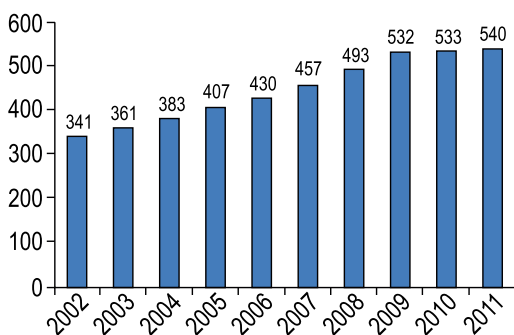


Figure 3: Domestic coal production (in Mt)

Source: TERI (2013)

³ <http://pib.nic.in/newsite/pmreleases.aspx?mincode=42>

The port capacities need to be built to handle the increasing volumes of coal imports and ensure a smooth movement of imported coal from the ports to consuming centres. There is an increase in the quantity of coal handled at both major and non-major ports with the share of non-major ports increasing substantially in the past five years. Such increase in coal traffic has also increased the need to create requisite infrastructure at the ports.

Another import component of the supply-chain infrastructure of coal is provision of 'coal washing and beneficiation'. As most of the coal produced in India is of low quality, washing of coal improves the quality by reducing the ash content and also helps reduce the damage to power generation equipment. Further, as per directives issued by the Ministry of Environment and Forests (MoEF), coal containing more than 34% ash if transported more than 1,000 km from the pithead, will need to be washed. However, the current washery capacity of around 145 Mt per year is not sufficient to meet the domestic demand.

Pricing

Up till January 1, 2012, the pricing of coal was based on the Useful Heat Value (UHV) system that used a 1960s formula taking into account the ash and moisture content. As against this, the international coal pricing is based on Gross Calorific Value (GCV) in which prices are determined on the overall heat content of coal, duly accounting for the ash and moisture content. CIL has migrated to the GCV-based pricing system with effect from January 1, 2012.

The revised system brings the price of coal produced at different mines under a standard

formula based on the total heat value of coal, with an exception of coal produced at Eastern Collieries Limited which is priced 6% higher than the prescribed notified rate. The new system divides coal into 17 grades from 2,200 Kcal/kg to 7,000 Kcal/kg and above with an interval of 300 Kcal/kg. This is an improvement over the previous system under which there were wider bandwidths for coal with 7 grades from 3,200 Kcal/kg to 6,400 Kcal/kg and above. Under the revised coal pricing effective from May 2013, the pithead run of mine price for non-coking coal (all sectors) ranges from INR 400 to INR 4,870 per tonne.

Considering the rising share of imports in the coal mix, the Government is also considering revising the pricing mechanism. With a view to provide a level playing field for power projects with high shares of imported coal, the Government mulled over the coal price-pooling mechanism in the beginning months of 2013. Under the pricing mechanism, the average of domestic and international price would be worked out and applied uniformly for all consumers. However, with opposition from various public and private power producers and the inability to arrive on to a possible impact on the power tariffs, the mechanism was shelved.

In June 2013, the Cabinet Committee of Economic Affairs cleared the pass through of imported coal cost to the consumers as an alternative to compensate the ailing private developers. While the move did certainly relieve private players by setting up proposed power generation projects, it would result in higher power tariffs for final consumers. The mechanism only applies to power plants that were commissioned after March 2009.

Technology

Mining methods

In the coal sector, two methods for mining, namely open cast and underground mining, are used. Open cast mining dominates the mining segment with a share of 90.40% (2011–12) in total raw coal production. Coal production from the existing underground mines has stagnated over the years growing at a Compounded Annual Growth Rate (CAGR) of just around 3% since 2010–11 (456.31 Mt in 2012–13, 439.19 Mt in 2011–12, and 431.03 Mt in 2010–11). The main reason behind underdevelopment of underground mining in India is the emphasis on enhancing production within a short time and at lower costs. The Coal Mines (Nationalization) Act of 1973 established public sector dominance on coal mining in India along with strict targets to increase production. Post-nationalization, only large open cast mines could meet the increased production requirement of coal.

Since a significant proportion of the coal reserves lies at depths that can be reached only with underground mining, the overdependence on open cast mining reduces the availability of reserves.

Key Issues

Uncertainty regarding availability of reserves

India's inventory of coal resources has been estimated at 298.91 Billion Tonnes (Bt) (as on April 1, 2013) (*Coal Inventory*, Central Mine Planning & Design Institute Limited). Of this, 123.18 Bt has been categorized as proved, 142.63 Bt as indicated, and only 33.10 Bt as

inferred. The resource estimation creates a notion that India is comfortable with over 100 years of domestic coal supply at its disposal. However, what is important is not the total inventory of coal but the technical and economic feasibility of extracting coal. The estimated coal inventory includes coal lying at a depth of 1,200 metres, which is not feasible for extraction using current methods and technology. It also includes inaccessible coal lying in protected areas or beneath forests, villages, towns, or water bodies, and even the coal that has been extracted and burnt during the past 200 years (estimated at about 10 Bt). Thus, the coal that can be extracted, taking into account geological, technical, and economic aspects, is only a small proportion of total estimated coal inventory in the country (Batra & Chand, 2011).

India's coal reserves have been estimated using the Indian Standard Procedure Code (1956). If the availability of coal is determined keeping in view the three aspects of economic viability, technical feasibility, and geological knowledge as is followed in the United Nations Framework Classification (UNFC), this may have vastly overestimated the available reserves. While a shift to UNFC was proposed in 2001, as per the report of the Comptroller and Auditor General (CAG, 2012), a final decision on the matter has not been taken yet and studies are still on-going. This has been highlighted as a recommendation in the *Working Group Report* of the 12th Five Year Plan as well. A shift to UNFC-based reserve estimation will affect the available reserves of coal. Further, imposition of restrictions on mining in forested areas will also reduce the available extractable reserves in the country.

Technology-related issues

Dependence on open cast mining

Over 90% of the coal mined in the country is based on open cast mining. After nationalization of the coal sector in 1973, only large open cast mines could meet the increased production requirement for coal. The quality of thermal coal has declined due to the increased dependence on open cast mining (Planning Commission, 2006). As was also identified in the *Integrated Energy Policy Report*, attempts to mechanize underground mining have not been successful so far.

Delay in obtaining clearances and approvals and its impact on the availability of coal

Issues related to seeking environmental clearances, land acquisition, and Rehabilitation and Resettlement (R&R) activities add to the time taken for bringing a coal mine into production phase. Significant delays in these processes have adversely affected the pace of development of coal mines. For instance, as of April 2013, a total of 49 proposals of CIL were awaiting clearance from MoEF and 138 proposals were awaiting clearances at the state level (Ministry of Coal, 2013). As per the *Report of the Working Group on Coal and Lignite for Formulation of 12th Five Year Plan* (Ministry of Coal 2011), "the EMP clearance process should take maximum of 210 days but the general experience of coal companies is that it invariably involves some 1½ to 2 years' time". In addition to environmental clearances, there are several other agencies that need to be approached for seeking clearances before

mining activities can be undertaken in any region. This prevalence of multiple windows also affects the pace of development of the sector. While at the same time, a single window clearance system may not be possible in the current state of operations.

Rising dependence on imports

Demand and availability: High dependence on coal and stagnation of domestic production

Coal forms a significant proportion of the country's energy basket and this trend is expected to continue. In fact, this trend will be replicated across the world with the International Energy Agency (IEA) projecting global coal consumption to grow in most countries other than the USA (*Mid-term Coal Market Report Factsheet*, 2012). The IEA has further projected that coal is likely to surpass oil as the largest source of energy by 2017.

The persisting dependence on a single source of energy affects energy security of the country. Even though coal is the largest domestically available energy source in the country, growth in domestic production has not kept pace with growing demand, leading to an increasing in dependence on imports for meeting the demand for coal.

Increase in imports of coal has two associated concerns. Firstly, existing domestic power plants can use only about 10–15% of imported coal due to the configurations of the existing thermal plant boilers. Secondly, the prices of imported coal are much higher than the domestic coal prices affecting the affordability of power generated by ultimate consumers.

The steadily increasing demand for imports has certain associated issues which include competition for meeting the demand with China and higher costs for imports and volatility in international markets due to changing policies in exporting countries. As compared to other energy resources, such as petroleum and natural gas, international trade in coal is a small portion of total global coal production. In 2011, close to 15% of the total thermal coal and 28.5% of metallurgical coal was traded internationally (IEA 2012). This has implications in the forms of availability of trade infrastructure and policies to address any concerns.

Volatile international coal prices

The dynamics of coal price in global market are influenced by a variety of factors ranging from rains in Indonesia, to world demand for steel. Steam coal prices are a function of a variety of factors, such as supply–demand fundamentals, freight rates, and other external factors. Of the total bulk trade, steam coal accounts for 20%, coking coal for 7–8%, iron ore 25%, and other commodities account for the rest. As the bulk fleet is used for a variety of commodities, a strong demand in one of these can bring a strain in the availability of ships and a surge in freight rates.

Prices of coal have been relatively stable during the 1990s and in the early years of 2000s. But prices had started moving up since 2003 and followed the trend till 2008, when it crashed due the global meltdown. Coal prices have been volatile in the past few years—rising

from US\$ 103/tonne in 2010 to US\$ 130/tonne in 2011 and then declining again to under US\$ 100/tonne towards the end of 2012 (IMF 2013).⁴ The rise in demand for Indonesian coal from China and India has further led to an increase in the price of Indonesian coal at a time when prices of coal from South Africa and Australia are stabilizing (Bose 2013). Volatility in international prices makes the domestic consuming sector vulnerable and this is compounded by the rise in import dependence.

Changing policies of exporting countries

Though coal is available in many countries around the world, due to its bulky nature the feasible options for India are Indonesia, Australia, and South Africa, and the recent developments in some of these countries are not quite encouraging. In Australia, in an attempt to internalize the environmental costs, the Government first introduced a carbon tax on mining of certain resources including coal. However, in late 2013, it was decided to repeal the tax and this change is expected to take place from July 2014.

In Indonesia, the Government lays down more responsibility on the license holder and seeks to retain earnings/benefits from mining in Indonesia by way of setting a benchmark price for selling the resource. The law recognizes community development as a responsibility of the mining permit holder and requires involvement of local communities in decision-making. Moreover, of late, the Government of Indonesia is moving towards resource nationalism and is demanding

⁴ These refer to the Australian export market prices

greater royalty and asking foreign companies to divest 51% of their share to Indonesians within a period of 10 years (TERI 2012). The benchmarking of prices to international rates in Indonesia and the resulting increase in prices has also affected the financial viability of power plants based on imported coal to a certain extent.

Infrastructure bottlenecks

Constraints on the availability of infrastructure

Various forms of support infrastructure are needed for facilitating the usage of coal. These include coal washeries, port facilities for handling coal imports, and rail transportation networks.

Washeries and beneficiation of coal

Coal produced in India is high in ash content and has low heat value. Given this handicap, it is essential to add washery capacity in order to improve the quality of coal, especially when it is transported over long distances to power generation stations to reduce the chance of transporting impurities over long distance. Currently, the washery capacity stands at close to 145 Mt—33 Mt coking coal and 112 Mt of non-coking coal. Washery capacity addition, however, has been limited and faces constraints in development due to issues related to environment and land acquisition. In fact, during the 11th Five Year Plan period, no additions were made to the washery capacity of the country (Lok Sabha Secretariat 2012). Further, recent issues of complaints on the quality of washed coal also highlight the need for improvement in the technology being

used currently. Even with coal that is sold after washing, losses have been reported on account of wet coal being supplied to power plants (CEA 2012).

Transport infrastructure

An expansion in the railway network is essential to facilitate the transportation of coal. Railways are already working at near full capacity and there is a need to add to coal handling and transportation expenditure keeping in view the rising demand of coal in the country.

Also, the coal handling capacity of ports will need to be enhanced in order to manage rising imports. As per the *Report of the Working Group on Coal and Lignite for Formulation of 12th Five Year Plan*, the coal traffic at ports is projected to increase from 89.34 Mt in 2011–12 to 284.8 Mt in 2016–17 (Ministry of Coal 2011). Among other infrastructure facilities, this will require additions to the dedicated coal handling capacity, inland connectivity, and increase in draft availability and storage capacity at ports.

Regulation

Absence of an independent regulator

The need for appointing an independent authority to regulate the coal sector in India has been felt for long. Several committees and independent bodies have recommended the establishment of such a body for the country. While this has also been realized in the successive Five Year Plans, the implementation of these recommendations has been slow. This fact is also highlighted in Sreenivas and Bhosale (2013) who compare the recommendations made by the Working

Groups for the 11th and 12th Five Year Plans. As of June 2013, a draft Bill—Coal Regulatory Authority Bill, 2013—was approved by the Union Cabinet. It is expected that setting up of the authority “shall help in the regulation and conservation of coal resources and will benefit all stakeholders; that is coal companies, coal consuming industries, such as power, steel, cement and coal bearing States and people, directly or indirectly associated with the coal industry” (PIB 2013a).

Absence of competition and resulting inefficiencies

CIL is a monopoly player in the coal sector in India. This affects the security of supply of coal as delays in development of coalfields owned by CIL will affect the overall availability of the energy source for the entire country. The lack of availability of domestic coal will further affect the energy security of the country, as dependence on imports to meet domestic requirement will rise further. This means that the absence of significant competition in the sector affects the efficiency and the technology employed by the incumbent monopoly player in the market. Although coal blocks have been allocated to private parties, they are for captive use rather than for bringing coal to the market. This monopoly status, apart from affecting the availability of coal and pricing, also affects the quality of coal produced as CIL faces no competition in the market.

Pricing

Although the prices of coal produced domestically have been decontrolled theoretically, the Government still plays an

important role in determining the prices. Further, the presence of a monopoly player like CIL has not allowed market-determined pricing mechanism to develop in the sector. Even though e-auctioning was introduced, a very small share of the coal trade in the country takes place through auction. A step towards implementation of recommendations of the Expert Committee on the Integrated Energy Policy (IEP) was taken in 2012 when the UHV-based pricing mechanism was replaced with a GCV-based mechanism. The number of bands for pricing coal grades has been increased and to some extent, this has led to an increase in the prices of coal. However, the impact of this increase on the consuming sectors has led the Government to ensure that CIL does not follow this recommendation.

Fuel supply linkages

Supply of coal to power producers has been an issue of controversy in the recent past, particularly in the context of new power plants. As per available reports, no Fuel Supply Agreements (FSAs) had been signed with power plants established after March 2009 (Lok Sabha Secretariat 2012). In April 2012, the Government of India had issued a Presidential Directive to CIL to sign FSA with power producers. By December 2012, FSAs were signed with power plants that are expected to be commissioned by 2015. Under different scenarios, the supply obligations of CIL in 2016–17 will be between 699.93 MT and 845.90 MT (Lok Sabha 2012). As per further developments, in July 2013 the Ministry of Coal has issued another Presidential Directive to CIL for signing of FSAs for a capacity of

78,000 MW instead of the earlier 60,678 MW. Following this, as of September 2013, CIL signed 140 FSAs for an aggregate 60,000 MW capacity power plants (PIB 2013b).

However, new power producers argued that terms of such agreements offered by the CIL are discriminatory. CIL has the option of supplying them imported coal and charging them on a cost-plus basis. The issue has also reached the Competition Commission of India (CCI), which is investigating a case of abuse of dominant position against CIL. Meanwhile, the Prime Minister's Office has advised CIL to reduce the sale of coal through e-auction. However, such a move will affect not only the profitability of CIL but will adversely affect other users of coal. An Inter-Ministerial Committee, headed by the Coal Secretary, has also been formed to examine the issue of fuel linkages with the power sector.

Environmental issues

Coal mining poses serious environmental hazards in the surrounding areas, particularly in the open cast type of mining, which also happens to be the mode that produces most of the coal mined in the country. It is not uncommon to see coal being transported in uncovered containers, particularly in areas close to mines leading to spillage and environmental hazards. Such mining activities damage the environment and severely affect the livelihood and living conditions of the people.

Additionally, land—often the only asset of a local community—is acquired for coal mining. Even when generous compensation is

provided, it is unlikely to offset the sustained impact on livelihoods as the displaced communities are mostly unskilled. Only a few of them are offered jobs in the mining projects (TERI 2012). The recent Mines and Minerals Development and Regulation (MMDR) Bill has proposed various provisions for the benefit of communities and Project Affected Persons (PAPs). Thus, in theory, these policy reforms can result in appropriate sharing of value with communities/PAPs. However, the question here is whether these policies will bring about any changes on the ground. There have been many instances where the funds have been created for the mitigation of externalities and other purposes. However, the proceeds have not been channelized to the beneficiaries or used for the desired purpose.

Impact of climate change policies

Climate change policies will have two implications. Firstly, companies will need to 'adopt clean technologies' for extraction of coal and this will have implications on both the cost and the quantity of coal produced. A second impact of climate change related policies will be on the 'change in export policies of major coal exporting countries'. As mentioned, changes in Australia's carbon policies and the possibility of banning the export of coal below certain calorific values in Indonesia are all examples of these changes. These and similar changes in policies of coal exporting countries will affect both the quantity of coal available as well as the prices at which coal is available to domestic markets.

Chapter 2

Oil and Natural Gas

KEY ISSUES

Upstream

- Unexpected decline in domestic gas production has caused significant supply problems, especially in the power and fertilizer sectors.
- High level of import dependence (82%) on crude oil exacerbates energy insecurity due to:
 - Geopolitical uncertainty in major crude oil supplying countries
 - Large import bill on crude oil which affects foreign exchange reserves
 - Petroleum product pricing regulations affect fiscal balances (detailed in downstream)
- Security concerns and potential supply disruptions increases the country's exposure and vulnerability to supply shocks.
- Slow progress on Strategic Petroleum Reserves (SPRs) perpetuates risk of supply shocks. Only 5.33 Mt of crude reserves have been planned till now. Crude filling at the SPRs has also progressed sluggishly.
- Natural gas pricing regulations and multiple price regimes discourage private investment and create barriers against entry of new players in the natural gas sector.
- Regulatory deficits impede the performance of the sector due to:
 - Absence of an effective, independent upstream regulator {Directorate General of Hydrocarbons (DGH) not a statutory body}; the downstream regulator Petroleum and Natural Gas Regulatory Board (PNGRB) is also involved in conflicts of jurisdiction
 - Delays in obtaining clearances from line ministries discourage companies from undertaking exploration and production activities

Midstream

- Progress on cross-border pipelines (Turkmenistan-Afghanistan-Pakistan-India pipeline and Iran-Pakistan-India pipeline) has been very slow although pipelines are a cheaper option for importing gas over relatively short distances.

- Lack of adequate Liquefied Natural Gas (LNG) infrastructure to handle the projected LNG demand. No terminals are present on the East coast. However, considerable terminal capacity has been planned to be added on both the East and the West coasts over the next 10 years.
- Acquiring right of use and right of way for pipelines has proven to be a tedious process in some areas.
- Issues regarding unbundling of marketing and transportation and third party access persist, with Gas Authority of India Limited (GAIL) and some others expressing discontent over unbundling of transportation and marketing verticals.

Downstream

- Pricing of petroleum products is one of the major issues affecting energy security. Regulated pricing has the following impacts on the economy:
 - Adverse impact on fiscal balances due to subsidies and Government compensation for under-recoveries
 - Adverse impact on balance sheets of Oil Marketing Companies (OMCs) and unavailability of investible funds
 - Detrimental impact on level of competition in the downstream segment since regulated pricing deters new entrants and private players
 - Adverse impact on upstream companies and GAIL due to under-recovery burden sharing
 - Artificially lowered prices of kerosene incentivize diversion of subsidized kerosene towards unintended uses
- Complications have arisen due to the Gas Utilization Policy. Newly constructed power plants are not getting gas due to shortfall in Krishna-Godavari (KG) basin D6 block production.
- Coverage of Liquefied Petroleum Gas (LPG) is inadequate, especially in rural areas. Only 56.2% of the total number of households have an LPG connection.
- In terms of biofuels, availability of ethanol is an issue due to competing uses. There is a requirement of large tracts of land for jatropha cultivation which is hindering production of biodiesel.

Overview

The oil and gas sector plays a critical role in determining India's energy security. Oil and gas account for 39.38% and 9.07% of the primary energy consumed in India, respectively (TERI 2012a). India is heavily dependent on crude oil imports since domestic production of crude oil is not sufficient to meet its demand. The level of import dependency in natural gas is much lower, but that is also expected to go up in the future as domestic production is declining. Although the upstream sector has not been able to meet the country's demands, the refining segment has performed better and India has become a net exporter of petroleum products. The downstream sector faces serious pricing policy issues, though the Government has recently been proactive in addressing these concerns.

Consumption and Supply

Total production of crude oil in India was about 38.30 Mt in 2012–13, up from 38.09 Mt in 2011–

12. The country imported 184.45 Mt of crude oil in 2012–13, incurring an import bill of about INR 782,950 crore (Figure 5). The value of crude imports had increased significantly over the years (2011–12 and 2012–13) due to a rise in volume of imports and the depreciation of the Rupee to the Dollar. Additionally, crude oil prices had risen in 2011–12, causing a 47% increase in value of crude imports over 2010–11.

Overall production of petroleum products in India went up by 7.4% in 2012–13, to 219.02 Mt. Consumption of petroleum products was at a total of 155.42 Mt in 2012–13, which was a 5% increase over the previous year's consumption. Petrol, diesel, and LPG consumption rose by 5%, 6.8%, and 1.6%, respectively, while kerosene consumption went down by 8.8% from the previous year. India continues to be a net exporter of petroleum products as shown in Figure 5, exporting 48.69 Mt in 2012–13.

India produced 40.68 Billion Cubic Metres (BCM) of natural gas in 2012–13, a 14.5% drop from the previous year's production.

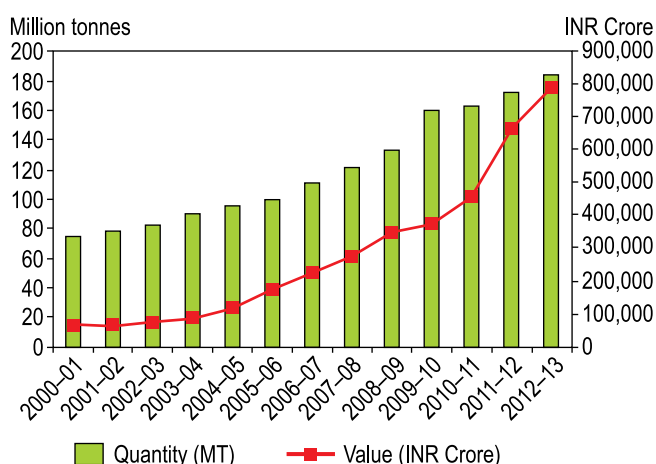


Figure 5: Quantity and value of crude oil imports into India

Notes: (P): Provisional

Source: PPAC 2013a

This was mainly due to the continued decline of production from the KG-D6 block operated by the Reliance Industries Limited (RIL)-Niko resources consortium. Off-take of natural gas is dominated by the power sector, followed by the fertilizer industry. City Gas Distribution (CGD) businesses, refineries, petrochemical plants, steel plants, and other end-consumers receive domestic gas after the Government allocated gas to the power and fertilizer sectors, as per the Gas Utilisation Policy.

Support infrastructure and technology

The availability of infrastructure is critical for all segments of the fuel chain of oil and gas. India faces infrastructural issues, especially in importing natural gas.

In the upstream segment, the chances are high that future oil and gas discoveries—at least conventional oil and gas—will occur only in difficult geologies. The existing fields of ONGC, primarily Bombay High and OIL (in Assam) are aging and their production profiles may have peaked. Making new discoveries in difficult geologies necessitates state-of-the-art technology and careful consideration of the additional environmental impact of such activities.

In the midstream segment, the issues of concern are mainly for natural gas. The gas pipeline grid has not been expanded swiftly enough, probably as a result of declining domestic production. Only two LNG terminals are fully operational, both on the West Coast, since currently gas is imported mainly from West Asia. Development of transnational natural gas pipelines has been extremely slow

since it has been hindered by geopolitical tensions and instability in the region.

In the downstream segment, the primary concern is the lack of distribution infrastructure for LPG in rural areas which is hindering the transition towards a cleaner, more efficient alternative to biomass and fuel-wood for cooking.

These issues and issues of pricing of oil and gas have a direct impact on the country's energy security. Each of them is examined in some detail in the following section.

Key Issues

Unanticipated decline in domestic gas production

The total domestic gas production in India has declined significantly over the past few years. This is clearly detrimental to energy security of the country and also hinders the transition to natural gas which is a more environment-friendly form of energy in comparison with crude oil or coal. When Reliance India Limited (RIL) had announced very large commercial gas reserves in its Krishna-Godavari (KG) basin D6 block, it was expected that production from that block could increase to 80 Million standard cubic meters per day (Mscmd) during 2010–11 and peak at around 120 Mscmd over the next few years. On the basis of these figures, a large number of gas-based power plants were set up in the country. Fertilizer and power companies were planning a major transition to gas-based production. However, this anticipated increase in production has been far from fulfilled. In fact, RIL's D6 production declined steadily since 2010–11 and is now below 16 Mscmd, less than 15% of the estimated peak production.

This has caused significant problems to gas consumers in the country. Consequently, the country's expected future dependence on more expensive Liquefied Natural Gas (LNG) has also increased quite significantly.

High level of dependence on imported crude oil

Crude oil reserves in India are not sufficient to meet the growing demand for petroleum products. Crude oil import dependence in the year 2012–13 was around 82.81% (Figure 6).⁵ In the period between 2004–05 and 2012–13, this dependence has steadily increased, averaging at around 79%. An analysis by TERI in 2008 had concluded that India was the 3rd most vulnerable country to oil supply shocks among 26 major oil importing countries (TERI, 2010).

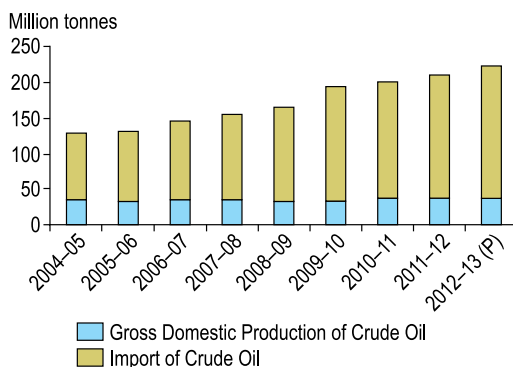


Figure 6: Import dependence for crude oil (2000-2012)

Source: MoPNG 2012a

High levels of import dependency on crude oil affect the country through three direct channels. These are:

- The countries supplying most of the crude oil to India are located in geopolitically unstable regions. After Saudi Arabia, Iraq and Iran were the second and third largest crude suppliers to India, respectively. Around 69% of India's total oil imports are from the Middle East. This exposes the energy sector to supply shocks and disruptions, adversely affecting the country's energy security (Gupta, 2008).
- The large import Bill has an impact on the current account balances of the country. This impact is exacerbated in years when the Rupee does not perform well against the US Dollar. According to statistics from the Reserve Bank of India (RBI), the value of crude oil and petroleum product imports is almost one-third of the value of total goods imports. The adverse impact on current account/trade balances leads to potential lowering of the nation's credit rating by international agencies, making it difficult for the Government to take further loans to finance its expenditures.
- Since the Government maintains control over the prices of key petroleum products, such as diesel, Public Distribution System (PDS) kerosene, and domestic LPG,⁶ the oil companies face heavy losses, or 'under-recoveries', on sale of these products.

⁵ The figure is arrived at by calculating quantity of crude oil imports as a percentage of the total of domestic crude oil production and crude oil imports into India as per data provided by the MoPNG. Exports of petroleum products have not been accounted for in calculating this import dependence.

⁶ As a short-term measure to control LPG subsidies in September 2012, the number of subsidized LPG cylinders had been capped at 6/household. However, the cap has since then been raised to 9 in a number of states. Additional LPG cylinders can be purchased at the non-subsidized price.

These artificially low prices not only affect the OMCs' balance sheets but also act as barriers to the entry of new players in the downstream retailing market. Moreover, since these under-recoveries are partially compensated for by the Government, current petroleum product pricing regulations are an additional significant budgetary expenditure incurred every year.

Security concerns and potential supply disruptions

Another factor which adversely affects the country's energy security is its exposure to shocks or disruptions in energy supply (Planning Commission, 2006). Such disruptions can have debilitating short-term effects on the major consuming sectors, including industry, households, agriculture, and transport. As mentioned earlier, the concentration of countries supplying crude oil to India in the geopolitically unstable Middle East region exposes the country to potential supply shocks (Gupta, 2008). Maritime security concerns and the threat of piracy on the open seas also increase India's exposure to supply shocks (Gupta, 2012). Chokepoints along international shipping routes also increase India's exposure to supply shocks. By volume of oil transit, the Strait of Hormuz, leading out of the Persian Gulf, and the Strait of Malacca, linking the Indian and Pacific Oceans, are two of the world's most significant chokepoints. Any blockage or threat to the security of the Strait of Hormuz—the only sea passage to the open ocean for large areas of the petroleum-exporting Persian Gulf—is capable of blocking anywhere from 31.5% to 66.6% of India's oil imports (TERI 2010).

The concentration of India's refineries and LNG terminals on the West Coast, especially in Jamnagar, increases the exposure of crucial energy supply sources to natural disasters or terrorist attacks in these areas. Such occurrences along major pipeline routes could affect supply of petroleum products across the nation.

Slow progress on strategic petroleum reserves

In 2004, India envisaged constructing strategic petroleum reserves (SPRs) as a first line of defence against crude oil supply shocks. Therefore, SPRs contribute directly to increasing the energy security of a country. The advantage of storing crude in underground caverns—as opposed to above ground—is that the stock is protected from external fires, sabotage, explosions, and earthquakes (*Business Today*, 2011). Strategic storage caverns require very little maintenance, resulting in low marginal capital cost of storage beyond a certain capacity.

Construction and operation of the storage facilities in India is managed by the Indian Strategic Petroleum Reserves Ltd (ISPRL), a special purpose vehicle owned by the Oil Industry Development Board. Over the last decade, work has progressed on three underground caverns in Vishakhapatnam, Mangalore, and Padur, with capacities of 1.33 Mt, 1.5 Mt, and 2.5 Mt, respectively. The initial construction cost of these three facilities has been estimated at INR 2,397 crore (Indian Petro, 2010). At US\$ 110 a barrel, the total cost of filling crude into these caverns has been estimated at more than INR 20,278 crore (Indian Petro 2012).

After some delays, the anticipated mechanical completion dates for the three facilities had been stated as March 2013 for Vishakhapatnam, September 2013 for Mangalore, and January 2014 for Padur (Indian Petro, 2012). The work on building the SPR facilities and crude filling needs to be expedited.

Ineffectiveness of regulator in both upstream and downstream segment

An effective and independent regulator forms the basis of developing an equitable and efficient natural resource sector. The oil and gas sector in India has, for the past several years, suffered from a regulatory deficit which has been reflected in the form of various issues arising in the sector. This has adversely affected energy security by hindering development of the sector, especially domestic exploration and production, and downstream marketing.

The upstream segment of the petroleum and natural gas sector is critical to check the increasing import dependency on crude oil. However, this segment does not have a statutory regulatory authority. Although the Directorate General of Hydrocarbons (DGH) has been entrusted with the task of overseeing the holistic development of the upstream oil and gas sector, it falls under the administrative control of the Ministry of Petrol and Natural Gas (MoPNG) and is not a statutory regulatory body. Further, concerns have been raised regarding the independence of the members of DGH, since they are mostly appointed on deputation from oil companies whose activities fall under

the regulatory purview of the DGH creating potential conflict of interest issues.

Bureaucratic controls and the continued control of Government in selection of members of the regulatory bodies have affected the independence of regulation in the downstream sector as well. The Government plays a major role in selection of the members of the Petroleum and Natural Gas Regulatory Board (PNGRB).⁷

Delays in grant of clearances

Another impact of ineffective regulations is that of inordinate delays in getting approvals from the concerned line ministries for oil and gas exploration blocks. For the blocks that are allocated under New Exploration Licensing Policy (NELP), the detailed ecological assessment of the block is carried out only after bidding is completed and the block has been awarded. Therefore, once a company has gone through the process of bidding for being awarded a block, the MoEF could decide to not allow the operator to explore or drill in some or all parts of the acreage.

Further, delays on account of clearances from the Department of Space and the Ministry of Defence have also been reported for many blocks (*The Hindu*, 2012). The lengthy process and high level of uncertainty dampens investor spirit, discourages participation of major private and international players in the sector.

Domestic gas pricing policy

Gas pricing in India has undergone several phases. Currently, there are multiple prices

⁷ The Selection Criteria is clearly laid out in the Act.

existing for gas originating from different sources. The Rangarajan Committee (2013) has recommended a new formula which uses a mix of international prices and gas import prices as its basis. The formula was approved and would have been applicable across all sectors till 2017, but its adoption was put on hold due to the general election in May 2015. However, there has been significant debate in the media and among various stakeholders on the validity and viability of the suggested mechanism.⁸

There is a need to make domestic gas pricing more transparent and competitive, but at the same time, lucrative for companies to continue participating in the exploration and production of the energy source in the country.

Inadequate LNG import infrastructure

Given falling production of D6 gas, rising domestic demand and global gas market trends, India would need to consider developing LNG infrastructure quickly. The Planning Commission projects steep increase in natural gas demand which will necessitate higher gas imports in the near future. More terminals would need to be developed, especially some along the East Coast to source gas from Australia or Indonesia. The capacities of the terminals in Dahej and Dabhol also need to be increased.

Currently, India imports LNG at Petronet LNG Limited's (PLL) Dahej terminal and at Shell's terminal in Hazira; total import capacity in operation is 13.67 Million Tonnes per Annum (Mtpa). PLL imports gas mostly through a long-term contract with RasGas in Qatar. The total quantum of LNG imported on this contract is

7.5 Mtpa. The Hazira terminal imports LNG from the spot market, mostly from Shell-operated liquefaction plants abroad. Another terminal, a 5 Mtpa receiving and re-gasification facility, is coming up in Kochi, Kerala (TERI, 2013).

India will have to expedite construction of new LNG terminals, especially on the East Coast, in order to ensure that the rising demand for natural gas can be satisfied. Moreover, pipelines have to be constructed for transporting gas from the regasification terminals to customers.

Acquiring Right of Use (RoU) and Right of Way (RoW) for pipelines

Before laying oil or gas pipelines, a company must obtain a Right of Use (RoU) or a Right of Way (RoW) for the land through which the pipeline is to pass. A RoU or RoW is supposed to be less disruptive than outright land acquisition, since landowners are allowed to carry out normal agricultural or other activities around the pipeline, although additional private construction activities are not allowed. However, there have been delays on the part of the central and state Governments in appointing the mandatory 'competent authority' for determining market price for land, thus delaying granting of the RoU or RoW (Projects Monitor, 2012). There have also been protests against the laying of pipelines through some areas which have delayed pipeline projects (*Desh Gujarat*, 2012).

Unbundling of transportation and marketing and Third Party Access for pipelines

In order to promote competition in the midstream oil and gas infrastructure sector,

⁸ For further more details, see Lagathe (2014), Sagar (2014), & Sethi (2013).

the Petroleum and Natural Gas Board (PNGRB) recently published a concept document on unbundling of transportation and marketing activities and allowing third party access to petroleum product and gas transportation pipelines (PNGRB, 2012). Currently, GAIL India Limited (GAIL) enjoys a near monopoly of these segments of the natural gas value chain. Many stakeholders, including GAIL, Gujarat State Petroleum Corporation (GSPC), Adani Gas Ltd, Reliance Gas Transportation and Infrastructure Ltd (RGITL), and NTPC have issued comments on the document.

Most stakeholders who are gas consumers, such as Tata Power, have expressed support to the proposed unbundling of these two segments. However, GAIL has objected to the idea, saying that India's natural gas markets are not adequately developed, with regulated pricing mechanisms and absence of gas trading hubs. Therefore, if transportation and marketing activities are unbundled, it would only increase operation and administrative expenses which would be detrimental to the development of India's natural gas market. GSPC has agreed with the idea but has argued a case for leaving LNG terminals out of the purview of these regulations.

Therefore, it seems that the regulator will have to strive harder to arrive at a workable consensus regarding unbundling and third party access. Until then, there would remain significant barriers to entry at this stage of the value chain against new players.

Pricing of sensitive petroleum products

Building on the point mentioned earlier regarding pricing of key petroleum products,

Government control on retail prices of diesel, PDS kerosene, and domestic LPG has extensive implications for the energy security of the nation. While the price of these fuels directly affects their affordability, the question needs to be taken in the larger context of the implication of subsidies for the Government's fiscal balances, efficiency in the sector, foreign and domestic investments in renewable energy, and viability of national oil companies.

Artificially low prices and subsidies provided on these products act as a drain on Government coffers, constrain the availability of investible funds for downstream oil companies, adversely affect the balance sheets of upstream PSUs (ONGC, OIL) and GAIL, incentivize diversion of kerosene towards unintended uses, discourages investment in cleaner alternative energy sources, and prevent the entry of new players into the downstream sector in India. The compensation mechanism for under-recoveries followed by the Government spreads the effect of under-recoveries across the Government, upstream oil companies (which sell crude at discounted prices to the OMCs), and GAIL (TERI, 2012b).

Moreover, the subsidies accrue disproportionately to the upper-income deciles, such that the poorer sections continue to be relatively worse off. The problems of reforming the system of pricing are manifold and any increase in prices is met with heavy opposition in the parliament. The opposition is on the grounds of reduced affordability of petroleum products and cascading inflationary impact of rise in price of diesel. The following sub-sections look at the adverse impacts of regulated pricing of petroleum products.

Impact on fiscal balances

The most apparent impact of regulated pricing is the cash outflow from the central Government's coffers towards compensating the downstream OMCs and towards paying the per-unit subsidy on PDS kerosene and domestic LPG. The total under-recovery burden incurred by the OMCs in 2011–12 was INR 138,541 crore.

The largest under-recovery was on account of sale of diesel (INR 81,192 crore). Of the total under-recovery, the Government paid INR 83,500 crore (PIB, 2012). In addition to the share in under-recoveries, the Government

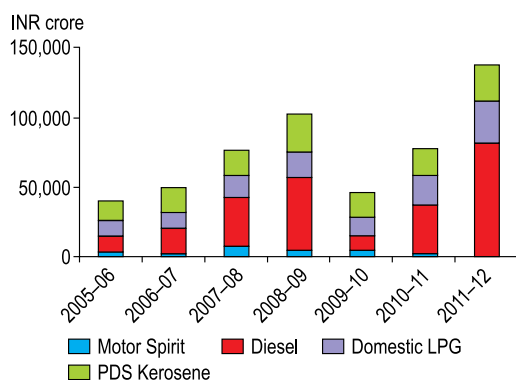


Figure 7: Contribution of four sensitive petroleum products to total under-recoveries from 2005–06 to 2012–13

Source: PPAC 2013b

also paid per unit fiscal subsidies on LPG and kerosene to the tune of INR 3,023 crore.

As per press releases by the Government of India, despite the increase in diesel prices and the capping of domestic LPG cylinders, the expected under-recoveries for 2012–13 is INR 1,67,000 crore.

While subsidies and under-recoveries in the petroleum sector are a huge burden on Government finances and on oil companies, it should be kept in mind that petroleum products are also heavily taxed by the central and state Governments. In 2012–13, the total contribution of the sector to the central and state exchequer was INR 2,43,939 crore. This is well above the total subsidies and under-recoveries incurred on petroleum products in the same year. This comparison further highlights the complexities of rationalizing petroleum product pricing. Reforming taxes is as difficult, if not more, than reforming subsidies since this is a major source of revenue for the central and the state Governments.

Impact on level of competition in the sector

The continued Government control on prices of final petroleum products has affected the level

Table 3: Fiscal subsidy on PDS kerosene and domestic LPG (in INR crore)

Year	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13
PDS Kerosene	1,057	970	978	974	956	931	863	741
Domestic LPG	1,605	1,554	1,663	1,714	1,814	1,974	2,137	1,989
Total	2,662	2,524	2,641	2,688	2,770	2,904	3,000	2,730

Note: In addition to this, the Government also pays freight subsidy for far-flung areas and this stood at INR 23 crore in 2012–13

Source: PPAC 2013c

Table 4: Contribution of the petroleum sector to the state and central exchequer (in INR crore)

Particulars	Annual Figures		
	2010–11	2011–12	2012–13
Contribution to Central Exchequer			
Tax/duties on crude oil and petroleum products	1,03,580	83,723	83,718
Dividend to Government/income tax, etc.	32,917	36,127	33,704
Total Contribution to Central Exchequer	1,36,497	1,19,850	1,17,422
Contribution to State Exchequer			
Tax/duties on crude and petroleum products	88,976	1,12,899	1,26,502
Dividend to Government/direct tax, etc.	21	20	14
Total Contribution to State Exchequer	88,997	1,12,919	1,26,516

Source: PPAC 2013d

of private participation in marketing of key petroleum products—petrol, diesel, kerosene, and LPG. Even though private companies are allowed to market petroleum products at market-determined prices, the participation from companies, such as RIL, Essar, and Shell, has been limited as the prices at which PSU OMCs sell these products are much lower than the market-determined prices. RIL has shut down most of its retail outlets whereas Essar and Shell continue to sell selected products across a few states. Therefore, while these companies do sell refined products in the domestic market to the marketing arms of the PSUs, their presence in the marketing segment is much more limited compared with their PSU counterparts.

Unavailability of investible funds

The lack of readily available investible funds hinders the ability of downstream and upstream oil companies to expand their business or invest in assets abroad.

Diversion

The price differential between PDS kerosene and diesel (as well as other substitutes) has led to large-scale diversion of the subsidized fuel towards unintended uses. Primary among such malpractice is the use of subsidized kerosene to adulterate diesel. In 2005, the National Council for Applied Economic Research (NCAER) observed that 37.6% of PDS kerosene was diverted towards unintended uses (Bery, 2006).

At a diversion rate of 37.6%, more than INR 5,000 crore (US\$ 1.13 billion) of subsidies and under-recoveries were lost in 2005–06. Assuming that all of the PDS kerosene diverted towards ‘non-household use’ was used for the adulteration of diesel, the state Governments would have lost an additional INR 1,021 crore (US\$ 230.61 million) in 2005–06 as excise duties foregone. If kerosene was not used to adulterate diesel, the state Governments would have collected these duties on sale of diesel (TERI 2012c).

Impact on PSU upstream and transportation companies

In addition to this, the upstream companies OIL and ONGC and the gas transportation company GAIL also share in the under-recoveries. As of December 2011, the contribution of these companies in the under-recovery burden was around INR 40,000 crore. Table 5 presents the total under-recoveries and their sharing between Government and oil companies.

Table 5: Sharing of under-recoveries (in INR Crore)			
	2008–09	2009–10	2010–11
Total under-recovery	103,292	46,051	78,190
Government share*	71,292	26,000	41,000
Upstream oil companies and GAIL	32,000	14,430	30,297
Oil Marketing Companies	0	5,621	6,893
<i>Note:</i> Until 2009–10, the Government share was in the form of Oil Bonds issued to OMCs. Source: TERI 2013			

The Government is cognizant of these impacts and has stated, “a phased price adjustment is needed that would reduce subsidy to manageable levels” (Planning Commission 2012b).

Gas utilization policy

While the share and importance of natural gas is expected to increase in the future, this growth hinges on the pricing and utilization

policy of gas in the country. Allocation of domestically produced natural gas is made by an Empowered Group of Ministers (EGoM) on the Commercial Utilization of Gas. According to the allocation policy, the fertilizer and power sectors are accorded first priority in allocation of gas. Under the existing policy however newly constructed gas-based power plants do not get priority and, hence, they are lying idle due to unavailability of cheaper domestic gas. Besides, power and fertilizer sectors, CGD businesses, sponge iron and steel plants, refineries, petrochemicals, etc., have to pay much more for imported LNG. However, many have shown willingness to transition to gas, even at higher prices.

Unavailability of LPG supply infrastructure in rural areas

The *Integrated Energy Policy* document (Planning Commission, 2006) says that India would be energy secure only when all citizens have access to lifeline energy irrespective of their ability to pay, as well as access to safe and convenient energy at competitive prices to meet their effective demand adequately. According to the draft *12th Five Year Plan*, energy security involves ensuring uninterrupted supply of energy to support the economic and commercial activities necessary for sustained economic growth (Planning Commission 2012a).

These definitions highlight the importance of energy access in increasing the country's energy security. Therefore, it is clear that a widespread distribution network for sale of petroleum products, especially PDS kerosene and domestic LPG, is required to ensure

that citizens have access to these fuels. In the case of domestic LPG, the coverage is not widespread with only 56.2% of the total number of households having an LPG connection (Lok Sabha 2012b). In states, such as Bihar, Jharkhand, Odisha, and Chhattisgarh less than one-fourth the number of households possesses an LPG connection. This low coverage can be a result of problems related to both affordability of and access to LPG.

As the penetration of LPG is low in rural areas, initiatives have been undertaken by the Government to promote LPG usage in villages through a distribution scheme called the Rajiv Gandhi Gramin LPG Vitaran Yojana (RGGLVY) under which small distributorships are being set up in rural areas. As part of the 'Vision-2015' adopted for the LPG sector, overall LPG coverage is targeted to reach 75% of the national population, which translates to adding 55 million new customers by 2015 (MoPNG 2010b). As of October 1, 2012, the total number of registered domestic LPG customers was at 142.14 million, as against 100.61 million as of April 1, 2008 (Lok Sabha 2012b). Table 6 below shows the customer population and coverage of LPG in India.

Biofuels

The Government of India has been encouraging use of biofuels (ethanol-blended petrol and biodiesel) in the automotive fuel industry in order to reduce the country's dependence on crude oil and mitigate air pollution. Targets have been set for 20% blending of biodiesel in High Speed Diesel (HSD) as well as 20% blending of ethanol in petrol by the year 2017. The National Policy on Biofuels was laid down in 2009 to pave the way for achieving this target. However, the uptake of biofuels has been slow and both the major biofuels have a number of problems associated with them.

Ethanol Blending Programme

The Ethanol Blending Programme (EBP) mandates 5% blending of ethanol in petrol in India. However, availability of ethanol for blending with petrol remains a concern since the oil companies would have to compete with a large number of other consumers, predominantly the alcohol industry. On the supply side, since ethanol is manufactured as a by-product of molasses and since sugarcane production is seasonal in nature, the availability of ethanol in the market is limited, constraining the achievement of the blending

Table 6: Domestic LPG customer population and coverage

Domestic LPG Customer Population (in Lakhs)				
IOCL	BPCL	HPCL	Total	Coverage (Ratio of domestic LPG customers to households)
696.3	354.5	373.88	1,424.68	56.20%
Source: Lok Sabha (2012b)				

targets. Further, compatibility of the current vehicle fleet will become an issue at higher blending levels, since more than 15% ethanol blending will necessitate engine modifications in cars.

Biodiesel

Blending of biodiesel has not commenced as yet since the industry is still in its nascent stages. In 2008, the Indian Government

announced its National Biofuel Policy (NBP) which aims to meet 20% of India's diesel demand with fuels derived from plants by 2017. The availability of land for arable land for jatropha cultivation is a major concern. Issues have also been raised about the adverse impact of using land for jatropha cultivation on food security of the country. Moreover, most of the jatropha plantations are located far off from biodiesel producing units leading to high production costs of biodiesel (TERI 2013).

Chapter 3

Power

KEY ISSUES

- **Slippages of the targets:** The capacity addition target set for the 11th Plan was 78,700 MW, but the capacity addition was only 54,963.9 MW having a slippage of about 12% approximately and achievement was 47.5% of the target set for the 9th Plan and 51.5% for the 10th Plan (CEA 2012).
- **Demand–supply mismatch:** The demand has been growing in terms of both, energy and peak demand at a fast pace resulting in shortages. The energy shortage in the country was recorded at 8.5% while the peak deficit was recorded at 11.1% during 2011–12.

Generation

- **Declining performance of thermal power stations:** Due to the fuel constraints (shortage of coal and non-availability of gas), the Plant Load Factor (PLF) of thermal power stations at the national level, during 2011–12, reduced to 73.32% from 75.08% achieved during 2010–11.
- **Shortage of coal:** Power utilities have reported a generation loss of 11.7 Billion Units (BUs) in 2012–13 (up to January 2013) due to shortage of coal. In addition, increasing import prices of coal have added to the financial burden of the utilities.
- **Shortage of gas:** Electricity generation loss of 58.73 BU from gas-based power projects from April 2012 to January 2013. The fall is being attributed to the decline in natural gas supply from domestic sources witnessed in the last few years.
- **Delay in obtaining clearances:** Power plants and utilities also face major constraints and delays regarding the availability of land and obtaining the requisite environment and other clearances for the projects.

Transmission

- Planning and developing transmission system has become increasingly complex due to the challenges such as delay in forest clearance, right of way problems, challenges in acquiring land for substations and uncertainty in generation capacity addition and load growth.

Distribution

- **Deteriorating financial health of utilities:** The current condition of discoms can be attributed to the continuing gap between Average Cost of Supply (ACS) and Average Revenue Realised (ARR). Stagnant tariffs have been one of the major reasons for the high financial losses and operational and management issues coupled with regulatory shortcomings.
- **AT & C** losses continue to remain a source of concern for the state sector distribution companies. The average AT&C losses (%) for utilities at national level have reduced marginally from 26.58% in the year 2009–10 to 26.15% in 2010–11.
- **Skewed tariff structure** is leading to unsustainable financial situation for the state utilities and is likely to impact the state budgets in the long term.

Overview

Generation

The Indian power sector has grown manifold over the years in terms of installed generation capacity, electricity generation, transmission, and distribution systems. A number of new technologies have been established and a national power grid is operational. In spite of these achievements, the sector faces numerous challenges in terms of increasing power availability, access, quality of supply, etc., in meeting rapidly growing demand and aspirations of people. A number of reforms as well as policy and regulatory measures have been initiated in recent years to address these challenges.

The installed capacity is 225.88 GW comprising 153.84 GW of thermal power (coal, gas, and diesel), 39.62 GW of hydropower, 4.78 GW of nuclear power, and 28.7 GW of renewable sources (Figure 8). The installed and generation capacity in India continues to be dominated by thermal power, which contributes 68% of the total installed capacity and nearly 77%

(709 BU) of the total power generated in the country during FY 2011–12. Hydro (130 BU), nuclear power (33 BU), and renewable energy (51 BU) contributed the remaining share in the electricity generation. Out of the total installed capacity, the highest share is contributed by the state sector (42.99%), followed by the central sector (29.86%), while the private sector contributed the rest (27.15%).

The installed capacity of captive generation in the country has been steadily increasing over the past few years. As per the Central Electricity Authority (CEA), the all-India installed capacity in Captive Power Plants (CPPs) of 1 MW capacity and above increased to 31,516 MW in 2009–10, from 26,673 MW in 2008–09, which is an increase of approximately 18%. The electricity generated from captive generating units during 2009–10 was 106 BU against 99.72 BU in 2008–09, representing a growth of 6.5%. The prominent source of generation in CPPs continues to be steam (coal based) accounting for 73% of the total generation from CPPs (CEA 2012a).

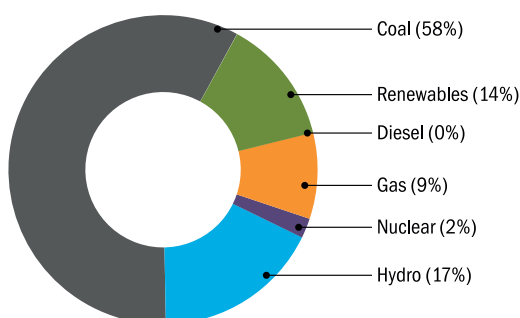


Figure 8: Installed generation capacity as on September 30, 2013
Source: Ministry of Power (2013)

Power supply position

Also, the demand has been growing in terms of both, energy and peak demand, at a fast pace resulting in shortages. Energy deficit was 73,112 MU in 2010–11 and increased to 79,329 MU in 2011–12. The energy shortage in the country was recorded at 8.5% while peak deficit was recorded at 11.1% during 2011–12 (CEA 2012b).

Transmission and distribution

The Indian electricity transmission system is demarcated into five regional grids. Since August 2006, four of the regional grids have been integrated: the Northern, Eastern, Western, and North-Eastern grids (the NEW grid). The southern grid is scheduled to be synchronized with NEW by 2014. At present, the Southern grid is connected to the Western and Eastern grids through a High-Voltage Direct Current (HVDC) transmission line and HVDC back-to-back systems. By the end of 11th Five Year Plan, the country had a total inter-regional transmission capacity of about 28,000 MW which is expected to be enhanced

to about 65,000 MW at the end of 12th Five Year Plan (PGCIL 2012).

The total line length of transmission and distribution network in India has increased to 83,65,301 Circuit (ckt) kms (as on March 31, 2011), an approximate increase of 7% over 2010. The backbone of transmission system in India is mainly through 400 kV AC network with approximately 90,000 ckt kms of line length. Highest transmission voltage level was 800 kV lines with line length of approximately 3341 ckt km as on March 31, 2011. There are about 90,731 ckt kms of 400 kV system and HVDC bi-pole (± 500 kV) of approximately 8,000 ckt kms. These are supported by 1,28,267 ckt kms of 220 kV transmission network. The length of distribution lines (up to 500 volts) was around 48,00,000 ckt kms during 2010–11 with approximately an increase of 6% over the previous year (CEA 2012a).

Table 7 presents the comparison of length of lines operating at various voltage levels in India during 2008–09, 2009–10, and 2010–11.

Table 7: Length of Lines (in ckt kms)			
Voltage	2008–09	2009–10	2010–11
800 kV	2,806	3,332	3,341
HVDC	6,428	6,428	8,008
400 kV	76,239	83,624	90,731
230/220 kV	1,18,664	1,23,052	1,28,267
132/110/90 kV	1,38,615	1,42,039	1,46,790
78/66 kV	51,096	51,024	52,668
33/22 kV	3,43,625	3,49,953	3,72,501
15/11 kV	23,26,546	24,38,962	26,76,229
6.6/3.3/2.2 kV	21,655	22,422	28,195
Distribution Lines upto 500 volts	44,02,303	45,80,262	48,58,571
Total (All India)	74,87,977	78,01,098	83,65,301

Source: (CEA 2012a)

Transmission and distribution losses

The transmission and distribution losses in 2010–11 were 23.97% as against 25.39% in 2009–10 and the average Aggregate Technical & Commercial (AT&C) losses for utilities selling directly to consumers at the national level have reduced marginally from 26.58% in 2009–10 to 26.15% in 2010–11 (CEA 2012b). There are states with AT&C losses between 30% and 40%, but there are also states with losses less than 20%.

State Government controlled power distribution companies had an accumulated loss of INR 1.9 lakh crore, as of March 31, 2011 and of INR 2.46 lakh crore, as of March 31, 2012. This has been primarily due to the non-revision of tariff, which increased the gap between the cost of supply and average tariff to INR 1.45 a unit in 2009–10 from INR 0.76 a unit in 1998–99 (PFC 2011).

Village electrification

As on March 31, 2012, a total of 5,57,439 villages, have been electrified. Nearly 36,293 villages are yet to be electrified in India. Eight states and five union territories in India have achieved 100% village electrification. However, the level of village electrification in some of the north-eastern states is still lower as compared to the other parts of the country.

Development of power eExchanges

With the advent of electricity exchanges in India since June 2008, power trading—earlier limited to bilateral contracts and Power Purchase Agreements (PPA)—has changed completely. Given the limitations of long-term bilateral contracts and banking arrangements

for meeting short-term power demand, power exchanges came as a solution to meet the short-term power demand at a price discovered through competitive bidding on electronic system. At present, there are two power exchanges operating in the country, the Indian Energy Exchange (IEX) and the Power Exchange India Ltd (PXIL). These exchanges are presently facilitating hourly day-ahead market contracts, weekly and monthly contracts for the term-ahead market, and contingency contracts. The volume of electricity traded through the power exchanges has increased by over five times from 2.77 BU in 2008–09 to 15.55 BU in 2011–12. In a move to boost the performance of power exchanges in the country, the Cabinet Committee on Economic Affairs has approved foreign investment of up to 49% in power exchanges. Of this, Foreign Direct Investment (FDI) should be limited to 26% and Foreign Institutional Investment (FII) should be limited to 23% of the paid-up capital.

International co-operation for power

The regional electricity market integration initiated with Nepal, Bangladesh, and Sri Lanka and the strengthening of the relationship with Bhutan through the umbrella agreement are important markers for regional energy security (see Box 1 for details).

With proactive government involvement in undertaking favourable policy amendments and increasing participation of private players, the future of the Indian power sector looks slightly more assured. However, as the Indian power sector is embarking on increasing its generation and transmission capacities, a number key challenges lies ahead that need to

BOX 1

- The Royal Government of Bhutan (RGoB) has embarked on a programme to harness over 10,000 MW hydro-power potential in its country by 2020. Under the MoU signed between RGoB and CEA relating to the preparation of National Transmission Grid Master Plan (NTGMP) for Bhutan, CEA as a consultant has prepared and submitted the final NTGMP report to RGoB in May 2012. The NTGMP report covers the associated transmission system for various upcoming hydro plants in Bhutan, system strengthening needs within Bhutan, transmission requirements to export surplus power of Bhutan to India, etc., corresponding to 2020 and 2030 time frame (CEA).
- The Government of India provided assistance to Nepal to implement four hydroelectric schemes, namely, Pokhara (1 MW), Trisuli (21 MW), Western Gandaki (15 MW), and Devighat (14.1 MW). In addition, a 130 km, 400 kV Muzzafarpur–Dhalkbar D/C line (to be operated at 220 kV) has been envisaged primarily for power trading between India and Nepal (CEA 2013a; PGCIL 2013)
- Inter-grid connection between India and Sri Lanka has seen significant progress. A Joint Venture Agreement between NTPC and Ceylon Electricity Board was signed on September 6, 2011 to set up a coal-based power project in Sri Lanka. Powergrid has already completed the feasibility study in the land route of Indian Territory as well as the sea route (Srinivasan and Mehdudia 2013).

be addressed. With ambitious capacity addition plans set for the 12th Plan, there is a need to understand the challenges being faced by the sub-sectors of generation, transmission, and distribution. Challenges persist with respect to site clearances, project execution, domestic fuel crunch, power equipment capacities, infrastructural constraints, problems in open access, AT&C losses, and fuel linkages. Also, other major constraints being faced by the power sector pertain to delays in environment clearances and other key inputs, such as land and water.

Key Issues

Generation

A review of the sector's past performances indicates that during the last three Five Year

Plans (9th, 10th, and 11th), there has been a shortfall in achievement of targets against planned targets. The capacity addition target set for the 11th Plan was 62,374 MW (targets as per the mid-term appraisal), and the capacity addition was 54,963.9 MW (CEA 2012a). However, the capacity addition achieved in the 11th Plan has been the highest—88% as compared to the previous plans—47.5% in the 9th Plan and 51.5% in the 10th Plan (Figure 9).

India's power generation capacity has significantly increased since the 10th Five Year Plan, and is also expected to show a strong growth in the future. The 11th Five Year Plan was one of the most successful plans implemented so far. The sector achieved a total capacity addition of approximately 53,922 MW (more than two and a half times that in the

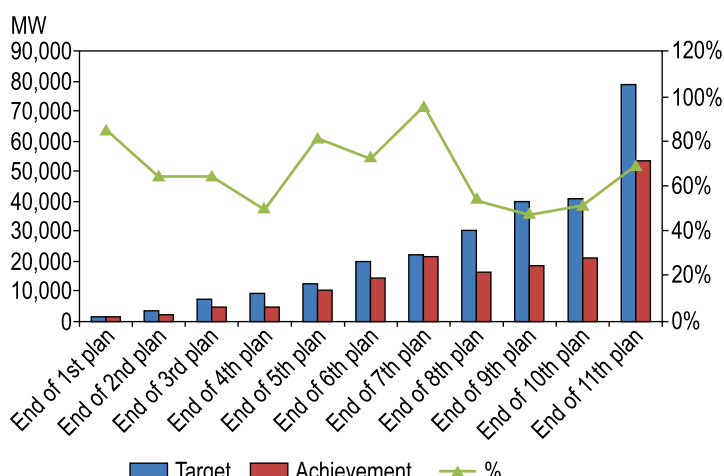


Figure 9: Planned v/s targets achieved in the Five Year Plans

Source: CEA 2012a

10th Plan), out of which close to 19,500 MW was added in the 2012/13 alone. Key issues affecting performance of the sector have been discussed below.

Shortage of fuel availability resulting in loss of generation

Due to shortage of fuel availability, the Plant Load Factor (PLF) of thermal power stations at the national level, has reduced to 73.32% during 2011–12 from 75.08% achieved during 2010–11. As per the provisional data of the CEA, the PLF of thermal power plants has further declined to 69.85% (April to January 2013) (CEA 2013). The lower PLF was due to increased generation loss due to coal supply problem and transmission constraints. Also, due to partial unavailability of the thermal generating units operating in the country during 2011–12, energy loss had increased to 9.43% of the maximum possible generation during the year, in comparison to the 9.34% in 2010–11 (CEA 2012c; Lok Sabha 2013).

Coal supply shortages

Domestic coal-based generation plants, which account for about 70% of the total coal requirement in the country, have been experiencing coal supply constraints and have lost generation. The coal shortages have occurred on account of factors such as constrained supplies from CIL—accounting for 85% of domestic coal supplies—and lack of progress in captive coal mining. Due to shortages of coal, power utilities have reported a generation loss of 11.7 BUs in 2012–13 (up to January 2013) (Lok Sabha 2013). Also, in the case of partial supplies from CIL, power producers have to either operate at a relatively low PLF or use expensive imported coal. The rising prices of imported coal—subject to political and legal uncertainties—have impacted the financial viability of the projects relying on imports.

Shortage of gas

Due to reduced availability of gas from the D6 block of the Krishna Godavari (KG) basin, existing power plants in the country are operating at low PLF. PLF level for all-India gas-based capacity has come down to 42.60% in April 2012 to January 2013 as against that from 61.25% in FY 2011–2012 (CEA 2013). According to the data released by the CEA, there has been electricity generation loss of 58.73 BU from gas-based power projects in the period April 2012 to January 2013. The fall is being attributed to the decline in natural gas supply from domestic sources witnessed in the last few years. Apart from the fall in generation from existing gas power plants, there are numerous projects that are not getting commissioned solely for want of gas. Several are already on the brink of being declared Non-Performing Assets (NPAs).

Given the uncertainty over supplies, only 1,086 MW of gas-based projects with linkages tied up with local sources have been planned for the 12th Five Year Plan. Another 13 GW of power projects, which are under construction, could be stranded if gas supply is not ensured. In this context, the central Government has advised project developers to not plan projects based on domestic gas till 2015–16 (Power Line 2012).

Infrastructure constraints

Growing demand and production rates have resulted in an increasing mismatch between coal production and rail capacity for coal evacuation (ICC 2009). This therefore results in delays in supply of coal and stock piling of coal at pitheads (of about

70 Mt in 2010–11), in turn increasing the overall costs. Thus, it is essential to have the requisite rail capacity to handle the high traffic.

Transmission

Planning and developing the transmission system has become increasingly complex over the years in view of opening up of the market and uncertainties in commissioning of the power plants. Main challenges are delay in forest clearance, right of way problems, and challenges in acquiring land for substations. These have been discussed in the following three sections.

Availability of Right of Way (RoW) as well as land

This is the most notable challenge that the transmission sector is facing today. There is thus a need to develop a high intensity transmission corridor (MW per metre RoW) in an environment-friendly manner.

Issues related to the large-scale integration of renewable energy

Owing to the variability in the nature of renewable energy generation and its potential sites lying in remote locations, there is a need for adequate transmission and other infrastructure to be built to ensure full evacuation of power generated at those remote sites to the grid. Since wind and solar plants installations have a lower gestation period (6–12 months) when compared to creating transmission infrastructure which typically takes 24–36 months, therefore, work on the transmission system has to be commenced well in advance. However, if the

renewable energy plant is delayed or scrapped, the transmission assets become stranded. Also, wind and solar plants have a low Capacity Utilization Factor (CUF) which leads to lower utilization of transmission infrastructure. Thus, the transmission cost per kWh for such infrastructure would be very high.

Uncertainty in generation capacity addition and load growth

Transmission projects are planned along with upcoming generation projects and any delay/mismatch in commissioning of associated evacuation lines may result in bottling up of power. For some of the transmission works, implementing agencies face challenges in completion of the task. Main challenges are delay in forest clearance, right of way problems, and challenges in acquiring land for substations as discussed.

Over all issues

Delays in obtaining clearances

■ **Generation sector:** Power plants and utilities also face major constraints and delays regarding the availability of land and obtaining the requisite environment and other clearances for the projects. Such

delays results in the increased financial burden to the developers. According to the Ministry of Power (MoP), about 55 projects amounting to 50,000 MW including two ultra-mega power projects—Sarguja UMPP in Chhattisgarh and Bedabahal UMPP in Odisha—have been impacted due to the above norms. Moreover, these UMPP projects as well as the additional UMPPs in Jharkhand have been facing delays in obtaining water linkage, besides issues in obtaining environmental and forest clearances (MoP 2012). Increasing environmental concerns are resulting in strong resistance to project development from the local population. In addition to these, delays in land acquisition have increased the financial burden of several projects.

■ **Transmission sector:** Forest clearance is a mandatory requirement for the portion of the line traversing through the forest. During first four years of the 11th Plan, i.e., 2007–11, about 60 transmission line projects (220 kV and above) under execution had faced major forest clearance problems by implementing agencies (CEA 2012e).

Chapter 4

Nuclear Energy

KEY ISSUES

Issues in exploitation of domestic uranium resources

- There are varying estimates about the extent of availability of uranium resources in India. In addition, due to the low grade of uranium ore in India, the techno-economic feasibility of extracting these deposits is also questioned.
- There have also been several delays in commissioning new uranium mines, and sometimes even prospecting for more deposits due to public protests and problems in land acquisition.

Increase in import dependency with increase in domestic nuclear generation capacity

Constraints in imported fuel

To support higher plant load factors for domestic reactors under safeguards, and future expansion, India's dependency on imported fuel will increase and this may expose it to international fuel market variability and geopolitics of nuclear energy.

Constraints of imported technology

- Cost of imported technology is much higher than domestic technology, making it an expensive option; the recent depreciation of the Rupee escalates the expenses even further.
- Concerns have been raised by the domestic and international nuclear industry and also civil society on the Civil Liability for Nuclear Damages Act. The industry has critical issues with its extent of coverage (supplier's liability) and ambiguity on who all get covered under this. The public has concerns that the Government will dilute the law for the benefit of the industry.
- Imported reactors are being procured based on an agreement that India will not undertake any nuclear testing in future. In case it does, there will be disruption in respect of fuel supply and technical support for the imported reactors.

Delays in achieving targets

There is substantial deficit in the targets of capacity addition and achievements of nuclear power, due to various reasons such as technological issues, availability of fuel (especially before Nuclear Supplier Group (NSG) clearance), public protests, delays in land acquisition, etc. According to the expansion plans of the Indian nuclear energy sector, Fast Breeder Reactors (FBR) programmes are projected to play a bigger role in India's nuclear future. However, there have been major delays in commissioning the prototype. In addition, the history of unsatisfactory development of FBRs globally leads to safety concerns about this technology; this might necessitate closer monitoring of the prototype post commissioning and gaining additional operating experience domestically before commercialization.

Land issues

Delays in commissioning of new projects—expansion and green field—due to public protests in acquiring land for uranium mining and construction of nuclear power plants.

Public perception

Strong negative perceptions about nuclear energy and the impact of radiation on the environment, human, and animal health. In the aftermath of Fukushima, this fear has only increased and has led to stronger public protests.

Need for an independent regulator

The absence of a financially, administratively, and statutorily independent regulator has led several to raise questions about the credibility of Atomic Energy Regulatory Board (AERB).

Overview

The nuclear industry in India has seen increased activity in the recent past and the voices from both the proponents of nuclear energy and the sceptics have gotten stronger. The Indo-US nuclear deal, the

distinction between civil and military facilities, International Atomic Energy Agency (IAEA) safeguards for specific reactors (classified for civil use), the clearance from the Nuclear Suppliers Group (NSG),⁹ the opening up of Indian nuclear market for foreign investment

⁹ The Nuclear Suppliers Group is multi-national body established in 1974 by seven nuclear supplier states in response to India's nuclear weapon test. The group was formed to supplement nuclear non-proliferation by controlling the export and re-transfer of nuclear and nuclear-related materials which may be applicable to nuclear weapon development. It works to improve safeguards and protections for the existing materials. It requires adherence to the Non-Proliferation Treaty (NPT), which India has not signed. According to the treaty, India is a non-nuclear-weapon State. The nuclear club of nuclear-weapon States includes only those countries which had tested before 1967 (cut-off of the NPT) viz. United States of America, United Kingdom, Russia, France, and China.

are all important developments in this sector. This openness, however, also coincided with the Fukushima accident which has led to a slowdown of the growth of civilian nuclear power and has prompted a rethink on the continuance of nuclear-based energy in many countries. Nuclear industry globally is under greater scrutiny and even nationally, the hitherto opaque box of nuclear energy sector is opening up to greater public inspection.

In the backdrop of India's ambitions of civilian nuclear power, this changing scenario, both globally and nationally, is bound to throw up energy security challenges.

Key Issues

Exploitation of domestic resources

Availability

India is considered to have low deposits of uranium with a low-grade ore. According to Chaki, Purohit, and Mamallan (2010), India has around 80,000 tonnes of established uranium reserves while the Atomic and Minerals Directorate under the Department of Atomic Energy (DAE) has identified around 184,964 tonnes¹⁰ of in situ uranium reserves (Lok Sabha Question 379 2012). This deposit is almost equivalent to India's total reserves discovered till date. However, stakeholder consultations show some concerns over the economic as well as the technical feasibility of mining these reserves. This is echoed by Gupta and Sarangi (2010) who state that the "efforts to mine and process progressively lower

grade ore does not record a matching rise in uranium production capacity". According to them, often, the identified resources cannot be commercially mined and several techno-economic factors need to be taken into consideration. The location of some of these resources in ecologically sensitive zone also causes an issue in getting MoEF clearances.

Currently, only the mines in Jharkhand and Tummalapalle — and in Andhra Pradesh since 2012 — are producing uranium. Since the NSG clearance,¹¹ 9 out of the 19 operating reactors in India, which are under IAEA safeguards, are fuelled by imported uranium while requirements of the rest are met from domestic fuel. The latter have been operating between 68% and 100% of their available capacity due to insufficient supply of domestic fuel (Lok Sabha Question 2296 2011). "A 220 MWe plant requires 45 tonnes of uranium per year, a 540 MWe plant needs 80 tonnes and a 700 MWe plant requires 100 tonnes per year" (Ghosh 2011). Thus, if we consider 80,000 tonnes as the available domestic resources, these will be sufficient to supply around 14 reactors of 700 MWe for roughly 60 years (without accounting for losses incurred in mining, milling, and fabrication).

Reports state that production from the existing mines has been stepped up; however, this is not sufficient. Unless production begins at other identified areas of the yellow cake (uranium) as well, the plants supplied with domestic fuel will continue to function at a lower capacity. The alternative

¹⁰ RAR and inferred

¹¹ In 2008, NSG gave a waiver to India to engage with nuclear supplying countries, making an exception to its rule of adherence to the Non-Proliferation Treaty. For a chronology of events and brief background, see, ExpressIndia (2008)

is to bring more reactors under safeguards to ensure better fuel supply. But, this will further increase our import dependence in addition to other issues (discussed in the next section). Here, strategic considerations also become paramount.

Commissioning of new uranium mines has also been stalled due to public protests at several sites and difficulty in land acquisition. This has also contributed to stagnating production. Figure 10 shows the location of identified uranium deposits.

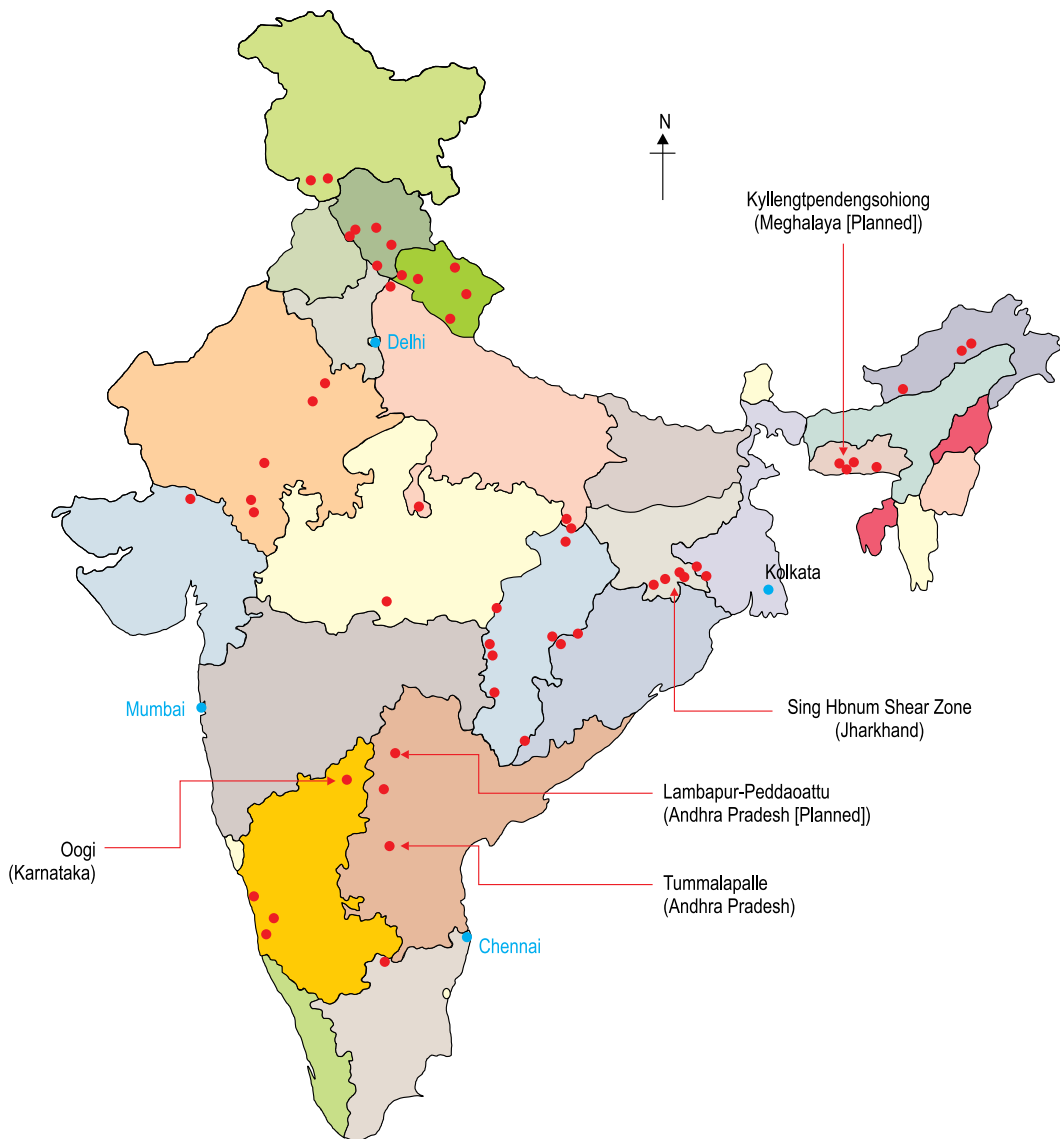


Figure 10: Identified Uranium Deposits: India
 Source: Uranium Corporation of India Ltd (2013)

Increasing imports

Till a few years ago, the Indian nuclear establishment was almost isolated from the world nuclear industry with limited engagements restricted to a couple of countries. However, this has slowly started changing with the signing of the IAEA's safeguard agreement (Application of Safeguards to Civilian Nuclear Facilities) in 2009 and the subsequent NSG clearance. India can now enter into agreements with member countries to import fuel and/or technologies, both of which will be required to expand India's nuclear programme. India has, since, signed civil nuclear agreements with USA, France, Russia, Kazakhstan, Namibia, South Korea, the UK, Mongolia, Canada, and Argentina.

However, some key issues will arise from increase in imports.

Import of fuel

Planned increase in nuclear facilities will lead to an increase in imports of uranium—so far, we have fuel supply agreements with only five countries. Since India has not signed the NPT, the basket of countries it can import fuel and technology from reduces. India has to individually negotiate contracts with nuclear supplier countries, some of which may have reservations about supplying to a non-NPT country; for instance, the initial resistance in Australia.

Imported fuel can only be used in those reactors which have been placed under the IAEA safeguards, thus leaving the ones

outside the purview, dependent on limited domestic supply. Further, spent fuel from such sources can be reprocessed only if a reprocessing plant is put under safeguards. This has been stipulated in the NSG clearance as well. Discussions are also underway to consider having a dedicated reprocessing unit for imported fuel under safeguards as per the terms of the India–US civil nuclear agreement.

Import of technology

For the initial stages, India plans to supplement the planned increase in electricity generation from nuclear energy with imported reactors as well. The long-term view, however, is that of indigenization, based on the success of the 2nd and 3rd stages of India's three-stage Nuclear Programme.¹² India has signed agreements with Russia, France, and the USA so far to help achieve this. Each of these imported reactors will come with an assured, lifetime (life of the reactor) fuel-supply guarantee. This fuel-supply guarantee agreement, linked with reactor import, helps secure the country from supply disruptions. However, the decision to import technology has led to a number of issues and debates from different sectors of the society—from realist hardliners who believe that increasing imported technology will compromise our nuclear programme to those who are more suspect of the 'political costs' of the imported technology. Some of the crucial issues related to import of reactors which have wide ranging effects are discussed in the two sub-sections that follow.

¹² India follows a three-stage nuclear programme. Stage 1—PHWRs (Pressurised Heavy Water Reactors); Stage 2—FBRs (Fast Breeder Reactors); Stage 3—AHWRs (Advanced Heavy Water Reactors) which are thorium-based.

Cost of imported reactors¹³

Import of uranium is relatively inexpensive; however, this is not the case with imported reactors. A domestic 700 MWe PHWR is estimated to cost around INR 5 crore per megawatt (Rajya Sabha Question 1247 2012) While the imported ones will easily cost more than triple. The Kundankulam 1 and 2 reactors from Russia cost around INR 16 crore/MWe (Bharadwaj, Rajgopal, Krishnan, and Bellarmine 2012). The Civil Liability for Nuclear Damages Law passed by India could also lead to an increase in costs. The cost of the next two reactors is estimated to double. The highest estimate for the Areva reactors is between INR 21 crore per megawatt (US\$3,860/kWe for the reactor at Flamanville, France) (OECD 2010, p.59) and INR 36 crore per megawatt (8.5 billion euros—the estimate of similar reactors being built at Finland)¹⁴ (Ramana & Raju, 2013).¹⁵ This enormous cost difference between domestic and imported reactors has often been criticized and is seen as a political cost for allowing India access to the international nuclear market. Delays are expected on cost negotiations both because of the extent of India's willingness and ability to pay. The depreciation of the Indian Rupee in the recent past has further pushed up the costs of these already expensive reactors.

Liability law

Another major reason for delay could be the apprehensions of foreign companies (some

more vocal and less hesitant than others) to engage with India till they receive more clarity on the 'Liability law'.

The law allows operators to hold the suppliers liable to a maximum limit of INR 1,500 crore—if it is found that an accident/incident took place because of a fault with the equipment. However, the opinion on the nuclear liability has been fractured. Within India, this law has caused a lot of debate due to the limitation on the period of claim and the ceiling, i.e., cost of the instrument, put on the total possible claim by the operator. Many are of the opinion that there should be no limit on the damage claims. An amendment seeking changes to the law has also been moved by the Communist Party of India (Marxist)¹⁶ (Jacob 2012), which is yet to be debated. In 2012, a parliamentary panel also strongly recommended against capping the liability amount and added that victims of a nuclear accident could seek a judicial review if dissatisfied with the compensation amount (Koshy 2012).

On the other hand, suppliers have raised concerns regarding the supplier's liability. Many of the negotiations on the imported reactors have stalled on this point. As seen in the case of the Russian reactors, the next two which would be included in the liability law are expected to cost more. While the Government has steadfastly stood by its liability law, the outcome of the amendment will be awaited by the suppliers. Till such time, it is possible that

¹³ All costs of reactors quoted in this section are overnight costs unless stated otherwise

¹⁴ It is unclear whether this number is an indication of the overnight costs or escalated costs. However, there have been significant changes in the reactor design post Fukushima which have greatly increased the costs

¹⁵ Conversion rate: Euro 1 = INR 70; \$1 = INR 54

¹⁶ Sitaram Yechury and K N Balagopal

negotiations for most planned international reactors will be stuck on this point. Concerns have been raised about the possibility of meeting the targets of increased capacity from imported reactors.

Another major issue with the liability law is the lack of clarity over the vendor's liability, i.e., manufacturers of small and high precision equipment that supply parts and components to companies which make the reactors. The debate on this issue is on-going with some interpreting the law to mean that vendors' liability exists and the DAE stating that it doesn't. Lack of clarity on this has also caused some consternation amongst the vendors.

Strings attached

Use of imported fuel and technology comes with additional conditions. Imported fuel and reactors are procured on an agreement that India will not undertake any nuclear weapons testing in the future. In case it does, there will be a complete supply disruption of both support and technical support. Also, imported fuel and technology can only be used for civilian purposes (reactors under safeguards). The spent fuel from such reactors as well as the imported reactors has to be accounted for. Further use of this spent fuel also has to be in facilities under safeguards as well (reprocessing units, and subsequent reactors which will use the fuel) with no room for diversion. This could affect India's expansion plans, particularly of the FBR which are currently classified under military use, unless more reactors are bought under civilian use.

Delays in achieving targets

It has been almost 40 years since the first commercial nuclear reactor was commissioned in Tarapur. However, since then, one of the criticisms against the Indian nuclear industry has been its inability to deliver on the promised potential, precipitated by a host of reasons, such as technological issues leading to delays, availability of fuel, etc. In the envisaged three-stage programme, however, only the first stage has been implemented successfully. The first prototype of the fast breeder reactor of the second stage is expected to start operations in 2013, while site identification for the third-stage reactor is targeted to be undertaken in the 12th Five Year Plan.

Table 8 shows the target for capacity addition for nuclear and actual achievement in the 11th Five Year Plan.

As per Grover and Chandra (2006) and the Integrate Energy Policy of 2006 (Planning Commission 2006), the estimate for 2010–11 was 11 GW, while around 5 GW¹⁷ was achieved. This gap between the targets and achievements needs to reduce, to enhance energy security and lessen the uncertainty of the ability to deliver of the sector. The 12th

Table 8: Capacity addition target and achievement

Year	Target (MW)	Actual Achievement (MW)
2007–08	660	220
2008–09	660	0
2009–10	660	440
2010–11	1,220	220

Source: Ministry of Power 2012

¹⁷ 4.78 GW

Five Year plan has set a target of 10 GW by 2017 (Lok Sabha Question 192 2011).

FBR technology

FBR technology plays a major role in the plans of India's nuclear future. The projections made by Grover and Chandra (2006) assume that by 2052, India will have around 275 GW of nuclear power, of which FBRs would contribute around 262.5 GW. Even if these targets are revised, it still remains that India's nuclear power future will see a major role of the FBR technology. However, stakeholder consultations have revealed grave reservations about the performance of this technology.

The global history of the breeder reactor, however, has not been very encouraging. There are only two countries where fast breeders are still operational, viz Japan and Russia. All others have shut it down. Several reasons were identified through stakeholder discussions and literature. One of the reasons was that these reactors were costly to build and operate; it was hoped that they would eventually become as competitive as the light water reactors. In the case of India, as compared to imported light water reactors, the cost estimates of FBRs are significantly lower. However, it is difficult to estimate the operational costs over the period of time. The Governments of Organisation for Economic Co-operation and Development (OECD) countries have reportedly spent around \$50 billion on fission and breeder reactor research and development (Hippel 2010). Literature suggests that breeder reactors will also not be economical till uranium prices see an astronomical increase.

Another problem which was referred to often was that fast-neutron reactors have special safety problems primarily due to the liquid sodium coolant used. While it has safety advantage when used in fast breeders, the major disadvantage is that it reacts violently with water and burns if exposed to air. Thus, any leaks can lead to a major sodium–water fire (Hippel 2010; Stakeholder Consultations 2013). France's Rapsodie, Phénix, Superphénix; Dounreay Fast Reactor and Prototype Fast Reactor in the UK; and Japan's Monju all suffered sodium leaks resulting in fires. The fire at the Japanese reactor took place in 1995 but its restart was frequently delayed. In addition, international experience with sodium-cooled reactors has also shown major reliability problems.

Further, the capacity of the reactor has also been raised as a concern by few. Most global experiences have been on a much smaller scale. The only reactor operating which is a little bigger (600 MWe) than India's prototype (500 MWe), is in Russia. France had tried to upgrade its Phénix (250 MWe) to Superphénix (1,240 MWe) but this too was shut down for numerous reasons (Schneider 2010). Superphénix had seen opposition both from the civil society as well as scientists.

For India to fulfil its ambitious nuclear programme, the fast breeders will have to be scaled-up in size. Historical experience so far has shown this to be unsuccessful.

Land issues

Land acquisition for future projects, especially Greenfield ones, have encountered severe protests resulting in delays. While it is

important to note that several infrastructural projects have faced protests in land acquisition due to socio-economic and political reasons, the protests associated with sites for nuclear power plants or uranium sites also have associated perception challenges. The methods used for land acquisition by the state have also been questioned (as in the case of Jaitapur where Section 144 was applied, banning public gatherings or meetings).

One of the main obstacles in fully exploiting the available domestic uranium reserves have been public protests. Deposits have been identified in certain parts of Meghalaya, but the Khasi Students Union have opposed any developmental work initiated by Uranium Corporation of India Limited (UCIL) in this area (*India Today* 2009). There have been continuous protests to stop any mining-related activity by UCIL there. While down south, villagers in the Mahbubnagar district, Andhra Pradesh, had objections to even aerial survey of the villages to estimate the extent of deposits (Vadlapatla 2012). Similar protests and resultant delays have been seen at various locations where uranium reserves have been identified. The two key reasons for protest at these sites have been the possible health impacts of radiation on the inhabitants around these mines as well as the workers; and concerns related to loss of land and livelihood. These protests are likely to have an impact on the construction and commissioning of plants as well leading to delays. Public engagement by Government officials and the nuclear sector has been insufficient in most areas; in addition, many of these protests have also been dealt with

strongly by the use of force in some places, for instance in Kudankulam and Jaitapur.

Public perception

For the Indian nuclear industry, certain aspects, such as access to international markets, better domestic power evacuation facilities (though these need to be augmented further) have improved; however, there has been a rise in public perception against nuclear power.

Globally, the safety apprehensions of nuclear power have increased; these have also been a catalyst for increased protests in India. The fear of radiation, unknown consequences of a complete or even a partial meltdown, the extent of potential damage to life and property, and long-term waste management are the main catalysts for the negative perception regarding nuclear power generation. These voices have grown post-Fukushima. Two years after the accident, while some countries have restarted or announced plans to return to nuclear, and some continue to forge ahead, the apprehension among people still remains strong.

Absence of an independent regulator

The perceived lack of independence of the regulator and the historical opacity of the sector has also been an important concern regarding the sector. While many argue that the revolving doors within the nuclear industry makes it weaker because of institutional protection, others argue on the merits of having people who understand the strengths and weaknesses of the technology as a part of the regulatory body. However, a close relation between the regulated and the regulator can

lead to problems. In addition to the earthquake which triggered the tsunami and the failure of the back-up power which led to the core melt-down, many commentators and analysts also point out, "The close ties between public regulators and the private plant operators could have led them to collude and neglect safety and other features that could have been built into the design of the plant and affected responses to the accident and the timing and transparency of information released. (Srinivasan, Rethinaraj, and Sethi 2012)"

The decoupling of the military and civil use of nuclear power in India, according to many, has translated into some amount of openness but not as much as one would expect. The *CAG Report* (2012) has raised questions about the legal status of the AERB itself. This has led to several being suspect of the decisions

and approvals of the regulator, as well as the numbers and information coming out of the industry. On the other hand, many others are of the opinion that the regulator has been quite effective, and the absence of any major accidents in India is the proof of this; but nonetheless a legal separation is imperative. A draft legislation titled, 'Nuclear Safety Regulatory Authority Act', is under consideration in the Parliament to bring about greater independence of the regulator. It is also seen necessary to staff the regulatory body with people from outside the nuclear establishment which is, often, seen to have revolving doors. However, the major challenge for this has been the availability of people with the relevant experience outside the system to hold such a post (Stakeholder Consultations 2013).

Chapter 5

Renewable Energy

KEY ISSUES

Regulatory Issues

Absence of a unified law governing the sector and presence of multiple implementing agencies

There is no unified law that governs the development of the renewable energy sector in India; instead, there are several laws, regulations, and agencies that govern the renewable energy sector. There are several institutions empowered under different laws which often lack coordination leading to implementation gaps.

Land acquisition

Acquisition of land is also a critical aspect for infrastructure development and the approval processes and inability of the state governments to provide an effective single-window clearance to developers has caused further challenges.

Policy uncertainty

Another key challenge faced by the renewable energy market in India is the degree of uncertainty surrounding the enforcements of Renewable Purchase Obligations (RPOs). The RPOs are fixed and enforced at the state level, and though most states have RPOs, they are not actively enforcing them.

Visibility of Renewable Energy Certificate (REC) prices

The REC mechanism needs to gain more momentum in India. So far, lack of RPO enforcement and the uncertainty surrounding the price of the REC beyond 2017 has not helped its growth. Clarity on long-term pricing of RECs, would make it easier for REC projects to obtain financing, thus inducing more players to enter this sector. Unless, there is visibility on prices, investors will continue to be hesitant to invest.

Inadequate long-term funding sources

Renewable energy developers have difficulty in obtaining financing at rates comparable to those for conventional energy facilities. High financing costs are a significant barrier as renewable power plants generally require relatively higher initial investments as compared to fossil fuel plants, even though they have lower operating costs.

Policy dependent

Renewable energy continues to be policy-dependent rather than being adequately market-driven. Policies have been set up by the Government to ensure that renewable energy contributes substantially to the increase in overall energy and power demand in the future.

Issues Related to Support Infrastructure

Lack of evacuation facilities

The lack of adequate evacuation infrastructure and grid interconnections is one of the biggest barriers to harnessing the renewable energy potential, which remains untapped because of lack of adequate grid evacuation capacity. Grid evacuation infrastructure is critical to the success of both large projects that sell power generated to the grid and small distributed-generation projects for which access to the grid improves financial viability and reduces risks of projects by acting as a reliable back-up.

Lack of good-quality data on resource assessment

Lack of good-quality resource assessment data is a significant problem. A number of state nodal agencies are not able to establish and maintain a technical library, a data bank, or an information centre or collect and correlate information regarding renewable energy sources.

Lack of forecasting and scheduling

The high variability of renewable power generation makes forecasting and scheduling critical for maintaining the reliability of the grid. Improving the accuracy and reliability of forecasts is critical for increased penetration of renewable energy.

Energy storage

There is a need to balance the impact of variability of renewable energy in the grid. With greater penetration of renewable generation and its increasing share in the generation mix, the ability of conventional resources to compensate renewable energy's variability will decrease, requiring the storage of electricity generated by wind, solar, and other renewables for later use. Although such technologies are available, the challenge lies in large-scale implementation, costs, technology suitability, and lack of regulatory interventions for implementing systems.

Overview

Renewable energy technologies utilize energy that comes from resources which are continually replenished and will never run out; such as sunlight, wind, biomass, hydel, geothermal heat, ocean energy, etc., (NREL 2012). The worldwide growth of renewable energy began in the 1990s and accelerated greatly in the 2000s. By 2011, global investments in renewable energy reached US\$ 260 billion annually. India's investment requirement in renewable energy would be in the range of at least US\$ 50 billion in the next five years alone (NREL 2012). Growth in renewable energy has been due to supportive government policies, rising costs of conventional energy, reductions in renewable energy technology costs, and economies of scale in manufacturing. Development of renewable energy also results in increased energy security, climate change mitigation,

creation of jobs, industrial development, and increased energy access. Renewable energy technologies find off-grid and on-grid applications. Renewable energy applications are continuing to grow in end-use sectors, such as heating/cooling, transport, and power.

Grid-connected renewable energy

India has around 28 GW of installed renewable energy capacity, about 14% of the total installed capacity. In the year 2011–12, the total gross grid-integrated renewable energy generation was around 51,226 Million Units (MU) which is about 5.52% of total generation of 928,113 MU (CEA 2012). The renewable energy technologies that are being developed for grid-connected, large scale applications are solar power, wind (on-shore) power, biomass power, and small hydro power. So far, wind power installations account for the highest installed capacity among all the renewable energy technologies in India. Figure 11 is a chart showing the

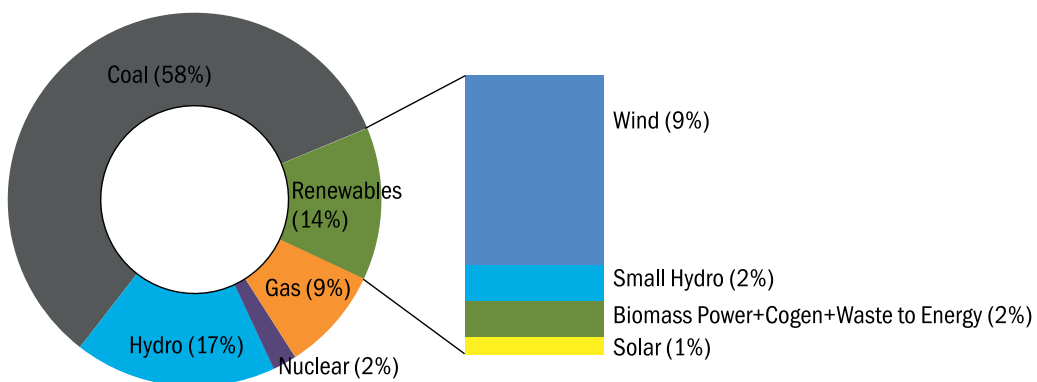


Figure 11: Renewable energy installed capacity

Source: MoP 2013 and MNRE 2013

installed capacities of various renewable energy technologies and share of renewable energy in the total installed capacity in India.

With each Five Year Plan of India, renewable energy capacity as well as capacity addition targets have been increasing.¹⁸ The capacity addition targets for renewables have so far been met and exceeded. The 12th plan targets are more than double the 11th plan target and the next Five years will see the largest additions to the renewable energy sector yet. Figure 12 shows the cumulative capacity additions after each Five Year Plan beginning with the 9th Plan.

Off-grid renewable energy

Off-grid renewable energy consists of distributed/decentralized renewable power

projects using wind energy, biomass energy, hydro power, solar energy, and hybrid systems which are being established in the country to meet the energy requirements of isolated communities and in areas that are not likely to be electrified in near future (Table 9).

Policy and Regulatory Environment for Renewable Energy in India

General legal and policy initiatives

Supportive government policies are critical to the development of the renewable energy industry. The major policies that have influenced the development of renewable energy in India are mentioned below:

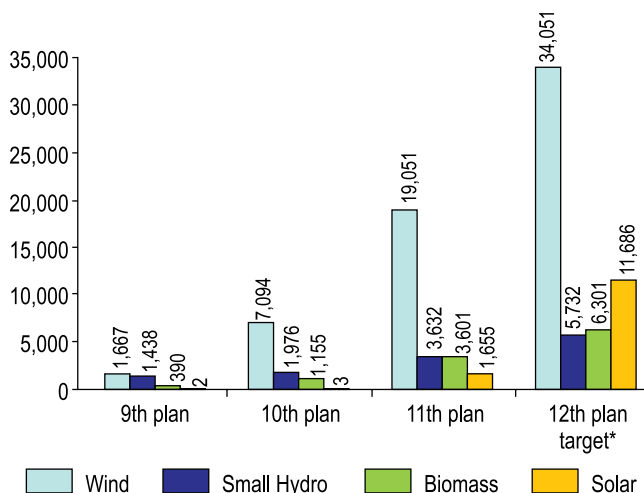


Figure 12: Cumulative renewable energy capacity (MW) that existed at the completion of each five year plans

Note: Indicates expected capacity addition at the end of the XIIth plan
Source: MNRE¹⁹

¹⁸ The 11th plan target was 14,000 MW whereas 14,660 MW was added. The target set for the ongoing 12th plan is 29,800 MW, of which 15,000 MW is to be wind power; 10,000 MW solar power; 2,100MW small-hydro power and 2,700 MW bio-power (including waste to energy). Available at <http://pib.nic.in/newsite/PrintRelease.aspx?relid=95249>

¹⁹ Compilation of information from Strategic plan for new and renewable energy sector for the period 2011–17, MNRE.

Table 9: Off-grid renewable energy in India		
Off-grid/captive power technology	Sub-classification	MW equivalent
Waste to Energy	Urban	132.7
	Industrial	-
Biomass (non-bagasse) Cogeneration		531
Biomass Gasifiers	Rural	17.5
	Industrial	147.2
Aero-Generators/Hybrid systems		2.3
SPV Systems (>1 kW)		174.4
Water mills/micro hydel		13.21
Bio-gas based energy system		2,643 Nos.
		3.77
	Total	1,022.8
Other renewable energy systems		
Family Biogas Plants (No. in lakhs)		47.4
Solar Water Heating - Coll. Areas (Million m ²)		8.1
Source: MNRE 2013a		

- **Electricity Act 2003:** The Act has set stage for competition and private investment by de-licensing generation and providing open-access in the Indian power sector. The legislation was important for renewables as it allowed the state-level commissions to promote generation of electricity from renewable sources. It also introduced some provisions that were conducive for accelerated development of grid-connected renewables.
- **National Electricity Policy (NEP) 2005:** The Policy stipulates that the share of electricity from non-conventional sources would progressively need to be increased. It also specifies preferential feed-in-tariffs for renewable energy to help them compete with conventional sources, in terms of costs. The Central Electricity

Regulatory Commission (CERC) is required to determine preferential tariffs to promote these technologies.

- **National Tariff Policy (NTP) 2006:** The NTP 2006 mandates that SERCs purchase a minimum percentage of energy from renewable sources, taking into account the availability of such resources in the region and its impact on retail tariffs. The Renewable Purchase Obligations (RPO) system was implemented in 2010 to aid in achieving the National Action Plan for Climate Change (NAPCC) target of 15% of the total power requirement being supplied from renewable energy sources by 2020. Within this 15%, there is a solar power purchase obligation of 0.25% in Phase 1; going up to 3% by 2022. To meet obligations, state utilities can also

purchase Renewable Energy Certificates (RECs) from participating projects. This policy further elaborates the role of regulatory commissions, the mechanism for promoting renewable energy, the time frame for implementation, etc.

■ **Integrated Energy Policy (IEP) 2006:**

The Policy recognizes and emphasizes the importance of renewable energy to meet the energy demands of our country. The broad vision behind the IEP is to consistently meet the demand for energy services of all sectors. These include the lifeline energy needs of vulnerable households in all parts of India with safe, clean, and convenient energy at the least-cost.

■ **National Clean Energy Fund (NCEF):**

In the Union Budget 2010–11, the then Finance Minister proposed to levy a cess on coal consumed in the country, the revenues from which will go towards the creation of a fund for research and innovative projects in clean energy technology. The clean energy cess of INR 50 per MT will be levied on all coal, lignite, and peat produced in India. This tax will be levied on all overseas imports.

■ **Indian Electricity Grid Code (IEGC) 2010:**

The IEG Code 2010 is another central enactment. Though not exactly a sector booster it is an enforcement that supports the integration of renewable sources energy into the Grid.

■ **Planning Commission sets up Expert Group on Strategy for Low Carbon Economy:**

Led by the Planning Commission of India, this 26-member group has been set up to prepare a strategy for low a carbon economy in India.

■ **National Action Plan on Climate Change (NAPCC):**

The NAPCC announced by the then Prime Minister's Council on Climate Change was notified in June 2008. As per the NAPCC, renewable electricity injection into the National Grid had been set at 5% at the beginning of FY 2009–10, increasing at 1% per annum in subsequent years to reach 15% by the end of FY 2019–20.

■ **Jawaharlal Nehru National Solar Mission (JNNSM):**

As a part of the eight National Missions announced under the NAPCC, the JNNSM (announced in 2009) aims to promote the development of solar energy for grid-connected and off-grid power generation. The definitive objective is to make solar power competitive with fossil-based applications by 2022. The JNNSM aims to create an enabling policy framework in 3 phases for the deployment of 20,000 MW of solar power by 2022.

Along with the policy support mentioned above, the regulatory framework created for renewable energy includes fiscal and monetary incentives from various agencies both at the central and state level. A chart showing the broad incentive framework in India is summarized in Figure 13.

Renewable energy technologies

Solar

Resource and potential

Solar energy is considered as the most abundant of all renewable energy resources in India. According to the Ministry of New and Renewable Energy (MNRE), the average

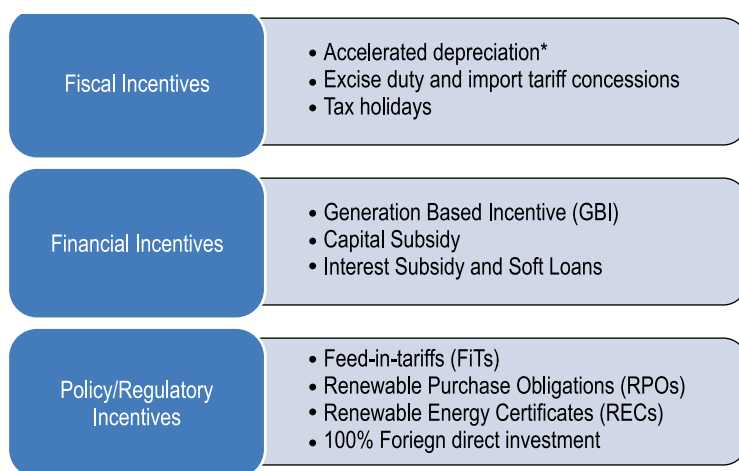


Figure 13: The incentive framework available for renewable energy

Note: As it stands, the Government has removed Accelerated Depreciation for wind projects

Source: TERI compilation

irradiance over the country is between 4–7 kWh/m²/day giving an average potential of 20–30 MW/m². Table 10 shows solar resource estimations by MNRE and the Planning Commission. It has been observed that wind and solar potentials are mainly confined in southern and western states, such as Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, and Rajasthan.

Solar radiation has two components—the Global Horizontal Irradiance (GHI) and the Direct Normal Irradiance (DNI). Adequate GHI is required for the functioning of Solar PV technology, whereas DNI is required for Concentrating Solar Power (CSP). Figure 14

shows solar resource (DNI and GHI) availability in India, marking various ‘solar zones’.

In terms of land requirement, literature review suggests that the land area required per MW of installed solar power is around 20,234 m² (approx. 2 ha) (Mitavachan & Srinivasan, 2012). Solar power can also be harnessed through rooftop solar installations. In a recent report, Bridge to India claims that 31 km² or 4.42% of Delhi’s rooftop space is available for PV systems. This translates to a solar potential of 2,557 MW in Delhi alone (Bridge to India, 2013).

India has a vast potential for solar power generation as 1.89 million km² (58% of total land area of 3.28 million km²) of land receives

Table 10: Overall solar resource assessments

Source	Estimated Potential (GW)
MNRE	Average irradiance over the country is between 4–7 kWh/m ² /day giving an average potential of 20–30 MW/m ²
Planning Commission	Deploying solar on 1% of the land area could result in over 500,000 MW of solar power

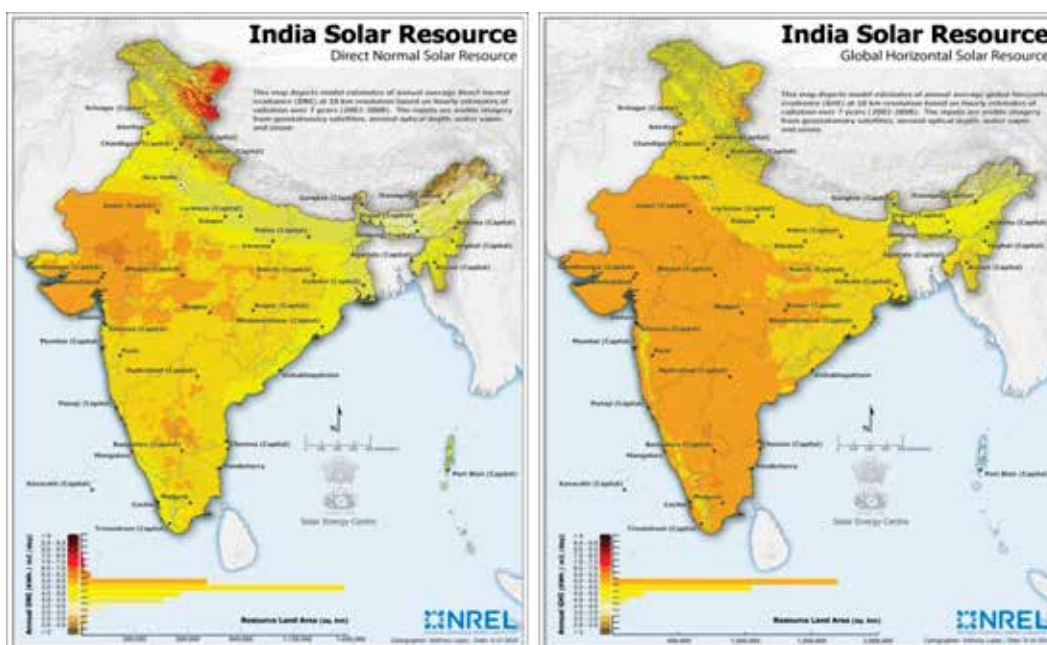


Figure 14: Solar resource maps

Source: MNREa

average global insolation above 5 kWh/m²/day (Ramachandra, Jain, & Krishnadas 2011). However, residential, agricultural, and industrial demands on land are priorities for land use and thus only barren land is used for solar power. Recent land use statistics highlight the availability of barren or uncultivable land in many states as shown in Table 11.

Solar Photovoltaic²⁰

Present status in India

Over the past decades, Photovoltaic (PV) technology has been constantly improving its performance and reducing costs and PV

power is expanding very rapidly in with the support of Governmental incentives and is becoming more competitive and catching up with conventional power sources. Current commercial PV technologies include wafer-based crystalline silicon, either single-crystalline or multi-crystalline silicon (c-Si) and thin-films (TF), i.e., amorphous silicon, cadmium-telluride, and copper indium thin films. The c-Si technology accounts for 80% of the market and TF for the remaining 20%. Though lower than the share of c-Si, the share of TF is increasing due to the lower costs of production (IEA 2011).

²⁰ Solar Photovoltaic (SPV) directly converts solar energy into electricity using a PV cell made of a semiconductor material. It works on the photoelectric effect. PV cells are assembled into modules to build modular PV systems that are used to generate electricity in both grid-connected and off-grid applications, e.g., residential and commercial buildings, industrial facilities, rural and remote areas, and power plants (utility PV systems).

Table 11: Area of barren or uncultivable land in representative states of identified solar hotspots in India

State/Union Territory	Total area (1,000 Ha)	Barren or Uncultivable land (1,000 Ha)	%
Andhra Pradesh	27,505	2,056	7%
Bihar	9,360	432	5%
Chhattisgarh	13,790	308	2%
Goa	361	0	0%
Gujarat	18,866	2,595	14%
Haryana	4,371	103	2%
Himachal Pradesh	4,548	656	14%
Jammu Kashmir	3,781	288	8%
Karnataka	19,050	788	4%
Kerala	3,886	25	1%
Madhya Pradesh	30,756	1,351	4%
Maharashtra	30,758	1718	6%
Punjab	5,033	24	0%
Rajasthan	34,270	2,295	7%
Sikkim	723	107	15%
Tamil Nadu	13,027	492	4%
Uttarakhand	5,673	224	4%
Uttar Pradesh	24,170	507	2%
West Bengal	8684	21	0%
Chandigarh	7	0	0%
Delhi	147	16	11%

Source: Ramachandra, Jain and Krishnadas 2011, citing Ministry of Agriculture

By March 2013, grid-connected PV systems in India reached 1,686 MW. Initial developments in Solar PV (SPV) plants were based on fixed feed-in-tariff and Generation- Based Incentive (GBI) scheme. However, during the first phase of the JNNSM

(500 MW of grid-connected PV) reverse bidding emerged as mechanism to award projects (where projects were awarded to the lowest bidder quoting the lowest tariff). Solar PV was bid out in two batches of 150 MW and 350 MW. The lowest tariff discovered in the first batch for SPV project was INR 10.95/kWh, whereas the CERC suggested tariff was INR 17.91. During Batch II, the average tariff discovered was INR 8.77/kWh. (MNRE 2012). State-level solar policies have been emerging lately and though states, such as Andhra Pradesh and Tamil Nadu have opted for reverse bidding for their solar allocation states, such as Gujarat, Karnataka, Madhya Pradesh have opted for feed-in tariffs.

Most of the existing manufacturing capacity is based on crystalline silicon manufactured as wafers. Solar PV applications include solar home systems, solar power plants, solar lighting (street lighting, home lighting systems, and lanterns), solar pumping, PV modules for telecommunications and data logging.

Cost and performance

The current capital cost of Solar PV is approximately INR 8 crore/MW. Of this, the PV module cost is about 40% of total capital cost. Benchmark cost by CERC has been taken to be US\$ 0.60/Wp. The capacity factor for the grid-connected systems was 6% in 2001–2002 but has risen to 19% in recent years.

Key issues

Critical issues include the relatively high cost, modest capacity factor and intermittent

operation, which translate to higher electricity generation costs, and the need for appropriate grid management and energy storage—or backup power in off-grid installations. The high cost can be attributed to India's dependence on imports for silicon and solar wafers used for the manufacture of solar cells. There is also a lack of collaborative and goal oriented effort within the R&D programmes in the sector. There needs to be increase in operating efficiency, as currently the typical efficiency of a flat-plate crystalline Si solar cell module is around 15%. However, flat-plate PV and concentrator III–V compound multi-junction solar cells have the potential in principle to increase efficiency to almost 30% and more than 50%, respectively, (Ansari, Kharb, Luthra, Shimmi, & Chatterji 2013). Cost-effective energy storage is not yet available to supply uninterrupted and continuous power supply and this needs to be the focus of R&D efforts. High financing costs due to perceived risk by financial institutions and relatively higher capital costs as compared to conventional technologies are also a barrier. PV power plants are often located in far-flung and remote areas and require the construction of additional transmission lines, increasing the system cost and thus require careful planning. Land acquisition is also a critical aspect for infrastructure development and the approval processes and inability of the state governments to provide single window clearance to developers has caused further challenges.

Concentrating Solar Power²¹

Present status in India

Currently, there is just 5.5 MW of installed capacity of Concentrating Solar Power (CSP) in India. There is a 3 MW parabolic trough project by IIT-Mumbai in the Solar Energy Centre in Gurgaon and a 2.5 MW project commissioned in Bikaner, Rajasthan (CEEW; NRDC 2012). During JNNSM Phase I, a 50:50 split was provided between projects employing PV technologies and CSP. More than 60 CSP bids were received during this time and MNRE selected seven projects, totalling 470 MW. MNRE also “migrated” three existing CSP projects of 10 MW each into the JNNSM to reach a combined total of 500 MW. The CSP projects’ weighted average bid price was INR 11.48/kWh (US\$ 0.21/kWh) as compared to the average electricity price of INR 4.70/kWh (US\$ 0.09/kWh). Though these projects are to be commissioned in May 2013, all Phase 1 CSP developers have petitioned MNRE for a 6 to 12 month extension.

Cost and performance

The capital cost of a CSP project is around INR 12 crore/MW with O&M cost of INR 15 lakh/MW (with 5.52% escalation each year). The Capacity Utilization Factor (CUF) is considered to be 23%. The key strength of CSP is its ability to utilize storage and hybrid technologies which also reduce the risks associated with integrating renewable energy in the grid. Through thermal energy storage (with molten salt technology), CSPs can generate electricity even after sundown to address both peak and off-peak power needs and enhance grid flexibility. With hybridization, CSPs can be configured to be used in conjunction with conventional power plants, industrial thermal systems, renewable sources, such as biomass, etc. CSP can be configured to use the existing plant’s turbines to cost-effectively increase its efficiency and reduce the carbon footprint. CSP can also provide heat solutions to industries with high energy and heat demand, such as pulp and paper, steel, cement, or textiles. CSP can also function to supplement base-load requirements and peak load requirements.

²¹ Concentrating Solar Power (CSP) uses lenses or mirrors and tracking systems to focus a large area of sunlight (Direct Normal Irradiance) to receivers. This concentrated sunlight is converted to heat, which drives a heat engine (usually a steam turbine) connected to an electrical power generator. This heat is transformed first into mechanical energy (by turbines or other engines) and then into electricity—Solar Thermal Electricity (STE). There are three main types of concentrating solar power systems: linear concentrators, dish/engine, and power tower systems.

- Linear concentrator systems collect the sun’s energy using long rectangular, curved (U-shaped) mirrors, and working fluid to boil water in a conventional steam-turbine generator to produce electricity. There are two major types of linear concentrator systems: parabolic trough systems, and linear Fresnel reflector systems.
- A Dish/Engine system uses a mirrored dish like a large satellite dish, or sometimes many smaller flat mirrors formed into a dish shape. The dish-shaped surface directs and concentrates sunlight onto a thermal receiver, which absorbs and collects the heat and transfers it to the engine generator. The most common type of heat engine used today in dish/engine systems is the Stirling engine.
- A Power Tower system uses a large field of flat, sun-tracking mirrors known as heliostats to focus and concentrate sunlight onto a receiver on the top of a tower. A heat-transfer fluid heated in the receiver is used to generate steam, which, in turn, is used in a conventional turbine generator to produce electricity. Some power towers use water/steam as the heat-transfer fluid. Other advanced designs are experimenting with molten nitrate salt because of its superior heat-transfer and energy-storage capabilities

Key Issues

CSP is currently more expensive, complex and time intensive than PV projects. CSP plants also have greater water requirement per unit of electricity produced and the projects are sited in arid zones. Further, the falling prices of PV modules and growing experience of PV project implementation is also adding pressure to CSP projects and CSP has been losing ground in the competition. There is also unavailability of accurate solar radiation data to establish power projects which has affected CSP projects are awarded, severely causing delays as developers need to re-evaluate site conditions after the projects. Additionally, new solar technologies are perceived as risky by financing agencies thus driving up interest rates which are detrimental to CSP project developers. CSP power plants are often located in far-flung and remote areas and thus require the construction of additional transmission lines. Land acquisition is also a critical aspect for infrastructure development and the approval processes and inability of the state governments to provide single window clearance to developers has caused further challenges.

Wind Power²²

Resource and potential

Wind power development in India started in the early 1990s with demonstration wind power projects in Gujarat and Maharashtra.

Simultaneously, a wind resource assessment exercise was initiated by the Ministry of New and Renewable Energy (MNRE), along with Indian Institute of Tropical Meteorology (IITM). With the formation of Centre for Wind Energy Technology (C-WET), the wind resource assessment exercise along with testing and certification of wind turbines were handed over to this Centre.

Under the wind resource survey programme 20 metre tall wind masts were installed. Stations deployed after 1992 used 25 metre tall masts. Keeping in view the increasing hub heights employed in wind turbines due to technology development, new wind monitoring stations established during 2004 employed 50 metre tall masts with three levels of wind speed sensors and two direction vanes. It was only from 2008 onwards the height of wind masts was increased to 80 meters and 120 meters with three levels of measurement (Figure 15).

However various agencies have conducted studies estimating wind energy potential in India. The numbers stated vary due to the different assumptions made during their assessments. Table 12 shows the different wind potential assessment studies conducted for India.

Apart from the potential shown in Table 11, repowering potential also exists. This refers to replacement of many of the older low-capacity

²² Wind turbines convert the kinetic energy of wind into electricity. A wind turbine consists of various components like rotor blades, aerodynamic power regulation, generator, reactive power control, yaw mechanism, and tower. Wind turbines can also be classified in terms of the axis around which the turbine blades rotate. Most wind turbines are Horizontal Axis Wind Turbines (HAWT), but there are some with blades that spin around a Vertical Axis Wind Turbines (VAWT). The amount of energy produced by a wind machine depends upon the wind speed and the size of the blades in the machine. In general, when the wind speed doubles, the power produced increases eight times. Larger blades capture more wind. As the diameter of the circle formed by the blades doubles, the power increases four times

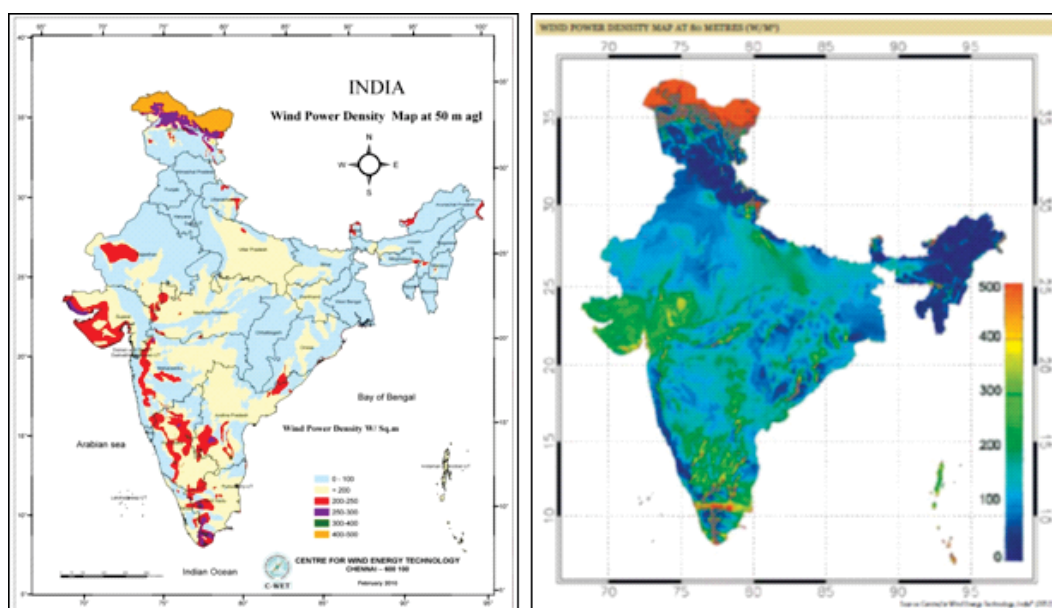


Figure 15: Wind power density maps at 50 meter and 80 meter heights

Source: CWETa and CWETb

wind turbines that were installed more than 10–12 years ago. These turbines occupy some of the best wind sites in India. Replacing these with more efficient, larger capacity machines

will result in greater electricity generation. Repowering potential is estimated to be approximately 2,760 MW (GWEC 2012).

Table 12: Wind power potential estimates by various agencies

Source	Estimated Potential (GW)	Hub Height (m)	Assumptions
CWET	49	50	2% land availability for all states except Himalayan states, North Eastern states and Andaman Nicobar Islands
CWET	102	80	
LBNL	2,006	80	Based on GIS data on topography and land use the study found a significantly high availability of land (7%) that can potentially be used for wind power development. The study excluded land with low-quality wind, slopes greater than 20 degrees, elevation greater than 1,500 metres and certain other unsuitable areas, such as forests, bodies of water and cities
LBNL	3,121	120	
Low Carbon Working Group (12th Plan)	500	80	6% land availability

Source: TERI and WWF India 2013

Present status in India

India currently has about 19,000 MW of wind power installed capacity. Wind power is a mature and scalable clean energy technology where India holds a domestic advantage. India has an annual manufacturing capacity for over 9.5 GW of wind turbines. During FY 2011–12 India installed a record 3.1 GW of new wind power capacity. The states of Tamil Nadu, Karnataka, Maharashtra, and Gujarat have been the leading states for wind installation, but Rajasthan and Madhya Pradesh are emerging as dominant players. Most of the wind energy development is concentrated in southern and western Indian states of Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra, and Gujarat. Unlike solar plants, wind farms do not need to be restricted to barren uncultivated land. They can be located on agricultural land, cattle grazing land. It is estimated that the land disturbed permanently by installing wind farms may vary from a negligible value to at most 0.6 ha/MW.

A key trend in the Indian industry is the development of multi-megawatt turbines installed at greater hub heights. Larger diameter rotors mean that a single wind power generator can capture more energy, or more 'power per tower'. This allows Wind Turbine Generators (WTGs) to take advantage of higher altitudes with stronger winds and less turbulence (wind speed generally increases with height above the ground). Subsequently, larger machines have resulted in a steady increase in the capacity factor on average from 10–12% in 1998 to 20–22% in 2010.

For two decades now, global average WTG power ratings have grown almost linearly,

with current commercial machines rated on average in the range of 1.5 MW to 2.1 MW. The average size of WTGs installed in India has gradually increased from 767 kW in 2004 to 1,117 kW in 2009. Currently, megawatt-scale turbines account for over half the new wind power capacity installed in India.

Cost and performance

The capital cost of wind power plant varies from INR 5 to 6 crores/MW. As wind power density increases, the CUF increases resulting in more production of electricity. The CERC determined CUFs corresponding to various wind zones are shown in Table 13.

Table 13: Capacity utilization factor in different wind zones

Wind Energy Annual Mean Wind Power Density (W/m ²)	CUF
Wind zone - 1 (Up to 200)	20%
Wind zone - 2 (201–250)	22%
Wind zone - 3 (251–300)	25%
Wind zone - 4 (301–400)	30%
Wind zone - 5 (Above 400)	32%
Source: CERC 2014	

However, different benchmarks have been fixed for CUF in different states. This is important as deviation will decide the tariffs.

Key issues

Due to the lack of an appropriate regulatory framework to facilitate purchase of renewable energy from outside the host state, inadequate grid connectivity, high wheeling, and open access charges in some states, and delays in obtaining land and acquiring statutory

clearances have hindered faster deployment. This is reflected in the fact that despite India having an annual manufacturing capacity of over 9.5 GW for wind turbines only about 3 GW is installed in a year. Also in the past few years, there has been a shift from an Accelerated Depreciation (AD) model (used mostly for tax breaks) to a GBI model. AD has been reduced (from 80% to 35%) and a higher GBI has been announced (although initially repealed) by the Government. However, this transitional period has been difficult for the wind industry and caused a drop in wind installations (between April and December 2012 only 982.5 MW of wind power capacity was added, less than half the previous year's numbers). This clearly shows the huge dependency of the wind industry on Government policies and incentives. There is also a lack of quality data and insufficiently developed forecasting tools for accurate RE forecasting. Renewable energy scheduling for wind and solar power is critical for large-scale grid-integration of renewable energy. Currently, scheduling is required for wind power projects but developers are opposing this due to lack of sufficient support infrastructure, such as well-developed forecasting tools and good quality data, without which they are vulnerable to penalties that can be imposed due to deviations from schedule resulting in negative impact on profits.

Small Hydropower²³

Resource and potential

India has an estimated potential of about 19,750 MW of Small Hydro Power (SHP) projects (MNRE n.d.). Most of the potential is in Himalayan States as river-based projects and in other States on irrigation canals. MNRE has earlier created a database of potential sites of small hydro and 5,415 potential sites with an aggregate capacity of 14,305.47 MW for projects up to 25 MW capacity have been identified (MNRE).

Present status of SHP in India

So far, 898 SHP projects with an aggregate capacity of 3,411 MW have been set up and 348 projects aggregating to 1,309 MW are under implementation. Setting up of small hydro projects comes under the purview of state Governments. Potential sites are either developed by the state or allotted to private developers for setting up of projects. During the 11th Plan, a capacity of 1,419 MW was added against 536 MW during the 10th Plan. A capacity addition of 2,100 MW from SHP projects has been planned during the 12th Five Year Plan. MNRE provides Central Financial Assistance (CFA) to set up small/micro-hydro projects both in public and private sectors. Financial support is also given to the state Government for identification of new potential sites including survey and preparation of Detailed Project Reports (DPR),

²³ Small-hydro power in India refers to those hydro power plants that are less than 25 MW. Small-hydro power is a renewable, economic, and environmentally benign source of energy obtained from the energy of water flowing from a height. The energy is converted into electricity by using a turbine coupled to a generator. The hydro power potential of a site is dependent on the discharge and head of water. These projects can have various configurations and be set up on rivers, canals, or at dams. They are further classified as Pico hydro (up to 5 kW), Micro hydro (from 5 kW up to 100kW), Mini hydro (101–2,000 kW, i.e., 2MW) and Small hydro (above 2 MW up to 25 MW).

and renovation and modernization of old SHP projects. It also helps the state governments in formulating their policies for the development of small-hydro projects and exploitation of this potential.

Under the CFA Scheme of the MNRE, capital subsidy is now provided to both private and State projects and for renovation and modernization of SHP plants. Besides, technical support is being provided to SHP units through Alternate Hydro Energy Center (AHEC), IIT, Roorkee.

Cost and performance

SHP plants have certain inherent advantages: they generate clean energy at a competitive cost; they have features that make them suitable for peaking operations; they are less affected by rehabilitation and resettlement (R&R) problems vis-à-vis large hydro power plants; they can meet the power requirements of remote and isolated areas too and they use mature and largely indigenous and proven technology.

According to CERC's renewable energy tariff regulations CUF of small hydro is quite high when compared to other renewables like solar and wind. CUFs found in Himachal, Uttarakhand, and North Eastern states are

as high as 45% whereas other states have a CUF of 30%. SHP implementation time from concept to commissioning takes 30–36 months, including a pre-construction period of 15–18 months and construction period of 15–20 months. The capital cost ranges from INR 6 to 7 crore/MW.

Key issues

Though streams running in the hilly region have large potential to generate additional power without impacting the environment, there are limitations in setting up plants in these areas due to difficult and remote terrains in hilly/mountainous regions with severe infrastructural constraints and transmission of power to the grid. The locational hurdles also serve to prolong the gestation period and push up the per-MW capital costs even as the power evacuation and transmission facilities at the sites remain inadequate. Additionally, there are also delays in acquiring land and obtaining statutory clearances.

Biomass²⁴

Resource and potential

India's biomass availability has been estimated at 500 million metric tonnes per year. Of this

²⁴ Biomass is renewable organic matter generated by plants through photosynthesis wherein the solar energy combines with carbon dioxide and moisture to form carbohydrates and oxygen. Mostly, biomass has a high level of moisture and volatile matter content but has a low bulk density and calorific value. It is renewable, widely available, carbon-neutral, and has the potential to provide significant employment in the rural areas. Biomass can be classified into two types: woody and non-woody. Woody biomass includes fuelwood, woody waste matter from industries and other sources. On the other hand, non-woody biomass comprises agro-residue and agro-industrial processing residue. Animal and poultry wastes are also referred to as biomass as they are biodegradable in nature.

There are a variety of ways for obtaining energy from biomass. These can be broadly classified into:

- **Direct method:** The direct way of utilizing a biomass resource is to burn it, the fuel most commonly used being wood. An interesting approach for the large-scale planned use of wood is the 'energy plantation' approach.
- **Indirect method:** These methods are classified into:
 - Biological conversion:
 - Anaerobic digestion
 - Thermo-chemical conversion
 - Pyrolysis
 - Gasification

surplus biomass availability ranges from 120–150 million metric tonnes per year originating from agricultural and forestry residues. This yields a total potential of 18,000 MW. Additionally 5,000 MW could be generated through bagasse-based cogeneration from the country's 550 sugar mills (MNRE 2013b).

Present status in India

The MNRE has planned to initiate the “National Bio-energy Mission” during the 12th Five Year Plan, in association with the state governments, public and private sectors, and other stakeholders to promote ecologically sustainable development of bio-energy to address the country's energy security challenge. The Bio-energy Mission aims at creating a policy framework for attracting investment and rapid development of commercial biomass energy market-based on utilization of surplus agro-residues and development of energy plantation in different parts of India. The main challenge involved in the Bio-energy Mission lies in how to increase the share of bio-energy on sustainable basis in renewable energy portfolio.

Cost and performance

Biomass plants have higher Plant Load Factor (PLF)/CUF as compared to other renewable energy as feedstock can be controlled. Typical PLFs tend to be very high and at par with other conventional power generation sources as shown in Table 14.

Table 14: PLF of biomass technologies

	PLF
(1) Biomass	
(a) During stabilization (6 months)	60%
(b) During remaining period of the first year (after stabilization)	70%
(c) Second year onwards	80%
(2) Biomass gasifier	85%
(3) Biogas	90%
<i>Source: CERC 2013</i>	

Key Issues

There is an absence of effective institutional and financing mechanisms reflected by the absence of commercial and service networks (biomass depots for collection, transportation, and delivery of biomass fuels) at national, regional, and local levels. There is limited access to financing and lack of interest on part of SEBs in promoting biomass power generation. Biomass projects have a long gestation period and project development cycle requires several years to be completed. Fuel-supply risks are twofold; the first set are the physical availability found in the case of all biomass power projects (rainfall, harvesting effectiveness, and productivity). The second are the questions of contracted supply encountered when dealing with distributed biomass supplies. The inability to lock-up sufficient supplies of biomass from various sources will serve as a hindrance to project finance and implementation.

SECTION II

Energy Demand Sectors

The energy demand sectors can be categorized into residential, commercial, industrial, and transport. A significant proportion of energy consumed in India is in the form of non-commercial biomass that includes firewood, dung cakes, and crop residue. If we consider the total energy consumed including these sources, demand from the residential sector formed 37% of the total energy demand in the country in 2011 (Figure 16). However, when biomass is excluded, this share reduces to 9 % of the total energy demand. Industry is the largest consumer of energy in India. In the scenario where we consider all the forms of

energy, it has nearly 40% of the total demand which increases to more than 57% when non-commercial biomass is excluded from the mix.

One of the major concerns in ensuring energy security is ensuring access to energy in the household sector, and facilitating a move away from traditional energy sources and methods of lighting and cooking that are considered to be more polluting. The use of traditional fuels (biomass, crop residue and firewood) for cooking in the residential sector also has the associated social implications in terms of the time spent by women in collecting the firewood and spent away from other useful employment activities.

Another important aspect that defines energy security in the key energy demand sectors is the level of energy efficiency achieved. The Integrated Energy Policy (IEP) states this succinctly, “*Lowering the energy intensity of GDP growth through higher energy efficiency is important for meeting India’s energy challenge and ensuring its energy security*” (Planning Commission 2006).

The following chapters examine the key demand sectors in terms of their energy consumption, the major policies introduced in the sector for addressing concerns related to energy demand, the key issues that affect the sector and its energy demand, and

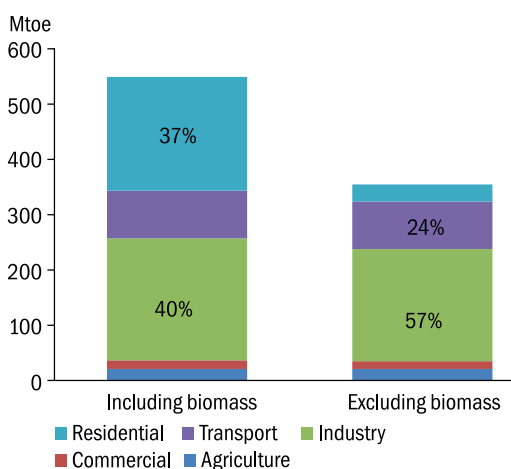


Figure 16: Final energy demand by sector in 2011
Source: TERI compilation

finally, provide some key recommendations/ suggestions for addressing the emerging issues. Some of the key policies that address the use of energy in the various demand sectors are IEP, the various missions introduced

under the National Action Plan on Climate Change (NAPCC), and various sector-specific programmes which are discussed in detail in the respective sections.

Chapter 6

Agriculture

Introduction

Understanding energy use in the agriculture sector is necessary for determining the energy invested in different agricultural activities and providing a basis for conservation and its efficient management for improved agricultural production. Energy use in agriculture at the farm level can be categorized as either direct or indirect. Direct energy use in agriculture is in the form of diesel and electricity to operate mobile and stationary equipment to prepare fields, plant and harvest crops, and transport inputs and outputs to and from markets. Indirect energy is consumed off the farm for the manufacture and production of fertilizers and pesticides.

This chapter first discusses energy use trends in agriculture in India. Subsequently, it examines and discusses the underlying issues and drivers of these trends. Next, an analysis of different policies and regulation influencing farm energy use in Indian agriculture is provided. The chapter concludes by commenting on how to influence the drivers and the possibilities to shift to a more rational energy system in view of energy security, access to energy, and environmental sustainability. Energy use for production of fertilizers and pesticides is not included in

this sector but rather is accounted for in the industrial sector. Non-commercial energy, an important element of traditional agriculture, is also not included in the analysis.

Trends in Energy Use in Agriculture

Yields of most of the crops have increased since the Green Revolution era. Steady yield gains have been the result of technological changes rooted in the breeding of higher-yielding plant varieties, increases in the number of seeds planted per hectare, more intensive use of fertilizers and pesticides, and more extensive irrigation of cropland. All of these new production technologies rely on the use of significant amounts of fossil energy.

Petroleum products

Diesel is the most important primary energy source in obtaining mechanical energy for crop production. It is used mostly in tractors for tillage and pump sets for irrigation in agriculture. In India, there are two types of diesel fuels:

- High Speed Diesel (HSD), used in automotive applications
- Light Diesel Oil (LDO), used in stationary applications

LDO is steadily being replaced by HSD, which is primarily a transport fuel. In the agriculture sector, HSD is used in tractors, power tillers, and pump sets. There has been an increase in the HSD consumption in the Indian plantation sector, which includes the agriculture sector from 7,015 thousand tonnes in 2005–06 to 11,212 thousand tonnes in 2009–10 (Figure 17). This represents 19.9% of the total HSD consumption in India during 2009–10.

India is one of the few countries that produce LDO, which is a distillate fuel with a small proportion of residual fuel. It is used in agricultural pump sets by small industries and as start-up fuel for power generators. The consumption of LDO in the agricultural sector has reduced significantly over the years. Other fuels that were once used in the agricultural sector and now almost account for negligible quantities include Low Sulphur Heavy Stock (LSHS) and heavy fuel oil (HFO), jointly known as fuel oils.

Electricity

The share of total electricity consumption of the agricultural sector increased from 81,673 GWh in 2001–02 (accounting for nearly 25% of the total electricity consumption in that year) to 129,051 GWh in 2010–11 (18% of the total consumption of electricity during that year). Figure 18 indicates the consumption of electricity in the sector from 2000–01 to 2010–11.

Issues and Drivers of Energy Demand in the Sector

Energy consumption in agriculture is mainly influenced and driven by the use of farm machinery, such as tractors, power tillers, and irrigation pump sets among others. Key drivers of energy use include **activity drivers** (total population growth, increasing food demand, crop production pattern, irrigation, and farm mechanization), **economic drivers** (agricultural GDP, income, and price elasticity),

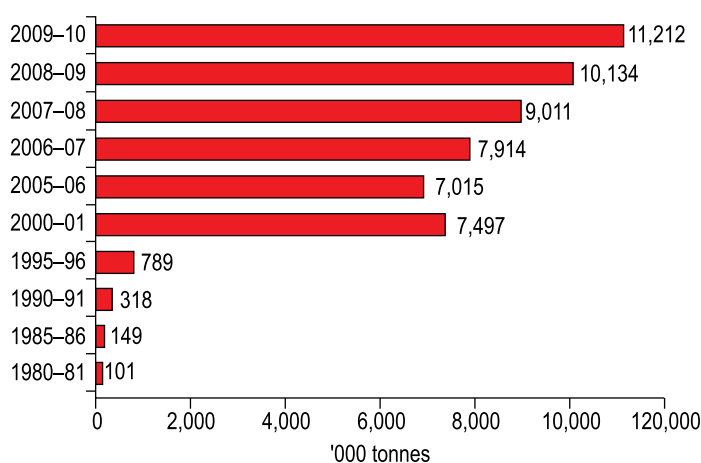


Figure 17: High Speed Diesel (HSD) consumption in the agriculture sector (1981–2010)

Source: MoSPI 2012

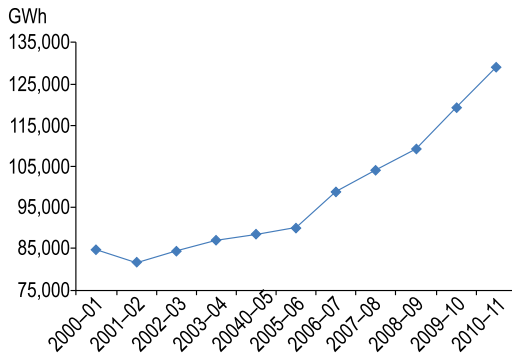


Figure 18: Electricity consumption in the agriculture sector

Source: CEA 2012

energy intensity trends (energy intensity of energy-using agricultural machinery) and **conditioning factors** (institutions/governance, policies, and infrastructure). These factors are, in turn, driven by changes in consumer preferences, energy and technology costs, technical change, and overall economic conditions.

To understand the drivers of energy use and demand in the agriculture sector, it is essential to understand the changes in crop patterns with respect to the nature and direction of area

shifts across crops and crop groups observed through time, farm mechanization trends, irrigation and energization of pump sets, and their implications on energy use in agriculture.

Crop pattern changes

The changing area share of crop pattern is a useful tool for understanding the direction in which crop pattern changes are influenced by the variations in the comparative advantage of crops and crop groups.

Of the total geographical area of India is 328.7 Million hectare (Mha), the net sown area is 141.36 Mha and the gross cropped area is 195.10 Mha. The gross and net irrigated areas are 88.42 Mha and 63.20 Mha, respectively, with a cropping intensity of 138%. The cropping pattern in India has undergone significant changes over a period of time. There has been a substantial area shift from cereals to non-cereals. Although cereals have gained a marginal increase in area share in the first decade of the Green Revolution; their area and share declined gradually thereafter (Figure 19). As the cultivated area remains more or less

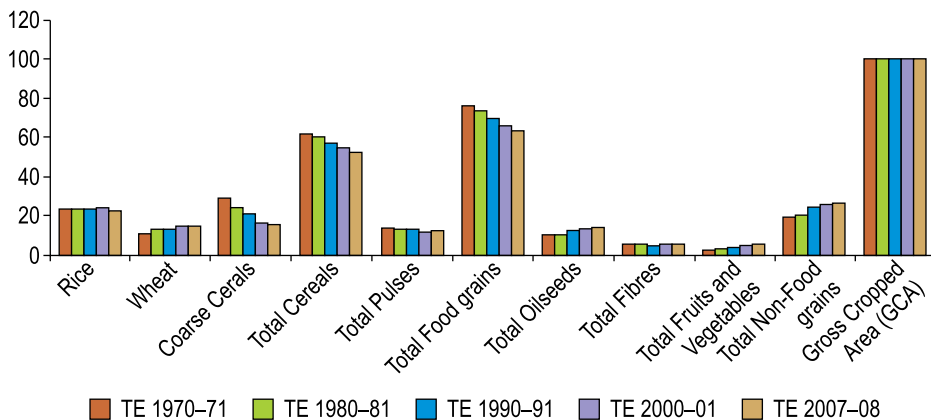


Figure 19: Share of major crops in gross cropped area in India (%)

Source: Kannan and Sundaram 2011

constant, the increased demand for food puts agricultural land under stress resulting in crop intensification and substitution of food crops with commercial crops.

State-wise change in cropping pattern reveals that Haryana, Uttar Pradesh, Rajasthan, Gujarat, and Bihar have increased their allocation of area under both the crop groups—rice/wheat and non-food grain crops (Figure 20). They have increased the overall allocation of non-food crops in their cropping pattern by replacing cereals. However, this is not the case with Punjab, which has increased the allocation of rice and wheat by reducing the proportion of area under other high value non-food crops. West Bengal, Tamil Nadu, Maharashtra, Jammu and Kashmir, Assam, and Andhra Pradesh have reduced the proportion of rice or wheat in order to increase the proportionate area under non-food crops.

To meet the growing food demand, higher growth in agriculture assumes great importance. This is a matter of concern for policy planners. The need for increasing

productivity factors and cropping intensity over the years has resulted in promotion of agricultural systems based on intensive irrigation, mechanization, and external chemical inputs (De la Rue du can, Mc Neil, Sathaye 2009). This has resulted in an increase in energy intensity per unit of Gross Cropped Area (GCA) and Net Sown Area (NSA) as depicted in Figure 21.

Technological and institutional support for rice, wheat, and plantations crops has brought significant changes in crop output composition across regions. This has resulted in cropping pattern changes across states in India. It should be noted that the changing area share of crops is due to the shift in area under other competing or alternative crops as to the relative area allocation of fresh areas brought under cultivation. For example, the area under coarse cereals in the dry land regions was replaced by high value crops in order to increase farm output and income to farmers. These developments have significant implications for energy use in agriculture as

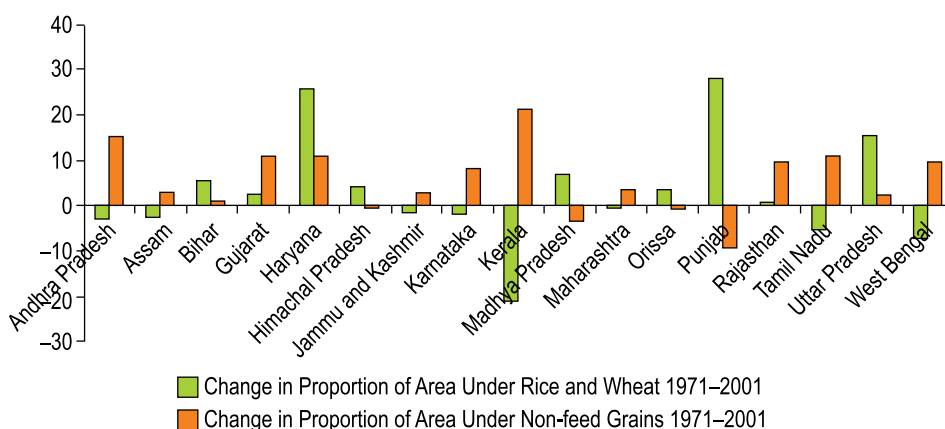


Figure 20: Proportionate area under rice/wheat and non-food grain crops and their changing pattern

Source: Kalaiselvi 2012

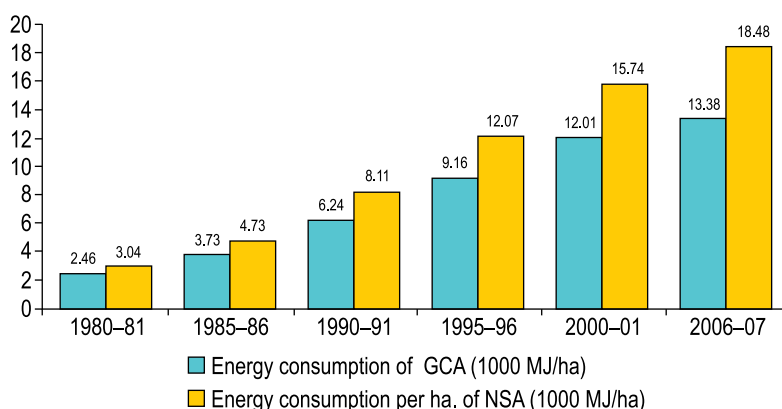


Figure 21: Energy intensity per unit of GCA and NSA

Source: Jha, Pal, and Singh 2012

share of energy cost is higher in case of high value crops as compared to coarse cereals. Besides, introduction of these high value crops in these regions may result in increased energy demand for irrigation besides depletion of groundwater resources and nutritional security to rural households.

Farm mechanization

The structure of energy consumption in Indian agriculture has changed substantially, with a significant shift from animal and human labour towards tractors for different farming operations and electricity and diesel for

irrigation (Figures 22 and 23). Till 1950s, farm machineries like agricultural tractors, power tillers, and pump sets were owned by a limited number of farm households. This scenario changed during the Green Revolution with the introduction of input intensive high-yielding varieties of wheat and other crops in the early 1960. Increasing area under HYVs and the consequent need for irrigation facilities could not be met by conventional methods of irrigation through water lifts driven by draught animals or manual operation. As a result mechanized pump-sets using electric motor or diesel engines increasingly gained prominence.

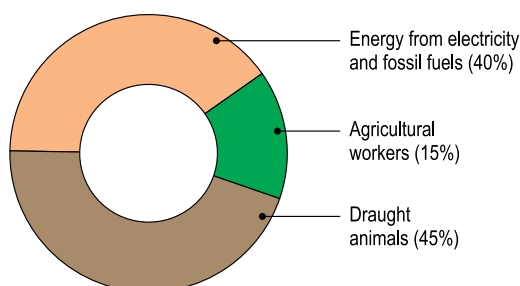


Figure 22: Structure of energy consumption in Indian agriculture (1970-71)

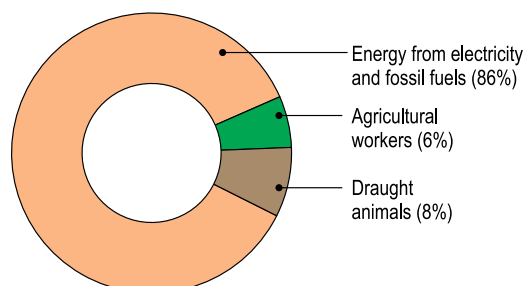


Figure 23: Structure of energy consumption in Indian agriculture (2006-07)

Furthermore, the expansion of area under HYVs and the consequent increase in food grains production made it difficult for the farmers to ensure timely completion of the harvesting and threshing operations using conventional methods. This led to large-scale adoption of threshers operated by electric motors, engines, and tractors. Tractors were also extensively used for primary tillage and transportation and tractor powered harvesting equipment.

Taking the case of tractors usage for land preparation, there are many factors which influence the amount of fuel used on tillage farms (Teagasc, 2011). These include:

- *Crop choice*: For example, producing potatoes will consume more fuel than cereals;
- *Soil type*: Heavier soils are generally more energy intensive to cultivate;
- *Farm size and distance to farm*;
- *Weather*: Very dry conditions during cultivation or the need to repair damage (e.g., subsoiling) after working the soil in wet conditions can use extra energy.

For energy demand calculations for tractors and power tillers, the number of operational farm machinery were estimated using the annual sale figures and the average useful life of tractors and power tillers is assumed as 15 years and 7 years, respectively (Srivastava 2004). Linking number of tractors to respective years agricultural GDP, future predictions were done using best fit regression line with natural log trend line).

The use of tractors has risen significantly over the years. In the 1950s, tractors were very limited; however, the number of tractors manufactured gradually rose to 11,000 by

1961. The number of operational tractors was 2,731,287 in 2001–02; however, with the joint effort of the Government and the private sector, the number increased to 4,403,198 in 2010–11 (Figure 24). The number of operational power tillers has also increased from 94,205 in 2001–02 to 219,798 in 2010–11 (Figure 25). This reflects the increasing use of HSD in agriculture machinery and implements. The growth of agricultural mechanization in agriculture in India has been driven largely by needs of the farmer who adopted new production technology besides an equal contribution made by the central and state governments and their various organizations through a large number of programmes (see, section on policy influencers) among others.

With increased irrigational facilities and cropping practices, the demand for agricultural machinery has seen an upward trend in the Southern and Western parts of the country even though initially agriculture machineries were mostly confined to the Northern region. The adoption of agricultural machinery in the Eastern and North-eastern states is still below the national average (IASRI 2006).

Irrigation and energization of pump sets

India, today, has nearly 80% of its water resources being used for irrigation purposes. This is sourced either from surface water through canals and tanks or from groundwater sources. Groundwater irrigation is highly energy intensive because water has to be harnessed from underground aquifers through tube wells using pump sets. Irrigated agriculture supports nearly 70% of India's food

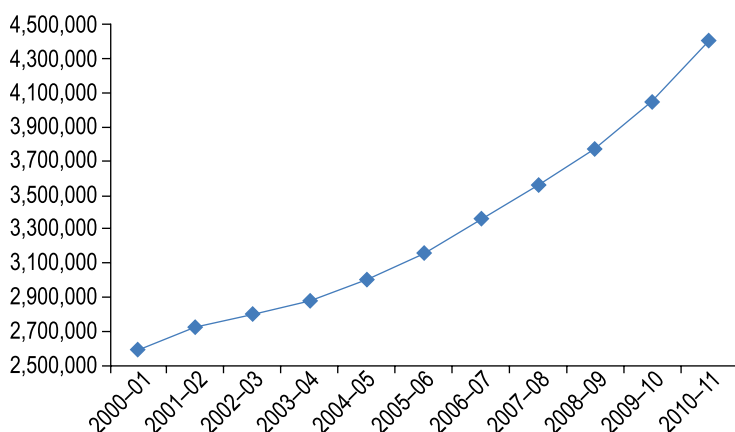


Figure 24: Number of operational tractors (from 1980–81 to 2010–11)

Source: IASRI 2012

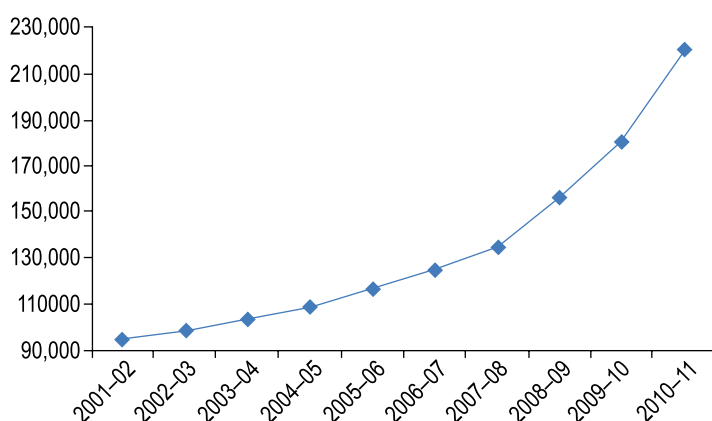


Figure 25: Number of operational power tillers (from 1982–83 to 2010–11)

Source: MoA 2012

grain production (Gandhi and Namboodiri 2009). On the other hand, it is clear that food production is increasingly reliant on ground water sources given that over 60% of irrigated area in India is dependent on groundwater (Gandhi and Namboodiri, 2009).

Cultivable land irrigated through tube wells increased from 0 Mha in 1940 to 28.948 Mha in 2009–10. The percentage of tube wells among

various sources of irrigation also increased to about 45% during the same period (Table 15). The factors that supported this trend include availability of pumping technologies, institutional credit, and expansion of electricity supply to rural areas. The initial abundance of groundwater in alluvial basins targeted for the Green Revolution also facilitated this rise. The use of groundwater for irrigation grew rapidly

because of the challenges faced with surface water irrigation (such as water logging, salinity, and poorly managed canal systems), although initially considered a potentially reliable supply of water by farmers (Gandhi and Namboodiri 2009). Over the years, there has been a dramatic increase in the number of tube wells utilized (Kelkar 2006). Correspondingly, there has been a rise in the use of pump sets operated using either electricity or diesel.

State-wise figures on irrigated area show a lot of variation in irrigation development from state to state which remains concealed in the all India estimates. Among the four Southern

states, except in Tamil Nadu, the net irrigated area in the remaining three states of Andhra Pradesh, Karnataka and Kerala increased reasonably between 1997–98 and 2009–10. However, the gross irrigated area during the corresponding period has declined in Tamil Nadu while increasing reasonably in Karnataka. In the case of Gujarat, the net irrigated area showed a significant increase. This has also been seen in Odisha and Haryana. In both these states, the gross irrigated area increased to some extent between different periods. The states of Madhya Pradesh, Maharashtra, Rajasthan, and West Bengal reflect stagnancy,

Table 15: Sources of irrigation in India: From 1950–51 to 2009–10 (Figures in '000 Hectares)

Year	Canal	Tanks	Tube Wells	Other Wells	Total Wells	Other Sources	Net Irrigated Area
1950–51	8,295 (39.78)	3,613 (17.33)	0 (0.00)	5,978 (28.67)	5,978 (28.67)	2,967 (14.23)	20,853
1960–61	10,370 (42.05)	4,561 (18.49)	135 (0.55)	7,155 (29.01)	7,290 (29.56)	2,440 (9.89)	24,661
1970–71	12,838 (41.28)	4,112 (13.22)	4461 (14.34)	7,426 (23.88)	11,887 (38.22)	2,266 (7.29)	31,103
1980–81	15,292 (39.49)	3,182 (8.22)	9531 (24.62)	8,164 (21.08)	17,695 (45.70)	2,551 (6.59)	38,720
1990–91	17,453 (36.34)	2,944 (6.13)	14257 (29.69)	10,437 (21.73)	24,694 (51.42)	2,932 (6.11)	48,023
1995–96	17,120 (32.06)	3,118 (5.84)	17894 (33.51)	11,803 (22.10)	29,697 (55.61)	3,467 (6.49)	53,402
2000–01	15,710 (28.65)	2,518 (4.59)	22324 (40.71)	11,451 (20.88)	33,775 (61.60)	2,831 (5.16)	54,833
2001–02	15,877 (28.41)	2,336 (4.18)	22816 (40.83)	12,020 (21.51)	34,836 (62.35)	2,827 (5.06)	55,876
2009–10*	16,697 (26.39)	1,638 (2.5)	28948 (45.76)	10,094 (15.95)	39,042 (61.72)	5,880 (9.29)	63,256

Notes: Figures in parentheses indicate percentage share of different irrigation sources

Source: Gandhi and Namboodiri 2009

while the states of Bihar, Jharkhand, Manipur, and Uttarakhand show a decline in the net and gross irrigated areas between different periods.

Increase in the use of energy and groundwater for agriculture is leading to groundwater scarcity which is already high in several parts of the country. The substantial use of diesel and electricity for groundwater extraction, projected to increase in the forthcoming years, also poses a threat given the pressure of limited availability of fossil fuels.

The use of power-driven pump sets in Indian agriculture began in late 1960s when monsoon failed for consecutive years and has had a northward run since the 1970s. This is reflected by a corresponding increase in the consumption of electricity, from 17,817 GWh in 1982–83 to 129,051 GWh in 2010–11. The number of diesel and electric pump sets used in India is provided in Figure 26.

There is thus a clear indication that electricity and its consumption has been growing significantly as a preferred input in

Indian agriculture, specifically for energizing irrigation pump sets. This increase is also supported by the fact that power supply to the farm sector in India is highly subsidized. This has also led to excessive usage of irrigation pumps and depletion of the water table resulting in wasteful consumption in the agriculture sector.

There are a range of factors that influence energy used in irrigation, such as change of system; for example, cultivation system; machine types used in the system and their setting; matching of machines within system and on farm; choice of specific machine/power unit, and operation of the machine in the fields.

It has been observed that a vast majority of agricultural pump sets used in India are inefficient. The possible reasons for low efficiency may include:

- Pump sets not purchased as per actual site requirements, such as suction head, delivery head, etc.
- Poor workmanship during installation

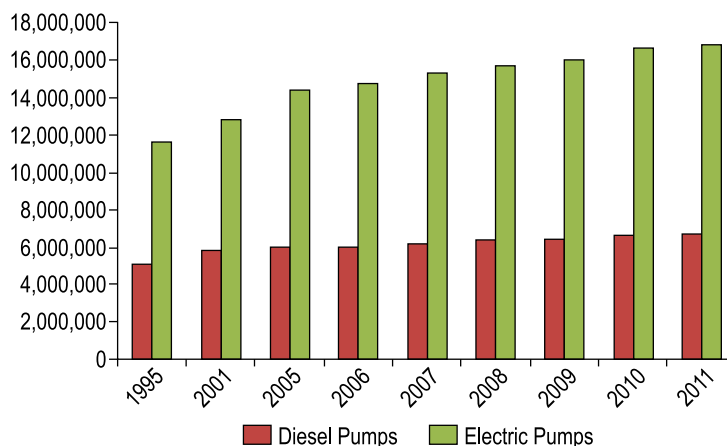


Figure 26: Number of diesel and electric pumps used in India

Source: MoP 2011

- Frequent rewinding of motors
- Absence of regular maintenance
- Poor quality of power supply
- Improper selection of foot valves, suction and delivery lines
- Local manufactured pumps are used which do not conform to IS specifications

Pump rectification work carried out by some Government and state agencies, such as PCRA, GEDA, and REC indicate achievement of 15–50% energy savings. Further, replacing sub-standard pumps with energy-efficient ones may result in energy saving potential of around 20–25%. Similarly, replacing sub-standard foot valves by energy-efficient ones may yield energy saving potential of 10–12%.

Key Policies and Regulations Affecting Energy Use in Agriculture

The above analysis on trends and drivers indicate that the largest impact on energy expenditures is due to irrigation and land preparation. These suggest that improving the energy efficiency of the technologies used for carrying out these two activities among others would also save energy. Concerns about the impact of production agriculture on our water resources has led to a number of policy initiatives geared toward electricity pricing, promotion of micro-irrigation, groundwater management, schemes for crop diversification, improving energy efficiency in irrigation. Similarly, energy consumption in

Table 16: Key policies and regulations impacting energy use in agriculture

Policy categories	Policies and their main features
Policies and regulations affecting energy consumption in irrigation	
Electricity pricing and tariff policy	<p>Tariff Policy 2006</p> <ul style="list-style-type: none"> • Differential tariffs for different geographic areas within states • Metered power supply via commercial arrangement with franchisees and involving relevant stakeholder (Panchayat institutions, user associations, cooperative societies, etc.) for management of local distribution in rural areas • To limit higher subsidies to resource poor farmers operating in groundwater depleted areas where greater quantities of electricity may be needed for irrigation which however must be subject to restrictions for maintaining groundwater levels and promoting sustainable usage of this resource <p>State initiatives</p> <ul style="list-style-type: none"> • Jyotigram Scheme of Gujarat provides reliable and adequate power supply at affordable cost resulting in water conservation and reduced pump maintenance costs • West Bengal and Uttarakhand have initiated metering of electricity supply and are charging farmers based on their metered consumption

Table 16: Contd...

Policy categories	Policies and their main features
Minimum Support Price Policy and schemes for crop diversification	<ul style="list-style-type: none"> MSP Policy has provided incentives to farmers to cultivate water intensive crops, such as rice Viability Gap Funding (VGF) scheme aims to encourage farmers in Haryana, Punjab, and Uttar Pradesh to reduce acreage under water intensive crops
BEE schemes to promote energy efficiency in irrigation	<ul style="list-style-type: none"> Standard and labelling programme – Agricultural pump sets has been included under the voluntary labelling scheme in the 11th plan period Agriculture Demand Side Management (Ag DSM) scheme – Initiated in 2009 the scheme seeks to organize and implement public private partnership frameworks to facilitate the replacement of existing pump sets with energy-efficient ones A draft national policy is anticipated for incentivizing: <ul style="list-style-type: none"> pump manufacturers to develop only energy-efficient pump sets for the market and consumers to comply with regulations and use these efficient pump sets for ensuing wide enforcement of the rules. Fiscal incentives offered for this purpose include tax rebates and exemption of excise duties. A target of 1.25 million pump sets is projected with energy savings to the tune of 3.45 billion units An integrated water and energy conservation scheme is proposed where farmers in drought prone areas will be provided with efficient pump set replacement as well as efficient irrigation facilities, such as drip irrigation systems through 100 joint demo projects
Policies and schemes for promoting micro irrigation	<p>National Mission on Micro Irrigation (NMMI) 2010</p> <ul style="list-style-type: none"> Target to bring 2.85 Mha under micro-irrigation resulting in savings in use of irrigation water, fertilizer, and electricity as well as increase in production and productivity of crops 40% subsidy to general farmers and 50% subsidy to small and marginal farmers as central share Revised cost norms and pattern of assistance based on the recommendations of Cost Norms Committee constituted by Department of Agriculture and Cooperation (DAC) Introduction of new components with advanced technologies on micro-irrigation like semi-permanent sprinkler system, fertigation system, sand filters, different types of valves, etc. Inclusion of closed space crops like vegetable, spices, and oilseeds Release of Central share to the State Implementing Agencies instead of districts
Policies and rules for groundwater management	<p>Draft Model Bill to Regulate and Control Development of Groundwater, 2011</p> <ul style="list-style-type: none"> Developed by the Planning Commission, the Bill intends to incorporate for strategies for energy pricing and energy rationing Energy-efficient pumps are one of the remedial measures sought to be implemented under the Groundwater Security Plans to be set up

Table 16: Contd...	
Policy categories	Policies and their main features
Others	<p>National Water Mission (NWM), 2011</p> <ul style="list-style-type: none"> Promotion of micro-irrigation techniques like the sprinkler and drip irrigation and incentivizing efficient irrigation practices <p>National Mission for Sustainable Agriculture (NMSA), 2010</p> <ul style="list-style-type: none"> The NMSA under its water use efficiency intervention is promoting agricultural practices for improving irrigation efficiencies (adoption of ridge furrow irrigation, raised bed farming, etc.) besides focusing on drip and sprinkler technologies Growth of less water demanding crops, mixed cropping, and agro-forestry practices to reduce irrigation dependency retain soil moisture is also encouraged Infrastructure development for artificial recharge in water scarce areas, secondary water storage structures, and laboratories for developing water efficient technologies is also being prioritized <p>Integrated Watershed Management Programme (IWMP), 2009</p> <ul style="list-style-type: none"> Aimed at an integrated approach for enabling optimal groundwater use and sustainable outcomes
Policies and regulations affecting energy consumption in land preparation	
Agriculture mechanization	<p>National Mission on Agriculture Mechanization (NMAM)</p> <ul style="list-style-type: none"> Implemented by the Department of Agriculture and Cooperation the mission aims at placing 'Small and Marginal Farmers' at the core of the interventions to bring farm mechanization to those villages where the technologies deployed are decades old Promoting 'Custom Hiring Services' through 'the rural entrepreneurship' model Ensuring quality control of newly-developed agricultural machinery through performance evaluation and certification at designated testing centres located across the country

land preparation for production agriculture has been supported by policies to promote farm mechanization and energy efficiency of

farm machineries. Table 16 provides a list of policies influencing energy use in agriculture and their salient features.

Chapter 7

Industry

Overview

The industrial sector has been a major driver of growth in India, accounting for around 28% of GDP between 2010–11 and 2012–13. This rapid growth has led to a concomitant increase in energy consumption and GHG emissions that threaten energy security and climate change mitigation in the future. The industrial sector has had the highest share in final commercial energy consumption, increasing from about 40.4% in 2000–01 to 43.62% in 2010–11 (TERI 2011).

The demand for industrial energy is driven and shared by Designated Consumers (DC), other large industries and Micro, Small and Medium Enterprises (MSMEs). A total of 334 large-scale industries have been identified as DCs from seven key energy intensive sub-sectors including Iron & Steel, Cement, Fertilizer, Aluminium, Textile, Pulp & Paper, and Chlor-alkali.²⁵ These DCs account for about 60 million tonnes of oil equivalent (Mtoe) of energy consumption annually.²⁶ Apart from these DCs, there are several other large industries that are energy intensive in nature, belonging to various sectors including glass, metals, food processing, vegetable

oils, automobiles, dairy, sugar, distilleries, petrochemicals, etc. The MSME sector also plays a vital role towards energy demand, accounting for a significant share of total industrial energy consumption. There are over 2,400 MSME clusters, spread throughout the country, manufacturing different products that are energy intensive.

Economic growth in India over the past few years has been largely driven by rising investments in physical infrastructure including power, transportation, buildings, agriculture, etc. Consequently, there has been a rise in demand for iron and steel, aluminium, cement and of their products, leading to increased production, energy requirements, and emissions from these industries.

Sub-sectors in the Industry

The industry sectors may be divided into several sub-sectors. This edition considers 10 sub-sectors that account for around 80% of the total energy consumption by the industry sector. These are:

- Aluminium
- Brick
- Cement
- Chlor-alkali (Caustic Soda and Soda Ash)

²⁵ Total DCs are 478 including power sector accounting for 165 Mtoe of energy consumption annually

²⁶ As per PAT notification 2012

- Fertilizers (Nitrogenous and phosphoric)
- Glass
- Pulp and paper
- Textile
- Iron and steel
- Petrochemicals

A brief overview of these sub-sectors is given below.

Aluminium

Aluminium is the third most abundant element in the Earth's crust and the most abundant metallic element. The aluminium industry in India is the seventh largest in the world. India's rich bauxite mineral deposits provide a competitive edge to the industry globally. The total annual installed capacity of aluminium in the country has risen from 1.08 million tonnes per annum (tpa) in 2006–07 to 1.71 million tpa during 2010–11. In India, aluminium was consumed mainly in the electrical sector (48%), followed by transport sector (15%),

construction (13%), consumer durables (7%), machinery and equipment (7%), packaging (4%), and others (6%).

The per capita consumption of aluminium in India is among the lowest in the world with only 1.3 kg as compared to world average of 12–15 kg. It is projected that aluminium production capacity in India at the end of the 12th Plan Period viz., 2016–17 would be about 4.7 million tonnes.

The aluminium production over a decade has been plotted in Figure 27.

The aluminium production has grown at a rate of 9.1% per annum during this period. The primary aluminium industry comprises three main producers—National Aluminium Company Ltd (NALCO), HINDALCO Industries Ltd, and Vedanta Group consisting of Bharat Aluminium Company Ltd, Madras Aluminium Company Ltd (MALCO), and Vedanta Aluminium Ltd (VAL). The contribution by each manufacturer has been provided in Table 17.

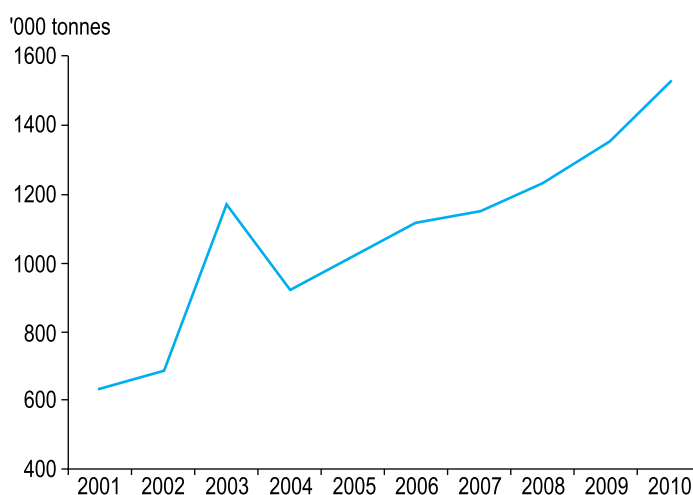


Figure 27: Aluminium production
Source: TERI (various years)

Table 17: Manufacturers' contribution to aluminium production

	2006–07 (%)	2011–12 (%)
NALCO	31%	25%
HINDALCO	39%	35%
VAL	0%	40%
BALCO	27%	0%
MALCO	2%	0%
Total	100%	100%

Source: TERI 2013

VAL started operations in 2008 and has since then replaced HINDALCO as the largest aluminium producer in the country having produced around 498 thousand tonnes in 2011–12. MALCO closed operations in 2008.

The main steps in production of aluminium are:

- Refining of bauxite to make alumina
- Smelting of alumina to make aluminium

Of these two, smelting is the more energy intensive process and consumes electrical energy accounting for about 85-90% of the electric energy consumption (BEE 2012 p6). Accordingly, smelting accounts for more than 80% of total energy consumption in aluminium sector and in this exercise, energy consumption in smelting operation is considered.

India occupies sixth place in the world with a share of 3.19% of the global bauxite reserves. About 1 tonne of alumina is produced from 3 tonnes of bauxite, and about 1 tonne of aluminium from 2 tonnes of alumina. Hence 1 tonne of aluminium requires around 6 tonnes of bauxite. Electricity, coal, and furnace oil are the main energy inputs for the production of

primary aluminium. Electricity is the major form of energy used in this process. Secondary aluminium is produced globally from recycled aluminium scrap. The industrial average for electrical energy consumption per tonne of primary aluminium is 14,000–17,000 kWh. Aluminium is formed at about 900 °C, but, once formed has a melting point of only 660 °C. In some smelters, this spare heat is used to melt recycled metal, which is then blended with the new metal. Recycled metal requires only 5% of the energy required to make new metal.

The average specific energy consumption for each of the manufacturers is provided in Table 18.

Table 18: Specific energy consumption for aluminium manufacturers

Plant	(toe/tonne)
NALCO	1.45
HINDALCO	1.38
BALCO	1.58
MALCO	1.56
VAL	1.56

Source: TERI 2007

Brick

India is the second largest producer of bricks in the world after China (TERI 2002). The brick industry in India accounts for a large amount of energy consumption; however, it is highly unorganized. Brick-making is a seasonal activity, starting after the rice harvest till the start of rainy season. As per 2000–01 estimates, there are around 1.0 lakh brick kilns in India with an estimated production of around 140 billion bricks per year.

For brick making, clay is the main raw material. Coal and biomass are the major fuels used in the country. Bull's Trench Brick Kiln (BTK) and clamp kilns are the two main brick firing technologies used in India. Other types of firing, which are not significant in terms of production, include Hoffman, downdraught kilns, Vertical Shaft Brick Kiln (VSBK), and tunnel kilns. Due to changing market and construction practices scenario including demand for energy-efficient products and shortage of labour, the brick industry in the country is on the threshold of transformation. It is expected that in near future, the brick industry will adopt mechanization for green brick moulding and will start producing resource efficient products like perforated bricks and hollow blocks. In general, brick making in the country is highly energy intensive and it is estimated (2000–01) that brick-making process consumes about 24 MT of coal and large quantity of biomass per year.

Cement

Cement industry in India occupies an important place in the economy because of its strong linkages to other sectors, such as construction, transportation, coal, and power. India is the second largest cement producer in the world after China and produces about 7%–8% of the world's cement. India (with an average annual growth of 9.8%) and China (with a growth of 11.4%) are the largest sources of cement output in the world (Planning Commission 2011).

There are about 183 large cement plants in the country with an installed capacity of 312 MTPA and more than 360 mini cement plants

with an estimated capacity of 11.1 MTPA, making the total installed capacity 323 MTPA in 2010–11. Large producers contribute about 97% to the installed capacity while mini plants account for the rest of the production. About 98% of the production capacity in the country is in the private sector. Indian cement industry is dominated by 20 companies which account for over 70% of the market. Individually no company accounts for over 12% of the market. Private housing sector is the major consumer of cement (53%) followed by the infrastructure sector. Partial decontrol during 1982–1988 and subsequently, total decontrol of the sector in 1989 have contributed to the growth of the cement sector and its adoption of the state-of-the-art technologies. Presently, about 98% of the total capacity in the industry is based on modern and environment-friendly dry process technology and about 50% of the capacity has been built in the last 10 years. Cement production over a decade is plotted in Figure 28.

The production of cement increased from 100.1 million tonnes in 2000–01 to 230.5 million tonnes in 2012–13. It registered a growth of 7.2% per annum during this period.

Indian cement industry produces different types of cement like Ordinary Portland Cement (OPC), Portland Pozzolana Cement (PPC), Portland Blast Furnace Slag Cement (PBFS), Oil Well Cement, Rapid Hardening Portland Cement, Sulphate Resisting Portland Cement, White Cement, etc. As regards the process used in production of cement, in India 98% of the cement production occurs through the dry process. Wet process contributes 0.5% while semi-dry process contributes the remaining 1.5%.

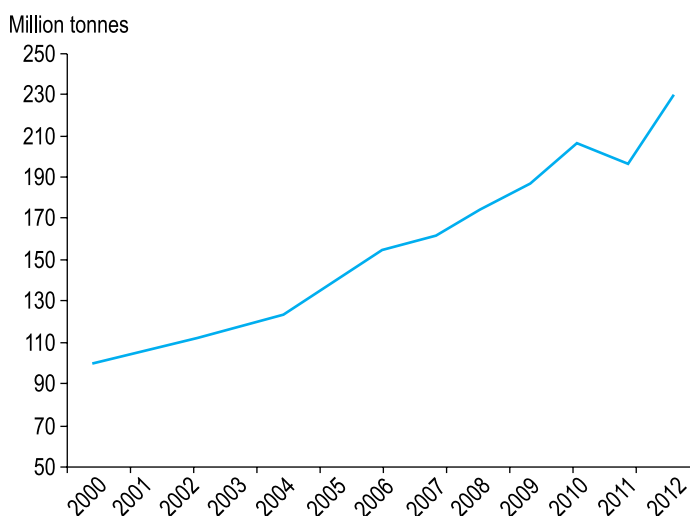


Figure 28: Cement production

Source: TERI (various years)

The Indian cement industry today is by and large comparable to the best in the world in respect of quality standards, fuel and power consumption, environmental norms for new cement plants, use of latest technology and capacity. Average annual installed capacity per plant in India is about 1.7 MTPA as against more than 2.1 MTPA in Japan. This is due to a blend of small and large plants coming up at various stages and still operating in India as against smaller plants having been decommissioned in Japan. The industry's weighted average energy consumption is estimated to be about 725 kcal/kg clinker thermal energy and 80 kWh/t cement electrical energy (Planning Commission 2011). The best thermal and electrical energy consumption presently achieved by the Indian cement industry is about 667 kcal/kg of clinker and 67 kWh/t of cement, which is comparable to the best reported figures of 660 kcal/kg of clinker and

65 kWh/t of cement in a developed country, such as Japan. It is expected that the industry's average thermal energy consumption by the end of the 12th Five Year Plan (2012–2017) will be about 710 kcal/kg clinker and the average electrical energy consumption will come down to 78 kWh/cement.

Chlor-alkali

The chlor-alkali industry is a sub-segment of basic chemicals industry. Comprising nearly 3% of the global markets, the Indian chemical industry is currently valued at US\$ 108 billion (Planning Commission, n.d.). Chlor-alkali industry mainly comprises caustic soda, soda ash, chlorine, hydrogen, and hydrochloric acid. Caustic soda and soda ash are responsible for most of the energy consumption in the chlor-alkali industry. Both find application in number of industries such as textiles, paper, PVC, water treatment, alumina, soaps and detergents,

glass, etc. The size of the Indian chlor-alkali sector at 7 million tonnes is 4% of the world market.

Caustic Soda

Caustic soda is used in various applications, such as finishing operations in textiles, manufacture of soaps and detergents, alumina, paper and pulp, control of pH (softening) of water, general cleansing, and bleaching. The aluminium industry is the biggest demand driver for caustic soda. Demand from alumina, paper and textiles drive caustic soda industry alone, constituting ~ 60% of total demand. China has the highest caustic soda capacity at 27 Mt, accounting for 34% of world capacity. Current global consumption of caustic soda is estimated at 65 Mt. India has more than adequate capacity to meet domestic demand of both caustic soda and chlorine. Asia is the largest consumer of caustic soda and is expected to remain the same in near future. There are 37 manufacturers of caustic

soda, having aggregate installed capacity to the extent of 3.246 Mt. These plants co-produce chlorine in the ratio of 1:0.89. Today 95% plants are running on state-of-the-art energy- efficient membrane cell technology. Gujarat is the largest caustic soda producing state with a capacity of 1.6 Mt. Power and salt are the key inputs in the manufacturing of caustic soda. Power accounts for almost 65% of the total cost of production. Caustic soda manufacturing is a highly energy consuming process and consumes 2.5 MWh/Mt of caustic soda.

Caustic soda production over a decade is provided in Figure 29.

Caustic soda production has increased from 1.7 Mt to 2.1 Mt during this period registering a growth rate of 2% per annum.

Caustic soda industry traditionally used the electrolysis process with a mercury cathode for producing chlorine and caustic soda from brine. Today with a rapid change in technology during the last decade only 5% is produced through the mercury cathode technology

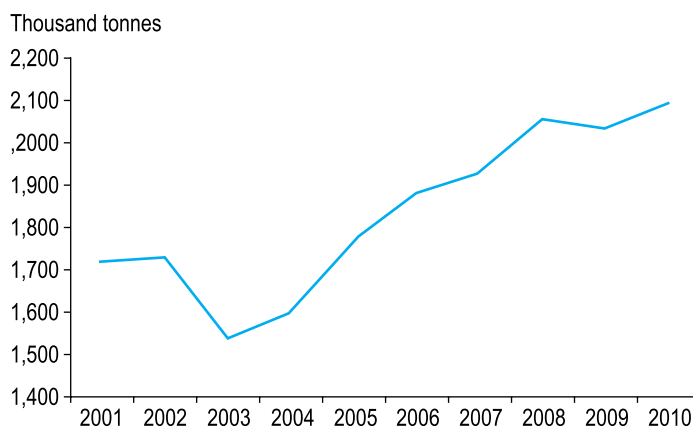


Figure 29: Caustic soda production
Source: TERI (various years)

while the rest 95% uses state-of-the-art membrane technology. India is next only to Japan in adopting membrane cell technology for caustic soda production. The specific energy consumption for the membrane technology is around 0.21 tonne of oil equivalent (toe)/tonne while that of mercury cathode is around 0.32 toe/tonne. The industry is in the process of continuous adoption of third/fourth/fifth generation electrolyzers and membranes. It is that mercury technology is going to be phased out completely in the near future.

Soda Ash

Soda Ash is an important inorganic chemical and constitutes one of the vital industry segments of the Indian chemical industry. It is used as a raw material for a vast number of key downstream industries, such as soaps, detergents, glass, silicate, specialty chemicals. Globally, majority of soda ash is used in the glass industry which accounts for 50% of the global soda ash consumption.

Soda ash is produced through Solvay Process and also available naturally in mines. Natural and synthetic are two methods of soda ash production. Of the total production, natural soda ash accounted for 11.7 million tonnes. China and the US are the biggest soda ash producing countries accounting for 40% and 20% of the total global soda ash capacity, respectively, (Planning Commission 2011). With a capacity of 3.16 million tonnes, India accounts for 5.3% of the total global capacity. Two varieties of soda ash are produced in India; light soda ash (used mainly by the detergent industry) and dense soda ash (used mainly in the glass industry).

The soda ash production over a decade has been provided in Figure 30.

Soda ash production has grown from 1.6 million tonnes in 2001–02 to 2 million tonnes in 2010–11 with an annual growth rate of 2.2% per annum. The technologies for soda ash production are the same as caustic soda as they are both formed from the same process in the chlor-alkali industry.

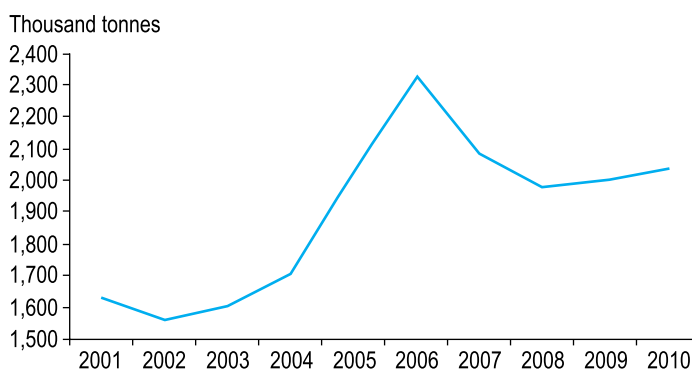


Figure 30: Soda ash production
Source: TERI (various years)

Fertilizers

Chemical fertilizers have played an important role in making the India self-reliant in food grain production. The annual consumption of fertilizers, in nutrient terms (Nitrogen, Phosphorus, & Potassium), has increased from 0.07 Mt in 1951–52 to more than 28 Mt in 2010–11. Fertilizer consumption per hectare has increased from less than 1 kg in 1951–52 to the level of 135 Kg now. The capacity of the fertilizer industry remained by and large stagnant during the 11th Five Year Plan period. Over the years, the consumption of fertilizers in the country has risen steadily, while the indigenous production of fertilizers has not increased commensurately to meet the growing requirement mainly due to raw materials/inputs limitations. There has been hardly any investment in urea sector in the last decade except for revamp and modernization activities that have been carried out by a few urea units after the Government notified import parity price (IPP) linked New Investment Policy in 2008. The production of Urea, Diammonium Phosphate (DAP), and complexes over the last few years is provided in Table 19.

Efforts for energy conservation intensified in the 1980s and have continued since then. The Indian fertilizer industry is benchmarked as one of the best in the world in terms of operational efficiency, energy consumption,

and maintenance of safety and environmental standards. The chemical and petro-chemical industry in India is dominated by ammonia production. Virtually all nitrogen fertilizers are derived from ammonia and production of ammonia itself involves almost 80% of the energy consumption in the manufacturing processes of a variety of final fertilizer products. Due to energy conservation efforts, the average specific energy consumption for ammonia production in India has improved significantly from 52.22 Giga Joules (GJ)/tonne in 1987–88 to 36.74 GJ/tonne in 2009–10. The Specific Energy Consumption (SEC) per tonne of urea varies between 21.59 GJ for the most efficiently operating plant to 52.38 GJ for the most inefficient plant during 2007–08 (Nand & Goswami 2011). The specific energy consumption of nitrogenous fertilizers have been provided in Table 20.

Table 20: Specific energy consumption

	2006 toe/tonne	2011 toe/tonne
Natural gas	0.60	0.50
Naphtha	0.72	0.58

Source: TERI 2013

In 2011, around 80% of the production was gas based while 20% was naphtha

Table 19: Production of Urea, DAP, and Complexes (in million tonnes)

Year	2007–08	2008–09	2009–10	2010–11	2011–12
Urea	19.86	19.92	21.11	21.88	21.98
DAP	4.21	2.99	4.25	3.53	3.96
Complex Fertilizers	5.85	6.85	8.04	8.73	7.77

Source: Department of Fertilizers 2012

based. The installed capacity of nitrogenous fertilizers during 2010–11 is 12.06 Mt and that of phosphate-based fertilizers was 5.6 Mt. Potassic fertilizers are not manufactured in India and are imported. The production of each kind is provided in Figure 31.

Production of nitrogenous fertilizers have grown from 10.6 Mt in 2001–02 to 12.6 Mt in 2011–12 at an annual growth rate of 1.6% while phosphate-based fertilizers have grown at a growth rate of 1.4% per annum, from 3.8 Mt in 2001–02 to 4.4 Mt in 2011–12.

The manufacture of all nitrogenous fertilizers together accounts for about 94% of the sector's energy use. The potential energy savings on a global basis at natural gas-based ammonia facilities could reach around 15%. The comparison of Best Available Technology processes for ammonia production is provided in Table 21.

Table 21: Global benchmarks in ammonia production using different sources and processes

Energy source	Process	Energy GJ/t ammonia
NG	Steam reforming	28
Naptha	Steam reforming	35
Heavy FO	Partial oxidation	38
Coal	Partial oxidation	42

Source: IFIA 2009

Glass

Glass is used in myriad of products, from construction projects to glass. The major glass producing countries in the world are Germany, USA, UK, China, and Japan. The main consuming regions are Europe, China, and North America, that together account for more than 74% of global demand for glass. The Indian glass industry comprises seven segments namely, sheet and flat glass, glass fibre, and glass wool, hollow glassware, laboratory glassware, table

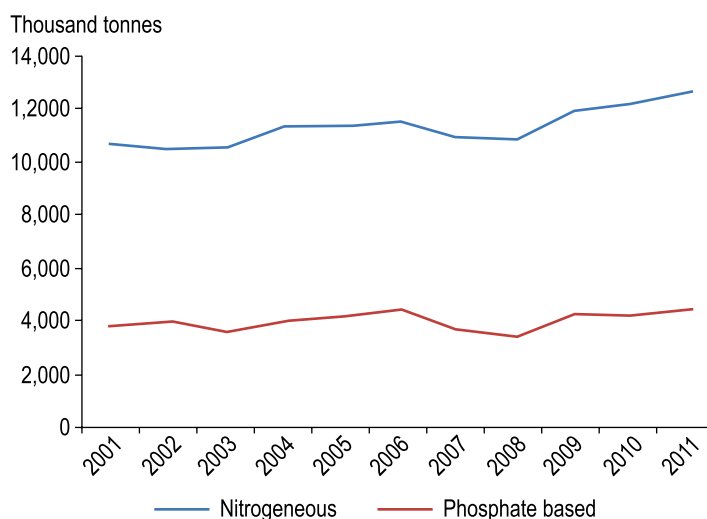


Figure 31: Fertilizer production
Source: TERI (various years)

and kitchen glassware, glass bangles, and other glass wares. In general, glass production can be categorized into four categories, viz.

- Flat glass
- Container glass
- Specialty glass, and
- Fibre glass

Indian glass industry

The Indian glass industry represents one of the largest markets and manufacturing capacity for glass products in the Asian region. Apart from few large manufacturers, there are more than 1,000 manufacturers in MSME segment. Majority of the units are located in Firozabad, Ahmedabad, Mumbai, Kolkata, Bengaluru, and Hyderabad. In clusters like Firozabad (UP), Gujarat, and West Bengal, Glass industry has evolved from being a cottage industry to an organized industry. During 2010–11, per capita glass consumption in India was 1.2 kg compared with 8–9 kg in developed countries and 30–35 kg in the US. The production of various glass products during the same period is provided in Table 22.

The glass industry is highly energy intensive and energy consumption is a major cost driver for the sector. The most energy intensive portion of the glass-making process,

regardless of product type, are melting and refining. This portion of glass manufacturing accounts for 60–70% of total energy use in the glass industry. Generally, float glass production consumes more energy than container glass production. Thermal energy consumption in glass industry contributes for significant share of total energy consumption, which is about 80%. Furnace oil and natural gas are mainly used as thermal energy source in Indian glass industry.

Iron and steel

Steel is an alloy consisting of iron (Fe), with a carbon (C) content between 0.02% and 2% by weight, and small amounts of alloying elements, such as manganese, molybdenum, chromium, or nickel. Steel forms the backbone of traditional sectors, such as infrastructure (construction and housing), ground transportation and major engineering industries (such as power generation, petrochemicals, fertilizers, automotive, steel tubes and pipes, consumer durables, and packaging), which are the most important components of a growing economy. The global steel industry is growing largely on account of the high growth rates in Asian countries mainly India and China. China was the world's largest crude steel producer in 2011–12 (684 Mt) followed by Japan (108 Mt), the USA (86.4 Mt) and India (73.79 Mt) at the fourth position. The Indian steel industry is characterized by fragmentation, particularly in the downstream segment, with a large number of unorganized players present in the market.

The Indian iron and steel sector accounted for around 5% of the world's total production

Table 22: Glass production in 2011–12

Glass sheet	Th. Sq. m	106,144
Toughened glass	Sq.m	2,678,263.93
Fibre glass	Tonnes	42,670
Glass bottles	Tonnes	12,719,208
Source: DIPP 2013		

in 2010. The crude steel production in the industry stands at about 73.79 Mt and the finished steel production (including secondary producers) stands at about 73.42 Mt for the year 2011–12. India is the world's largest producer of Direct Reduced Iron (DRI) or sponge iron. The sponge iron production for the year 2011–12 was close to 20.37 million tonnes. An analysis of the technology profile of sector in 2011–12 shows that 42.4% crude steel is produced through the blast furnace/basic oxygen furnace route (including marginal quantity from twin hearth furnace, 25.1% through Electric Arc Furnace (EAF) route, and the balance 32.5% through the Electric Induction Furnace (EIF) route.

The Government of India plans to increase its investment in ISS to the tune of US\$ 187 billion in the 12th Five Year Plan (2012–17). Steel production in India has been plotted in Figure 32.

Steel production in India has grown from 31 Mt in 2001–02 to around 61 Mt in 2010–11

at an annual growth rate of 7.6%. The steel industry mainly caters to domestic demands.

It is expected that steel demand would grow over at 10% per annum in the next five years because of the following projects and developments:

- Infrastructure projects like Golden Quadrilateral and Dedicated Freight Corridor
- Projected new greenfield and upgradation of existing airports
- Increased demand of specialized steel in hi-tech engineering industries, such as power generation, automotive, petrochemicals, fertilizers, etc.

In spite of that the steel intensity in the country remains well below the world levels. Our per capita consumption of steel is around 52 kg as compared to 150 kg for the global average and around 500 Kg for middle income countries like Malaysia. This indicates that steel consumption in India could increase to a large extent in the future.

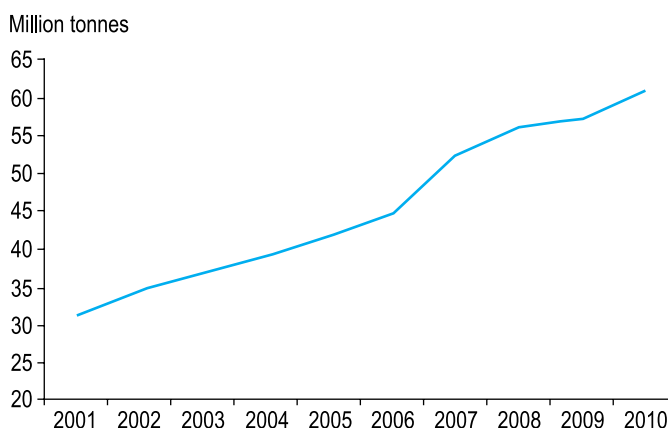


Figure 32: Steel production
Source: TERI (various years)

Iron and steel is one of the largest energy consuming sub-sectors in the Indian industry. Energy cost is about 30–40% of the total manufacturing cost in the sector. Iron making through the basic oxygen furnace route accounts for nearly 70% of the total energy consumed by the industry. The energy efficiency of steel making depends on various factors including production route, types of Fe-ore and coal used, product mix, material efficiency, technology used, plant capacity utilization, and economic and political incentives.

The industry has three major technologies—the Basic Oxygen Furnace, the Electric Arc furnace, and the induction furnace. The specific energy consumption of each has been provided in the Table 23.

Table 23: Specific energy consumption			
Process	SEC (toe/tonne)		
	2001	2006	2011
Basic oxygen furnace	0.79	0.73	0.65
Electric arc furnace	0.79	0.73	0.65
Induction furnace	0.75	0.70	0.63
<i>Source: SAIL 2013</i>			

The specific energy consumption of the Indian iron and steel industry has improved dramatically from about 0.76 toe/tonne of crude steel (tcs) in 2000–01 to 0.65 toe/tcs in 2008–09. However, the SEC values in Indian plants compare rather poorly against the SEC values in countries like Japan (0.56 toe/tcs-2004), US (0.48 toe/tcs-2001), EU (0.35t = toe/tcs-2002) and China (0.61 toe/tcs-2001) (CSE 2010). The emissions intensity of steel

production in India was estimated at 2.21 MT CO₂eq./tcs in 2007.

Pulp and paper

The Indian paper industry, comprising writing and printing paper, industrial paper, news print, and specialty paper, is the 15th largest in the world. The paper industry is highly fragmented as it consists of small, medium, and large paper mills with capacity variation ranging from 10 to 1,150 tonnes per day. As per the Report of the Working Group on pulp and paper sector for 12th Five Year Plan, India has 759 pulp and paper mills with an installed capacity of 12.7 MT which produce around 10.11 MTPA of paper, paper board and newsprint out of an annual consumption of about 11.15 MT (Planning Commission 2011). India's production of paper, paper board, and newsprint is 2.6% of the total world production. This industry is typically divided into three major sectors based on the raw material used—wood, agro residue, and recycled/waste paper and their share of paper production is 31%, 22%, and 47%, respectively. The variety-wise production of paper from different raw materials is presented in Table 24.

Growth of the paper industry is driven by the market demand, mainly on the overall industrial growth and literacy within the country. Paper consumption has been increasing gradually over the last two decades. But India still has one of the world's lowest per capita paper consumption standing at only 9.3 kg as against 42 kg in China, 22 kg in Indonesia and 312 kg in the USA. However, the increasing literacy

Table 24: Various type of paper production from different raw materials (2010–11)

Type of paper	Wood based	Agro based	RCF/Waste paper based	Total
Writing/printing	2.36	0.73	0.81	3.90
Packaging	0.77	1.50	3.15	5.42
Newsprint	0.03	Nil	0.76	0.79
Total	3.16	2.23	4.72	10.11

Source: TERI 2013

rate and fast emerging middle class has a positive impact on paper and paper board demand in the country.

The energy consumption and operational efficiency depends mainly on the level of the technology adopted by paper mills in their various processes. The technology level in Indian paper mills lags behind by about 30 years from the technologies being used in developed countries. Process optimization, waste heat recovery, and cogeneration systems offer significant scope for improving the performance of Indian paper mills.

Key Policies in the Sector Affecting Demand for Energy

Over the past few years, the Government of India has developed several policies, regulations and schemes targeting both large-scale industries as well as MSMEs to govern the energy and climate change agenda.

Energy Conservation Act, 2001: The formulation of the Energy Conservation Act in 2001 was the first major step taken by the Government towards energy conservation. The Act provides for the legal framework,

institutional arrangement, and a regulatory mechanism at the Central and State level to embark upon an energy efficiency drive in the country. Various provisions were created under the Act. These provisions included identification of DCs; standard and labelling of appliances; energy conservation building codes and establishment of an energy conservation fund. The Bureau of Energy Efficiency (BEE) was also set up as a component of the act with the primary objective of reducing energy intensity of the Indian economy.

National Mission for Enhanced Energy Efficiency (NMEEE), 2008: In 2008, the Government of India released the National Action Plan on Climate Change (NAPCC) to address both development and climate-related objectives. The action plan is being implemented through eight National Missions, one of which is the National Mission for Enhanced Energy Efficiency (NMEEE). The mission aims to scale up efforts for creating and sustaining a market for energy efficiency to unlock potential investments of around INR 74,000 crore (approximately US\$ 1.5 billion).²⁷ By 2014–15 NMEEE is expected to achieve

²⁷ www.beeindia.in/documents/BEE%20newsletter.pdf

about 23 Mtoe of fuel savings in coal, gas, and petroleum products, along with an expected avoided electricity capacity addition of over 19,000 MW. The carbon dioxide emission reduction is estimated to be 98.55 Mt annually. Four key initiatives have been conceptualized under the mission.

Perform, Achieve, and Trade (PAT): PAT is a market-based mechanism to enhance the cost-effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings (ESCCerts) that could be traded. Considering the quantum of energy consumption, the energy intensity and large bandwidth in energy usage pattern, eight industrial sectors (including power) have been selected in the 1st cycle of Perform, Achieve, and Trade (PAT) scheme. The scheme aims to achieve in the first commitment period of 3 years (ending in 2015), about 6.6 Mtoe (5.5% collective SEC reduction). The scheme is presently in the second year of implementation.

Energy Efficiency Financing Platform (EEFP): The function of EEFP is to create mechanisms to help finance the demand-side management programmes in all sectors by capturing future energy savings. EEFP will provide instruments, such as bankable Detailed Project Reports (DPRs) and other risk mitigation measures to enhance comfort for lenders towards aggregated energy efficiency projects. BEE has entered into MoUs with a few financial institutions for cooperation on energy efficiency initiatives and knowledge sharing.

Market Transformation for Energy Efficiency (MTEE): The objective of this initiative is to accelerate the shift to energy-efficient appliances, such as air-conditioners, televisions, ceiling fans, refrigerators, efficient lighting solutions, etc. The initiative also includes implementation of the Bachat Lamp Yojana (BLY) and the Super-Efficient Equipment Program (SEEP).

Framework for Energy Efficient Economic Development (FEEED): FEEED is focusing on developing fiscal instruments to promote energy efficiency. Two fiscal instruments—the Partial Risk Guarantee Fund (PRGF) and Venture Capital Fund for Energy Efficiency (VCFEE) are being developed under the framework. An estimated INR 66.62 crores have been allocated for both the funds.

Integrated Energy Policy (IEP): The IEP presents numerous recommendations pertaining to the industrial sector. It highlights the need to institute measures encouraging adoption of energy efficient technologies, particularly cross-cutting technologies, such as pumps, boilers, and motors. It also stresses the importance of strengthening energy service companies (ESCO) for facilitating energy audits. Benchmarking of energy intensive sub-sectors; creating regional testing facilities and labelling of products were other important issues covered under the policy report.

National Manufacturing Competitiveness (NMC) Programme: The Ministry of MSME launched the NMC Programme to improve the competitiveness of the MSME sector. Conceptualized by the National Manufacturing

Competitiveness Council, the programme was initiated in 2007–08. The programme covers 10 initiatives; of which, Technology and Quality Upgradation (TEQUP), focuses on energy conservation and support to SMEs. Other initiatives, such as the lean manufacturing competitiveness scheme, market assistance and technology upgradation scheme, design clinic scheme, and quality management standards and tools also contribute towards minimization of resource use, improved quality and overall efficiency in production.

Technology and Quality Upgradation (TEQUP) Support to MSMEs:

One of the main objectives of the TEQUP scheme is to assist MSMEs in upgrading their manufacturing technologies. The scheme offers technical assistance for capacity building; preparation of detailed project reports; and implementation of energy-efficient technologies. Subsidies of up to 25% of technology cost (with a maximum cap of INR 10 lakh) are provided for implementation under the scheme. It is expected that about 390 MSMEs will be supported to enhance their energy efficiency. Besides, reducing the energy cost, the activity will also enable the implementing enterprises in obtaining carbon credits.

National Steel Policy: Formulated by the Ministry of Steel in 2012, the National Steel Policy aims at transforming the Indian steel industry into a global leader in terms of production, consumption, quality, and techno-economic efficiency while achieving economic, environmental, and social sustainability. The steel policy recognizes the importance of environmental sustainability

through green technologies, energy efficiency, and optimal utilization of natural resources. It also highlights the need for technological improvements through research and development in the sector. The policy clearly highlights the targeted specific energy consumption and GHG reductions from the steel industry by 2025–26.

Key Issues

Despite the active involvement by the Indian Government in increasing energy efficiency measures in the country, the challenge to translate policies into action on ground still remains. Several gaps in current policies and measures contribute to the slow uptake of energy efficiency practices in industry.

Promotion of innovation

The failure to promote technological innovation is another notable gap. Keeping pace with constantly improving technologies requires an enabling environment and infrastructure that fosters innovation. Technology developers, supply industries and users need to cooperate, brainstorm and discuss market mechanisms to develop suitable technologies. However, Indian industries lack platforms for such innovation. The technological innovation is confined to fundamental in-house R&D efforts of a few progressive entrepreneurs and suppliers, and to reverse engineering methods. However, there are no major centres of excellence facilitating industrial technology incubation and evolution. Furthermore, technology adoption is a complicated process that requires handholding, fine-tuning, and

monitoring. Although incentive schemes are being developed to promote adoption of new technologies, there is limited implementation and deployment support offered to industries. This aggravates the existing inertia to execute changes.

Pricing of energy

It has been seen in several cases that favourable energy pricing frameworks can drive industry towards clean fuel technologies. However, such measures have only been executed on an ad hoc basis rather than in a planned manner, leaving significant missed opportunity for energy efficiency. It is also evident that large numbers of energy consuming equipment are procured by public sector bodies annually. The current system of procurement is based on a "L1" format, which gives extra weightage to least cost bids. Since energy-efficient technologies may have a higher upfront cost, such a system often hinders their penetration into public procurement tenders.

Lack of awareness and capacity building

Measures facilitating awareness and capacity building on energy-efficient technologies, best practices and financing energy efficiency projects are limited, particularly for the MSME sector. MSMEs are geographically dispersed across clusters and lack means to spread awareness. Similarly local suppliers, fabricators, and consultants also lack the capacity to implement new technologies and practices. Furthermore, there is limited

awareness on financial schemes, requirements, and procedures to access financing for energy-efficiency investment projects. There is a lack of Government policies that provide financial incentives to support industrial enterprises on the uptake of energy-efficient options. The lenders also face challenges in evaluating energy efficiency technologies, their returns and associated risks.

Lack of reliable data

The paucity of reliable data pertaining to industrial energy consumption is a fundamental gap that hinders targeted energy efficiency action. Currently, there is no formal energy data collection mechanism/framework at a national level for industry. This stems the possibility of detailed benchmarking and industries continue to operate with limited knowledge. While PAT has been the first step towards benchmarking at the level of large consumers, there are several other energy guzzling sectors and industries that remain out of its scope. Similarly, the standards and labelling programme of Bureau of Energy Efficiency (BEE) has created performance efficiency levels of different equipment/appliances. However, only a few equipment/appliances have been made mandatory for compliance with star rating, while many other energy intensive equipment are still in voluntary phase, resulting in significant missed opportunities for energy efficiency. In addition, it has been seen that market penetration of five star-rated products is still less as compared to lower star-rated products.

Chapter 8

Residential and Commercial

This chapter provides a brief overview of the energy consumption patterns in the residential and commercial sectors in India. This is followed by a discussion of the drivers and influencers of demand and the key challenges faced to meet the demand for energy and increase the efficiency of energy consumption in the two sectors.

Overview

Residential sector

At the residential level, energy demand comprises primarily of consumption demand for lighting, cooking, heating, and space conditioning in the rural and urban areas across the country. Over the years, an increase in the income level of households and an improvement in the access to energy sources have led to an increase in the consumption of energy in the sector.

The energy basket in residential areas comprises electricity, kerosene, liquefied petroleum gas (propane), and primary energy, such as coal, wood; and other renewable forms such as solar energy. Expenditure on energy forms an important component of the household spending. In 2011–12, it accounted for 6.5% of the household expenditure in urban areas and 8% in rural areas (NSSO 2013). The consumption of electricity in this sector has

increased from less than 77,000 GWh in 2002 to over 170,000 GWh in 2012 (CEA 2012).

The energy demand from the residential sector comprises demand from rural and urban areas. The access to modern forms of energy carriers has improved substantially in the urban areas with 92.7% (Census 2011) of the population now having access to electricity. However, access and availability of energy are still of primary concern in the rural areas. Rural households meet more than 70% of their energy demand from primary sources of energy, such as firewood and charcoal (NSSO 2013). Within the urban and rural sectors, energy consumption can be further disaggregated into usage for cooking, lighting, space conditioning, water heating, and other electrical appliances.

Urban

The urban residential sector is characterized by a higher uptake of modern forms of energy (Figure 33) and appliance usage. The rising rate of urbanization has increased pressure on demand for modern forms of energy in these areas which the current infrastructure like the transmission grid finds insufficient to handle. In addition, there are withdrawals from states due to high demand leading to a mismatch in supply and demand of electricity. The blackouts in July 2012 are one of the indications of this pressure.

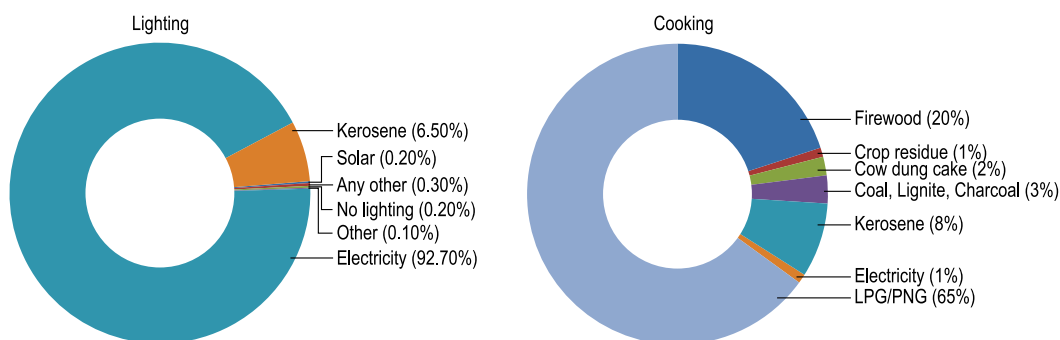


Figure 33: Share of urban households for different energy sources for lighting and cooking in 2011

Source: Census of India (2011)

The final energy basket of consumption in urban residential areas comprises petroleum products—kerosene, LPG and PNG for cooking, grid based and decentralized diesel and renewable energy-based electricity for lighting, appliance use, and space conditioning requirements. Traditional biomass is also used in some areas (mostly peri-urban and urban fringe areas and lower income households) for meeting the cooking energy requirements.

Rural

The rural areas depend largely on traditional biomass to meet their cooking energy needs

(86% firewood, crop residue, cow dung, and biogas) (Census 2011). In fact, since the share of biomass-based sources is very high in the energy consumption baskets of rural households, they actually consume more energy than urban households (Khandker, Barnes, & Samad 2010). With regards to lighting and appliance use, while the access to both grid-based and decentralized power has improved, a large proportion of the rural population continues to depend on kerosene to meet their requirements (43.2%) (Census 2011) (Figure 34).

One of the key developments in the residential sector has been the move

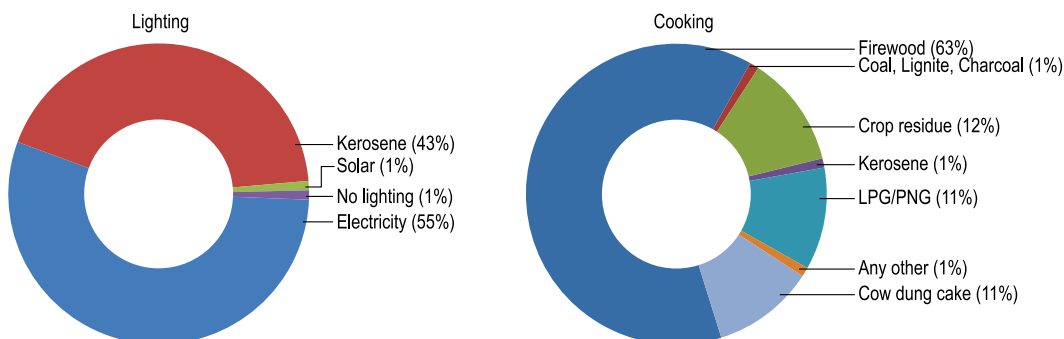


Figure 34: Share of rural households for different energy sources for lighting and cooking in 2011

Source: Census of India (2011)

towards enhancing the efficiency of energy consumption by introducing star rating of appliances and supporting the uptake of newer energy-efficient technologies in lighting, cooling, and heating. Further, in rural areas, introduction of policies such as the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), Bachat Lamp Yojana (BLY), Remote Village Electrification (RVE) Scheme, etc., for electricity and the National Biogas and Manure Management Programme (NBMP), National Clean Cook Stoves Programme, etc. for cooking energy have improved the level of access to energy-efficient appliances and have enhanced the efficiency of energy usage (MNRE 2013).

Commercial sector

Energy consumption by the commercial sector has increased from 11 Mtoe in 2006–07 to 16 Mtoe in 2011–12. In the year 2010–11, electricity consumption in the commercial sector in India accounted for about 10% of the total electricity supplied by the power utilities. The consumption has been growing annually at about 11–12%, much faster than the average electricity growth in the economy. This can mainly be attributed to the increasing energy intensity of the existing buildings, apart from new buildings that are being constructed rapidly all over the country (USAID ECO-III Project 2010), (TERI 2012). Electricity consumption in the buildings sector has increased at an average growth rate of 9% in the last 10 years (2001–11). Since buildings from the hospitality, hospital sector, commercial complexes, and offices form a major segment in the commercial sector, this sub-section looks specifically at the commercial sector (Figure 35).

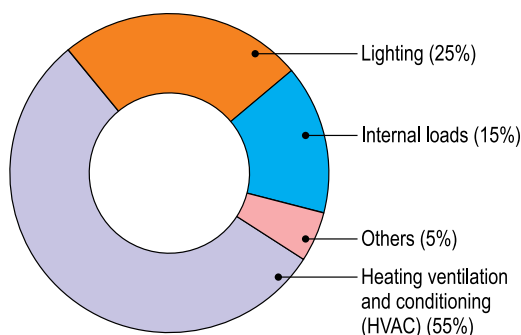


Figure 35: Energy consumption distribution in commercial building

Source: Planning Commission (2011)

Buildings in the commercial sector

Between the years 2009–10 and 2010–11, consumption grew by 14% with electricity being used to meet most of the end-use demands. The following section provides an overview of the major energy consuming sub-sectors in the commercial sector. The focus here is on urban areas but due to inadequate accounting of data, commercial rural sector is not covered in this chapter.

Commercial office buildings

Increased revenues of companies in the services business, especially in the software and IT services (ITES), as well as for IT-based Business Process Outsourcing (BPO), has resulted in the recent growth in the office buildings (Just 2006). According to the estimate of the consultancy firm Jones Lang LaSalle (Just 2006), up to 70% of the demand for office space is driven by over 7,000 Indian IT and ITES firms. About 15% is accounted for by financial service providers and the pharmaceutical sector, with the remaining 15% accounting to other sectors (Deutsche Bank Research

2006). Previously, commercial properties were concentrated towards Central Business District (CBD) areas in large cities. However, with the emergence of IT-ITES with rising office space requirement, commercial development started moving towards city suburbs. With influx of Multinational Companies (MNCs) and the growth of the services sector (telecom, financial services, IT & ITES, etc.), the demand for commercial office space is expected to grow further in the coming years.

Health care sector

During the last few years there has been an increase in the availability of health-care facilities in the country. As per the 11th Five Year Plan, the number of government hospitals increased from 4,571 in 2000 to 7,663 in 2006, i.e., an increase of 67.6%. Number of beds in these hospitals increased from 430,539 to 492,698, an increase of 14.4%.²⁸

The Government of India aims to develop India as a global health care hub. As per the *Energy Efficiency in Hospitals: Best Practice Guide*, there has been a wide array of policy support in the form of reduction in excise duties and higher budget allocation for the health care sector. Due to increase in the levels of health awareness, growing disposable income, focus on medical tourism, lifestyle-related diseases, there is an expectation to have a strong demand for health care services in India. This will create opportunities for greater investment in health care infrastructure and increase in the number of health care buildings in India (Address of Shri Ghulam Nabi Azad 2013).

Retail sector

The Indian Government has protected the local retail sector from Foreign Direct Investment (FDI) for many decades. The retail real estate market is still underdeveloped and is dominated by unorganized retail space providers.²⁹ These unorganized owners run local shops (i.e., *kirana* shop), general stores, footwear, and apparel shops. Street markets also comprise a majority of the retail sector. Several shopping malls have come up in the last few years, initially in Tier I cities and then in Tier II and Tier III cities as well. As per a Knight and Frank study, between 2010 and 2012, the organized retail real estate stock is expected to increase by more than double from 41 million square feet to 95 million square feet (KnightFrank 2010; TERI 2012).

With a historical growth in the market share of the retail sector, the energy consumption is expected to increase in future.

Hospitality sector

As per the statistics of the Ministry of Tourism, in 2010, the number of approved hotels and rooms in the country was 2,483 and 117,815, respectively, (TERI 2012). The number of unclassified hotels/establishment and rooms in the country was 233 and 10,956, respectively, (TERI 2012).

The Indian hospitality industry, especially in tourism — domestic, business, and leisure—has witnessed a strong growth over the last few years due to favourable economic and political environment. According to a

²⁸ For details, refer to the *Energy Efficiency in Hospitals: Best Practice Guide* (Prepared under ECO III project)

²⁹ These include owner-operated local shops that have sale areas typically less than 500 sq. ft.

research by the World Travel & Tourism Council (WTTC), travel and tourism in India is expected to grow at 12.7% per annum until 2019 (IBEF 2010). The total estimated supply of hotel rooms is expected to reach 6.6 million in 2020 (WTTC 2011).

Education sector

India is amongst the largest education markets in the world. The education sector in India is considered to be one of the major avenues for investments as the entire education system is going through a process of overhaul (PwC 2010).

The country has 544 university-level institutions and it is estimated that India will need 800 more universities and another 35,000 colleges by 2020 (OIFC 2013).

growth in population and income levels, size of households, level of urbanization, uptake of commercial and modern forms of energy, and Government policies.

The growth in population directly affects the demand for energy in the residential and commercial sectors. The rise in population over the years has had a significant impact on demand for energy (Figure 36).

The household size is also directly linked to the demand for energy in the residential sector (Gundimeda & Köhlin 2006). A reduction in the average household size is likely to increase the total number of households, thereby leading to a rise in the total demand for energy. Over time, the average size of households in India has changed, reducing from 5.34 in the year 2001 to 4.91 in 2011 (Census 2011).

Drivers of demand in the sectors

The key drivers for energy consumption in the residential and commercial sector are

Income

Concomitant to the increase in income levels in the past two decades, the demand for energy

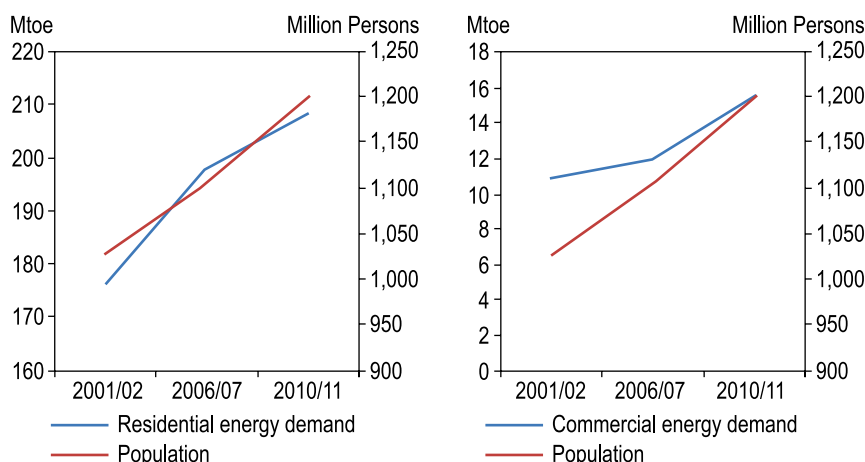


Figure 36: Trends in energy consumption in residential and commercial sectors and population (2001–2011)

Source: PFI 2007; TERI compilation

in the residential and commercial sectors has also increased from 191 Mtoe in 2001 to 224 Mtoe in 2011 (Figure 37).

An increase in income is generally associated with rising consumption of energy as economic affluence brings with it an increased demand for energy consuming appliances.

However, beyond a point, higher income can also lead to improvements in efficiency of energy use through uptake of newer appliances that may result in a reduction in overall energy consumption. However, usage of efficient appliances is not just dependant on incomes but must also be encouraged by various policies and institutions implementing these policies.

Urbanization

Higher levels of urbanization lead to a rise in demand for lifestyle goods (Das & Paul 2013)³⁰ that typically require more energy. Urbanization has also seen a rising demand for modern fuels which lead to an increase in the demand for commercial energy in the residential sector. The rate of urbanization in India has increased from 28% in the year 2001 to 30% in 2011 (Census 2011).

Government policies

Government policies can be key drivers in determining the demand for energy in the economy. Government policies have been introduced to address two aspects—increasing access to energy and to increase

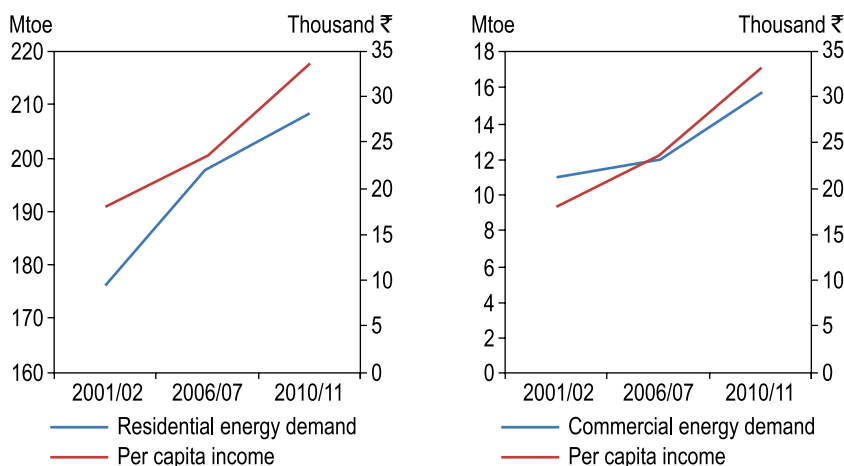


Figure 37: Trends in energy consumption in residential and commercial sectors and annual income levels 2001–11

Source: RBI 2010; TERI Compilation

³⁰ The authors define household effects as “These are not basic requirements but are purchased to give a comfortable and good lifestyle associated with one’s affluence; like carpets, wood products, furniture, leather, rubber and plastic goods for personal and household use as well as use in automobiles”

the efficiency of energy use in the residential and commercial sector in the country.

Major government policies

Government policies and initiatives can also be disaggregated into those intended towards providing access to energy and improving the delivery of energy services and those that support efforts to enhance efficiency for energy use. Particularly in this context, the Government of India has embarked on a number of programmes and initiatives to support stakeholders of the building sector to comply with and follow the strategies for achieving energy efficiency in buildings.

Enhancing energy access

Rajiv Gandhi Gramin Vidyutikaran Yojana (RGGVY): The RGGVY was introduced in 2005 in order to enhance electricity access to rural areas and facilitate the creation of electricity infrastructure networks. The programme is being implemented through the Rural Electrification Corporation (REC). For financing the project, a 90% capital subsidy is provided to create the Rural Energy Distribution Backbone, Village Electrification Infrastructure, and the Decentralized Distributed Generation and Supply. The BPL households are provided the connections free of charge. As of April 2013, 20,515,472 BPL households were provided electricity under the scheme (Lok Sabha 2013). Several financial and performance models have been introduced in order to achieve the objectives set under the scheme. As per the latest report of Lok Sabha Standing committee, the targets set under the scheme will be achieved by 2014–15 (Lok Sabha 2013).

Remote Village Electrification Programme (RVEP): The RVEP was introduced by the Ministry of Power in 2006 with the objective of electrifying remote villages where grids cannot be extended due to lack of financial/physical feasibility. As of June 30, 2013, 10,154 villages and hamlets had been provided with electricity under the scheme (MNRE 2013).

Rajiv Gandhi Gramin LPG Vitarak Yojana (RGGLVY): The Government has also introduced the RGGLVY which involves providing subsidy to households for getting LPG connections and purchasing LPG stove. The programme is being implemented through the creation of a fund from the Corporate Social Responsibility (CSR) contributions of the oil companies. Indian Oil Corporation is the lead coordinator for this programme.

Improving energy efficiency in the sector

National Mission on Sustainable Habitat: The Prime Minister's Council on Climate Change released India's National Action Plan on Climate Change (NAPCC) on June 30, 2008. One of the NAPCC's eight missions is the National Mission on Sustainable Habitat (NMSH) that promotes energy efficiency in the residential and commercial sector. To promote energy conservation in the residential and commercial sectors, the NMSH emphasizes the extension and incorporation of the Energy Conservation Building Code (ECBC) into municipal by-laws to mainstream energy efficiency.

Energy Conservation Building Code: The Energy Conservation Act (2001) led to the formation of the Bureau of Energy Efficiency (BEE) that started the formulation of the

Energy Conservation Building Code (ECBC) in 2007. The ECBC aims to reduce baseline energy consumption by setting minimum energy performance standards for new commercial buildings, including for building envelopes, mechanical systems and equipment, including Heating, Ventilation, and Air Conditioning (HVAC) systems, interior and exterior lighting system, service hot water, electrical power and motors.

Section 14 (P) of the Energy Conservation Act empowers the Government of India to prescribe ECBC for commercial buildings or building complexes for efficient use of energy and its conservation. State Governments have the flexibility to modify ECBC to suit local or regional needs, where GRIHA (Green Rating for Integrated Habitat Assessment) is being adopted as a tool to ensure implementation of the same. The plinth area rates of Central Public Works Department (CPWD) have been revised to incorporate energy efficiency through the GRIHA framework.

Standards and Labelling Scheme: The Bureau of Energy Efficiency, a subsidiary body of the Ministry of Power, has several programmes that lay down minimum energy performance standards for high-energy end-use equipment and appliances. Each appliance is ranked on a scale of five stars, with more stars indicating higher efficiency and more power savings—thus the programme motto ‘More Stars, More Savings!’³¹ The labels provide information about the energy consumption of an appliance, and thus enable consumers to make informed decisions.

The efficiency bandwidths used to determine Star Labelling for an appliance are revised periodically, and are currently defined for appliances in a mandatory phase up to 2015. Almost all fluorescent tubelights sold in India, and about two-thirds of the refrigerators and air conditioners, are now covered by the labelling programme (MoEF 2007).

Green Rating for Integrated Habitat Assessment (GRIHA): GRIHA is a five star rating system for green buildings endorsed by the Ministry of New and Renewable Energy (MNRE). It focuses on passive solar techniques for optimizing indoor visual and thermal comfort. It also encourages the use of refrigeration-based and energy-demanding air conditioning systems only in cases of extreme thermal discomfort (MNRE & TERI 2010, p21).

To promote energy efficiency, GRIHA encourages optimization of energy performance in building design. It optimizes energy performance within specified comfort limits (i.e., optimum temperature and relative humidity levels as per each climate zone of India) as specified in the National Building Code 2005. It mandates that certain minimum operational energy requirements are met from renewable energy sources of electricity to reduce dependence on grid electricity.

GRIHA integrates and facilitates implementation of all relevant Indian codes and standards for buildings (including mandatory compliance with ECBC, mandatory integration of renewable energy and recommends

³¹ For details visit Bureau of Energy Efficiency website for the Appliance Efficiency Standards at <http://www.bee-india.nic.in/Implementation/Standards per cent20& per cent20Labellings.html>

use of BEE star labelled appliances and lighting devices.

GRIHA is a voluntary tool, but has been adopted for all future buildings of the Central Public Works Department (CPWD), Ministry of Urban Development, Government of India. The CPWD is the largest agency responsible for constructing Government buildings across the country. The Pimpri Chinchwad Municipal Corporation (PCMC) has announced financial incentives for developers to make buildings GRIHA-compliant. Further, a property tax rebate is also offered by the PCMC to people who occupy and own GRIHA-compliant buildings. The New Okhla Industrial Development Authority (NOIDA) and Government of Punjab have announced a 5% additional floor area ratio incentive for projects that comply with GRIHA (GRIHA 2013; Department of Housing and Urban Development 2013).

Scheme for Star Rating of Office Buildings:

To accelerate energy efficiency activities in existing commercial buildings, the BEE has developed a star rating programme for buildings based on actual performance in terms of specific energy usage (in kWh/m²/year). Buildings are rated based on assessment of electricity bills against the benchmarks established for each building typology in different climatic zones.

Environmental Clearance of Building Projects:

Environmental Impact Assessment (EIA), which is mandatory for all projects over 20,000 square metres of built-up area, requires information on ECBC-compliance submitted for evaluation to relevant authorities as per the specific State Government requirements.

A questionnaire-based qualitative examination to ascertain compliance with the ECBC is conducted before awarding environmental clearance for construction of any proposed project.

Further, fast track environmental clearance has been linked to pre certification with GRIHA and LEED rating systems (which incorporate compliance with ECBC), thereby strengthening incorporation of energy efficiency in the built environment.

Key Challenges/Issues

Access and availability of energy sources

A major concern faced by the residential sector today is ensuring access to reliable energy. As mentioned earlier, the dependence on biomass-based fuels, particularly in rural areas is extremely high. As per the latest Census (2011), 86% of rural households reported fuelwood and other biomass-related sources as their primary sources for cooking energy. In urban areas, this figure stands at 24% of households. Various Government policies, such as provision of subsidized LPG, the National Programme on Biogas Development, and National Programme on Improved Cookstoves have been introduced to enhance access to cleaner forms of cooking energy.

The 55.3% of rural and 92.7% of urban households report electricity as their primary source of lighting energy (Census 2011). The transition to modern forms of energy is therefore more visible in meeting the lighting demand. Rural households where cooking forms a major component of energy use the transition has been limited. This is primarily

due to sustained efforts by Government to provide electricity in rural areas. Particularly, the RGGVY, which was introduced in 2005, aims at providing access to electricity to all rural households by providing a capital subsidy of 90% and soft loans from the Rural Electrification Corporation (REC) for the remaining 10%.

Ensuring efficiency of energy usage

Ensuring efficient use of energy at the rural and urban household level is another key challenge for the residential demand sector. In rural households, continued dependence on traditional appliances, such as traditional cookstoves, kerosene wick lamps leads to a significant loss of energy as these are inefficient forms of converting energy.

Various policies to ensure demand side management and enhancement of energy efficiency have been introduced in order to improve the levels of efficiency. These include the Bachat Lamp Yojana, Standard and Labelling Programme for appliances and the Energy Conservation Building Code (ECBC). However, large-scale uptake of these is limited to urban and metropolitan areas. Some of key challenges affecting the uptake of these measures are the perception of higher costs among both users and builders, higher initial costs of equipment—as in the case of Compact Fluorescent Lamps (CFLs) (Lefèvre, de T'Serclaes, & Waide 2006) and the lack of awareness.

Pricing

Another key issue affecting energy demand in the residential sector is the pricing of energy

sources. Pricing of modern cooking fuels, such as LPG, is one of the deterrents in its uptake in rural areas. Despite nearly 50% subsidy on each cylinder, the number of households reporting LPG as the primary fuel for cooking is low. As prices of energy products rise, affordability of modern energy products/carriers also gets affected, especially for rural households since expenditure on energy products/carriers form a part of their total consumption baskets.

Perceptions

Investment in more efficient forms of technology, though profitable in the medium to long terms, is perceived to involve high costs. A perceived notion of high costs of green buildings among developers and lack of confidence among financial institutions to incentivize energy efficiency in upcoming construction is a major impediment in large-scale implementation of green buildings. However, as a beginning, the National Housing Bank has started a refinancing scheme for public lending institutes that link construction of residential developments with incorporation of energy efficiency (through a tool called ResBuild) to a cheaper loan that may/may not be extended to end consumers.

Lack of knowledge and awareness

There is a need to spread awareness and increase knowledge on measures that enhance energy efficiency in the built environment. Lack of material at an optimum cost, and support for maintenance discourages the large-scale adaptation of new and innovative solutions.

Gaps in effective policy implementation

Some of the difficulties faced during implementation of policies on sustainable habitats are the lack of disincentives for policy non-compliance, agencies and systems working in factions (i.e., various departments at the Centre and State levels looking at issues related to energy efficiency, renewable energy, water and other material resources, waste management independently; as opposed to following a holistic approach that would address the building sector encompassing water, energy, etc., as a

whole); and implementation of codes and standards prior to verification on site leading to implementation challenges on site.

In case of rural areas, several policies to enhance access of energy to local population have been introduced but with limited success. There is a need to integrate the various efforts, such as the RGGVY, initiatives to enhance the implementation of clean cookstoves³² and put in place stronger monitoring mechanisms³³ (what are these monitoring mechanisms—give an illustration through a footnote) in order to ensure that the set targets are met in the targetted timelines.

³² The Ministry of New and Renewable Energy has revived the National Programme on Improved Cookstoves Programme which was initiated in the 1970s in India. MNRE formed a “New Indian Cook-stove Initiative” in 2009. A core group was established comprising experts from institutions, industries, NGOs, and other organizations active in the area of improved cookstoves. Pilot projects have been implemented as a part of this initiative. A steering committee was formed and delivery models to implement dissemination of family type cookstoves have been tested as a part of this initiative. The improved cookstoves went through BIS certification process and the ones which got certificate and were disseminated are: Vikram cookstove, Harsha Multi-fuel cookstove, Oorja cookstove, Phillips cookstove. Many of them were also disseminated as a part of the Indira Awaaz Yojana of the Government. Excise duty exemption was also given to these stoves. Information retrieved from http://www.inspirenetwork.org/mnre/New_India_cookstove.html

³³ These mechanisms could include regular updates, feedback from beneficiaries, and involvement of local governments in reviewing the implementation of the schemes

Chapter 9

Transport

Overview

The transport sector in India accounts for about 28% of the total commercial energy use in 2010–11 (TERI 2014). The transport sector has seen a two-fold increase in energy consumption in the last decade from about 34 Mtoe in 2001 (TERI 2006) to about 64 Mtoe in 2010–11 with a rate of growth of sectoral energy consumption of 7% Compound Annual Growth Rate (CAGR) (between 2001 and 2011).

Growth in transport sector's energy consumption is fuelled primarily by an unprecedented growth in road transport traffic. Road transport, for both urban and inter-city movement of passengers and goods, has grown at a rate of about 10% and 15% annually (CAGR) between 2001 and 2011, as compared to a growth of about 8% and 7% in the railways. In terms of growth rates, only air passenger traffic had a higher rate of growth (16%) than road.

Dominating the modal share in passenger and goods movement, the road transport sector has seen a significant increase in the last couple of decades. This has been accompanied by a declining share of traffic on the railways and marginal increase in water transport. Simultaneously, the last decade has also witnessed the emergence of low-cost airlines providing passenger transport services for longer distances.

Road transport, almost entirely dependent on petroleum products, consumes almost of 94.5% of the total energy demand of the transport sector as of 2010–11, followed by railways (3.5%) and airways (2%). The increasing energy demand of the sector would have strong implications for India's energy security, as the sector is heavily dependent on petroleum the bulk of which is imported. Constituting one of the largest shares of petroleum consumption in the country, this sector would have to bring about massive technological changes if dependence on petroleum products has to be reduced.

Key Trends

The following section outlines the key trends seen in the transport sector in India in the last two decades.

Road transport

Almost entirely in the form of petroleum products, road transport consumes the highest share of energy across all modes for both passenger and freight transport in the country. In 2011, passenger vehicles consumed about 58% of the energy in road transport while commercial vehicles carrying freight consumed the remaining.

Growth in passenger road transport sector

The last three decades have witnessed a significant increase in the demand for passenger mobility, primarily due to fast economic and population growths as well as increasing rates of urbanization in India. This has resulted in an exponential rise in the levels of motorization. The stock of on-road passenger vehicles comprising cars, jeeps, two-wheelers, taxis, three-wheelers, and buses has increased at a very high average annual growth rate of about 12% between 1981 and 2011 (Figure 38). Passenger vehicles sales have also witnessed high growth rates, with the last decade witnessing a high average annual growth of about 13% in vehicle sales. Overall, the annual growth in passenger vehicles in the last three decades has been faster than economic growth (Figure 39).

The rapid growth in passenger vehicles has been largely dominated by personal vehicles, i.e., two-wheelers, cars, and jeeps. In 2011, 92% of the total on-road passenger vehicles were two-wheelers, cars, and jeeps, the remaining 8% being buses, three-wheelers, and taxis. Two-wheelers comprised 76% of personal vehicles in the country in 2011 (Figure 40).

While personal vehicles have been growing rapidly, they carry only a small share of the passenger load (Figure 40 and 41). In 2011–12, most of the road-based motorized passenger traffic, both urban and inter-city, moved on public transport modes such as buses and omnibuses. Comprising less than 1% of the country's vehicle stock, buses and omnibuses generated about 78% of the road-based passenger traffic in 2011 and consumed

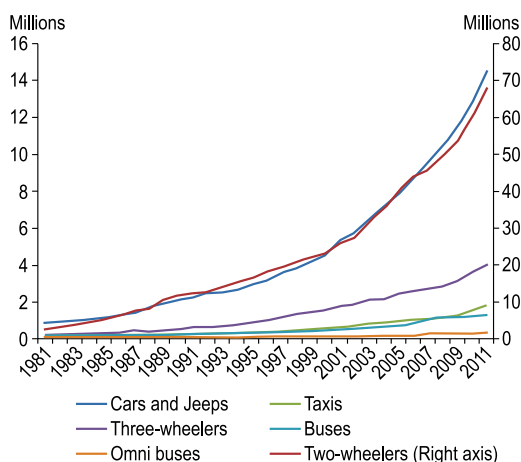


Figure 38: Growth in estimated registered on-road passenger vehicles in India (1981–2011)
Source: TERI estimates

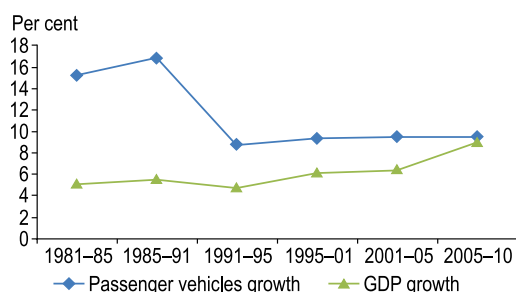


Figure 39: Average annual growth of passenger vehicles with respect to economic growth rates
Source: MoRTH 2012a

about 50% of the share of energy used by the passenger road transport sector (Figure 40, 41, and 42). On the other hand, cars and jeeps with just 8% share in passenger traffic, consumed almost 20% of the energy within the transport sector (Figure 42).

Road-based freight transport

About 70% of the freight traffic in India moves on roads; with commercial goods vehicles forming the backbone of freight transport in

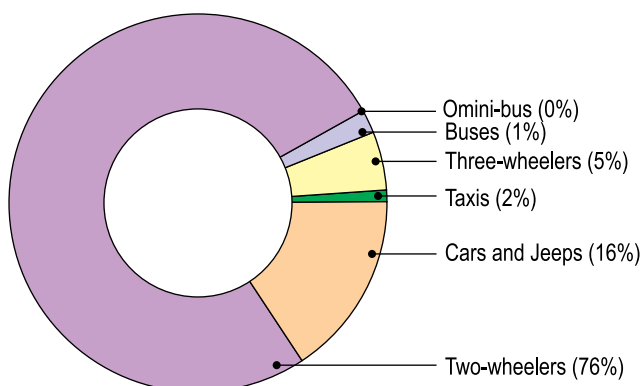


Figure 40: Estimated on-road passenger vehicle composition in 2011

Source: TERI estimates

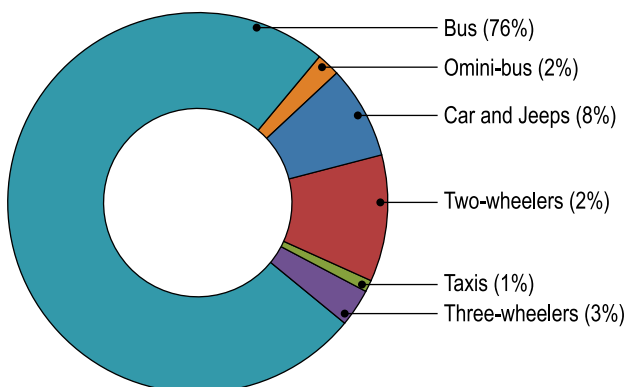


Figure 41: Share of road-based passenger traffic on different vehicle types (2011-12)

Source: TERI estimates

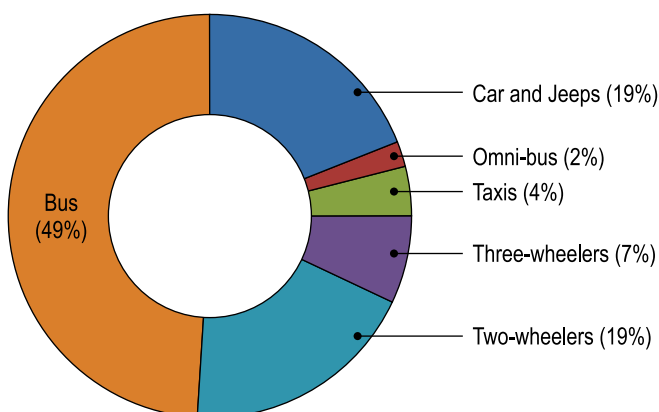


Figure 42: Share of energy consumed by different road passenger vehicles (2011)

Source: TERI estimates

India. They are also however the category of vehicles consuming the highest share of diesel in the country.

With the ease of last-mile connectivity provided by trucks and trailers and a supply-constrained railway network that does not offer customized logistics support to end customers, the last decade in particular has seen a rapid growth in the use of these heavy and medium commercial vehicles in the country. This is clearly reflected in the sales numbers of such vehicles that also seem to coincide with the roll out of the National Highways Development Programme in 1998 (Figure 43).

The total number of registered HCVs and LCVs in India in 2010–11 was 3.8 million and 3.3 million, respectively. The cumulative annual growth rate of HCV registrations increased from about 4.2% during 1991–2001 to about 6.2% during 2001–2011. At the present rates of growth, the number of on-road HCVs and LCVs will grow over 10 times, crossing the 30 million mark in the next two-and-a-half decades. Being the principle workhorses for moving freight across the country, these vehicles have also become the single largest consumer of diesel in the country with largely inelastic fuel demands.

Rail transport

True to its theme, the railways in India have historically played the role of being the “lifeline to the nation” by being the principle mobility provider for both people and goods across the vast expanse of the Indian sub-continent. While being the lifeline, it has also become the single largest consumer of energy in India (CAG 2012). For traction alone, the Indian Railways consumed about 2,705 million litres of diesel and over 14,157 million units of electricity in 2011–12 (Indian Railways 2013). To put this into perspective, the diesel used by the Railways is about 3.8% of the diesel used nationally (MoPNG 2012), and the electricity used would be able to power an Indian city of almost million people for a year (CAG 2012).

From purely steam-based traction in 1950–51 (using 9,500 thousand tonnes of coal), the Indian Railways introduced diesel traction in a major way in the 1960s, followed by electric traction in the 1980s. As of 2011–12, Indian Railways operated 5,197 diesel and 4,309 electric locomotives for moving over 1,047 billion passenger and 668 billion tonne kilometres. At a CAGR of 9% for passenger and 8% for freight between 2000–01 and

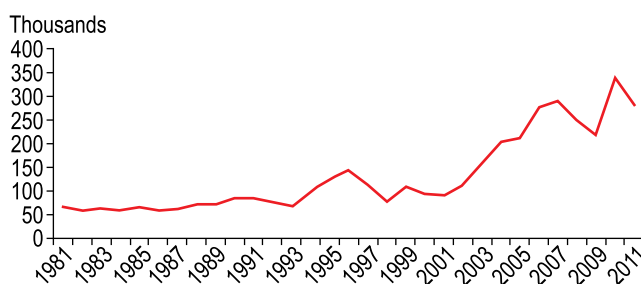


Figure 43: Sales of medium and heavy commercial vehicles (including exports)

Source: SIAM 2012

2011–12, the railways have seen more than doubling of the traffic in the last decade alone (Figure 44).

To meet this rapidly increasing demand, the Indian Railways has been in a limited way trying to increase the bandwidth of its overall network by green-field expansion as well as doubling of its tracks on various sections. In addition to the introduction of more powerful locomotives, the Indian Railways has also increased train lengths for both passenger and freight services. However, given that the rate of growth of traffic is much higher for road and air transport, the limited growth rate in the railways has been continuously leading to a decline in its share in national traffic.

In addition, the average leads of freight transport on railways have also seen a significant variation over the last two decades. From an average lead of 741 km for revenue earning traffic in 1990–91 the lead distance went down to 660 km by 2000–01, before rising to 689 km by 2011–12. Although in absolute terms the freight volumes on rail have been consistently rising, a declining average lead has

meant that the railways has also been losing some of the long-distance transport shares. The drop has been most acute for iron-ore and cement, each of which forms approximately 10% of the share of the railways. While the average leads for cement dropped from 656 km to 576 km between 1990–91 and 2011–12, the average leads for iron ore dropped from 574 km to 385 km during the same period. The leads for coal, which forms almost 44% of the freight earning traffic on railways (2011–12), also declined between 1990–91 (636 km) and 2000–01 (597 km), marginally rising to 639 km by 2011–12. The creation of the Dedicated Freight Corridors (DFC) along the western and eastern arterial railway corridors is expected to help the Indian Railways gain some of its declining leads and its shares in overall traffic.

In terms of the choice of traction, most of the trunk routes of the Indian Railways along the western and eastern corridors of the country have already been electrified over the course of the 9th, 10th and 11th Five Year Plans. Of the 64,600 route kilometres of the Indian Railways, about 20,275 kms, or about

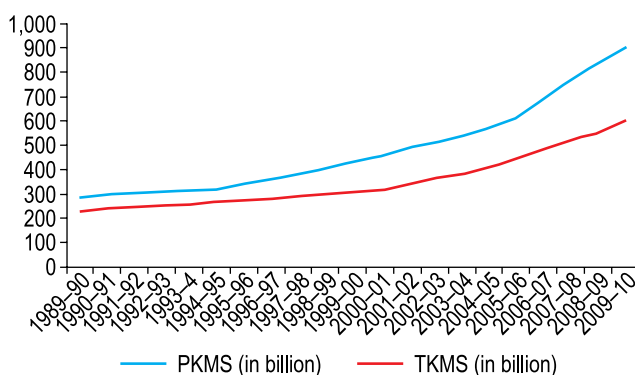


Figure 44: Growth of traffic on the Indian Railways (passenger and freight)

Source: Indian Railways 2013

31%, was electrified as of 2011-12 (Figure 45). This translates to about 43% of the running track kilometres.

Air transport

Civil aviation in India celebrated its centenary year in 2011-12. However, for most of its existence, it had been seen as a choice of mobility for the upwardly mobile and rich. This perception started to change with the emergence of the low-cost air carriers in India at the turn of this century. Their impact has been so large that in the last 10 years, the market share of low-cost carriers has gone from nothing to more than 60% (between 2003 and 2012) (Indigo-27.3%, GoAir-7.4%, SpiceJet-19.5%, Jetlite-6.9%, Jet Airways-18.3%, Air India-20.7%) (DGCA 2013). When compared with the overall growth in volumes over the last two decades (12% CAGR between 1993-94 and 2010-11), the growth has been much sharper since the introduction of low-cost carriers since 2003 (17% between 2003-04 and 2010-11) (Figure 46).

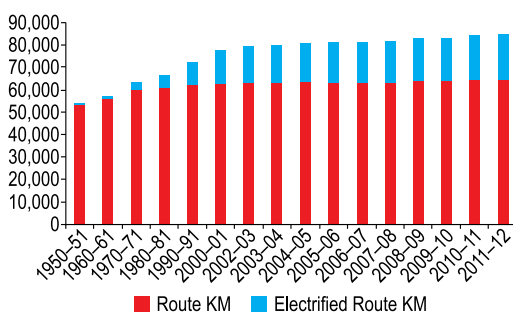


Figure 45: Railway route kilometres electrified

Source: Indian Railways 2013

Generating about 53 billion passenger kilometres in 2010-11, the aviation sector is responsible for about 1% of the overall share of mobility in India. Although under the reference energy scenario, this share is not expected to increase significantly over the next couple of decades, the air-traffic passenger volume is expected to grow manifold. This would be made possible by the expansion of the present heavily used domestic and international airports and the addition of another 50 new low-cost small airports (PMO 2013) over the course of the next few years.

Airline Turbine Fuel (ATF) consumption in India has gone up from 2,811 thousand tonnes³⁴ in 2004-05 to over 5,078 thousand tonnes by 2010-11 (MoPNG 2012). With a rapidly growing economy and increasing per capita incomes, coupled with the inadequate supply of quality railway services for long distance mobility, it is expected that the aviation sector will become a significant mobility provider for India. Air freight, however, has still only limited presence in India.

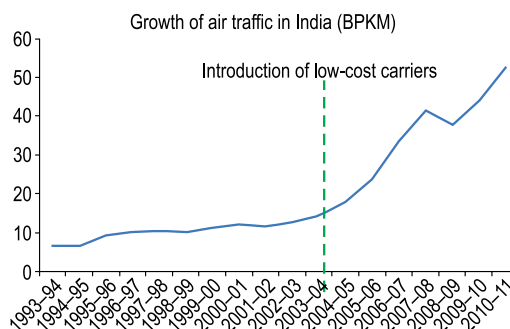


Figure 46: Growth of air passenger traffic in India between 1993-94 and 2010-11

Source: DGCA 2013

³⁴ ATF consumption figures include sales volumes for domestic and international flights. However, all traffic volumes considered are domestic traffic

Water transport

Owing to the rapidly growing economy with intense demands for trade, the last decade has seen significant changes in the freight traffic handled by Indian ports. The decade between 2000–01 and 2010–11 saw a growth of over 9% (CAGR) of total cargo traffic at Indian ports. As of 2010–11, there were 199 major and non-major ports (12 major, 187 minor) in India handling over 885.5 Mt of both international and domestic cargo and another additional 114 Mt of container shipments. Of this, over 83% was overseas traffic, and 153.2 Mt was attributed to coastal shipping for the domestic markets. However, the share of traffic for coastal shipping is declining and most of the traffic growth is due to international/overseas trade.

In the recent years, the emergence of the non-major ports has fuelled a large portion of maritime growth. As of 2010–11 about 36% of the total cargo and 31.5% of the total coastal cargo in India was handled by non-major ports across the country.

There is also a small amount of passenger traffic on Indian ports catering to mostly

international traffic. But even this traffic has been very erratic over the years (Figure 47).

Key Issues

Rapid growth in economic activity accompanied by increasing urbanization over the last couple of decades has resulted in a phenomenal growth of transport activity all across the country. A result of numerous overlapping factors, this growth in transport demand has been characterized by a shift towards more energy intensive modes of transport.

The economic liberalization in the early 90s, has had a significant impact on the growth of the transport sector in the country. With the automotive sector being opened up to 100% Foreign Direct Investment (FDI) after de-licensing, the automotive industry has grown by leaps and bounds to serve both the domestic and export markets. Automobiles for different needs and of different price ranges are now available much more easily than they were in the past, especially with easy availability of finance. As a result, the sales of automobiles in the country have witnessed

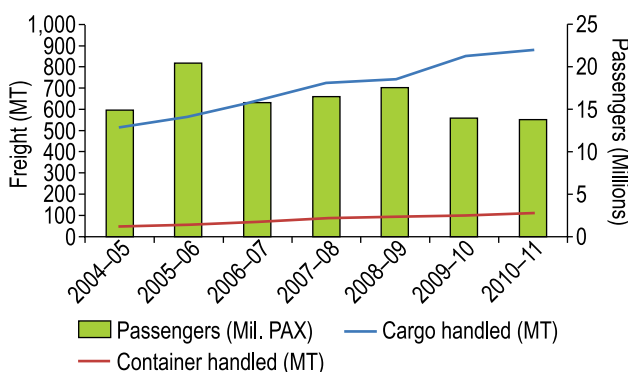


Figure 47: Growth of traffic handled at Indian ports

Source: MoRTH 2013

unprecedented growth; total registered cars and jeeps for instance grew from about 850 thousand in 1981 to about 2.7 million in 1991, 6.4 million in 2001 and 17.4 million in 2011 (MoRTH 2012a).

The increased focus on developing more and better quality of road infrastructure, both urban and inter-city, through several national and urban development programmes like the National Highway Development Programme (NHDP) and the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), has further provided a boost to the growth of automobiles and transport by roadways. Railways, on the other hand, have been largely constrained by the limited infrastructure growth and have been losing a significant percentage of the share of total mobility to road transport for both passenger and freight mobility. In passenger transport, the share of the railways has declined from about 15% in 2000–01 to about 12% in 2010–11, while in freight transport there has been a more drastic decline from about 50% to 36% during the same period. This is a cause for concern given that the railways are the most energy-efficient land surface mode of transport mode in terms of energy consumption, in both passenger and freight kilometre. Similar to rail infrastructure growth, the growth in public transport infrastructure in urban areas has also been much slower as compared to the growing demand for mobility in cities. This has resulted in increasing use of personal vehicles, which are much more energy intensive as compared to public transport modes (Figure 48).

Given the higher energy intensity of road-based transport as compared to rail-based transport and that of personal modes as

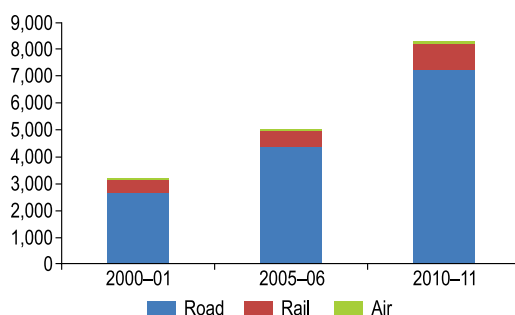


Figure 48: Changing share of passenger mobility between 2000–01 and 2010–11

Source: TERI estimates

compared to public modes of transport, the current trends in favour of road and personal transport have large implications in terms of energy requirements for the sector (Figure 49 and 50). As can be noted, there has been a significant increase in the energy consumed in the transport sector between 2001 and 2011, with the road transport sector dominating energy consumption in both passenger and freight transport. The share of road transport in total energy consumption has been steadily increasing; from 92% in 2000–01, to about 95% in 2010–11 (Figure 51).

Given the vital role that transport systems play on the overall growth and development of the economy, it is critical that the key issues constraining mobility be understood and addressed quickly. The following sections outline the key issues facing each of the sub-sectors of the transport sector particularly from the point of view of its energy demands.

Road transport

Road transport is the largest energy consuming transport sector in India. However, given that it is not as energy efficient as railways and waterways, increasing share on roadways

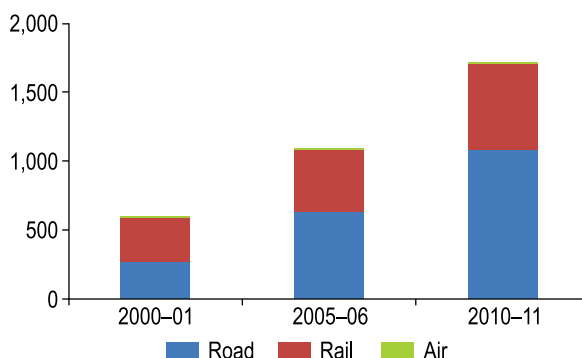


Figure 49: Changing shares of freight mobility between 2000-01 and 2010-11

Source: TERI estimates

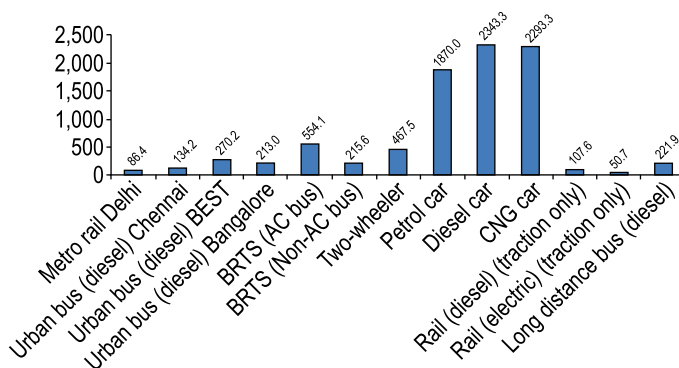


Figure 50: Energy intensity of different urban and intercity modes of transport

Source: TERI 2013

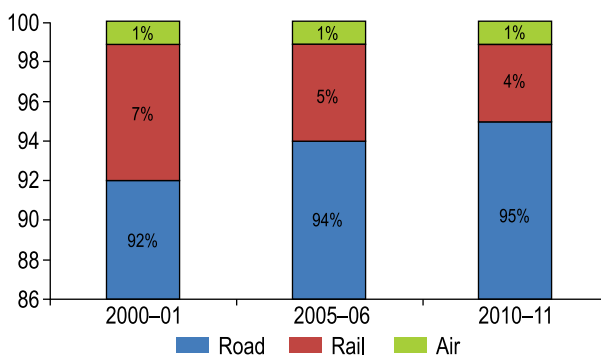


Figure 51: Changing shares of energy use in different modes of transport

Source: TERI estimates

has the potential to significantly increase the energy demands for transport in the country.

Rapid growth in motorized private passenger vehicles

As seen in the road transport trends, with a rapidly growing economy and increasing rates of urbanization there has been a high growth in the number of private vehicles in the country. Given that, an increasing share of mobility on private motorized modes leads to increasing energy intensities per passenger kilometre travelled, the energy intensity of road transport is also on the rise.

However, it is interesting to note that even with higher growth rates being witnessed in passenger vehicle sales, India has one of the lowest car ownership levels in the world, with 13 cars per 1,000 people as of 2011–12. While these average car ownership levels at the national level may seem to be low, it is important to note that the larger cities of India have a significant concentration of the total car population and much higher car ownership levels (Figure 52). With the increasing number of million-plus cities, car ownership levels are expected to rise significantly over the course of the next 2–3 decades. This will have an impact on energy consumption in urban transport sector (Ghate & Sundar 2013).

Similar to passenger cars, the two-wheeler ownership levels in India are also expected to increase significantly from the current levels of 60 two-wheelers per 1,000 people as of 2010–11. A significant proportion of growth in two-wheeler population is expected to occur in Tier-II cities, smaller towns and rural areas, which will experience increase in

per capita incomes and will have improved road connectivity.

Not only does this lead to increased energy intensities and energy demands for the transport sector, it also causes an increase in the levels of congestion which has further potential to reduce the fuel efficiencies of all road-based modes of transport.

Decline in the share of public transport

Despite the fact that public transport modes carry bulk of the traffic and are more energy efficient, there has been a continuous decline in the share of public and intermediate para-transit modes, i.e., buses, omni-buses, taxis, and three-wheelers. The share declined from 11% in 1981 to 8% in 2011 (Figure 53).

These vehicle segments have also witnessed slower growth in the last three decades as compared to the growth in personal vehicles. Specifically, the growth in the number of on-road buses and omni-buses has been slow with an average annual growth rate of about 8% between 1981 and 2011 as compared to annual growth of 12% in two-wheelers and 10% in cars and jeeps. The declining share and slow growth of public and intermediate para-transit modes indicates that while the demand for mobility has increased, the growth in public and intermediate para-transit modes hasn't been able to match up with this demand.

The Government of India has made efforts through the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and the National Urban Transport Policy to improve and enhance public transport in the large urban centres across the country. Although the JNNURM reforms have led to an increase

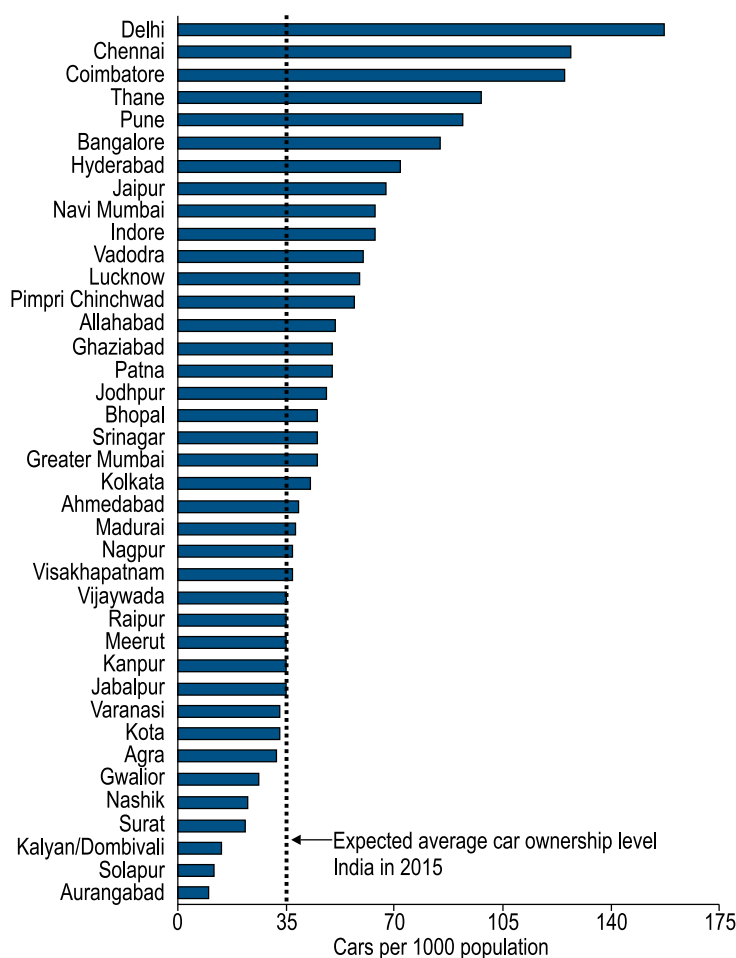


Figure 52: Car ownership levels in 39 out of 53 million-plus cities in 2011

Source: Ghatge & Sundar 2013

in the total number of registered bus services in the country, only about 25 of the over 60 million plus cities in the country had any form of organized bus services as of 2008 (MoUD 2008). Lack of adequate and quality public transport systems has been fuelling use of more energy intensive modes of personal transport; increasing the share of public transport, hence, it is critical to reduce the overall energy demand from the sector.

Increasing share of goods movement on roads

At present there is no defined long-term policy planning for the trucking industry in India. It remains highly unorganized, fragmented, and unstructured with a large number of small operators in a very competitive market.

However, the large impact that commercial freight vehicles have on the overall petroleum

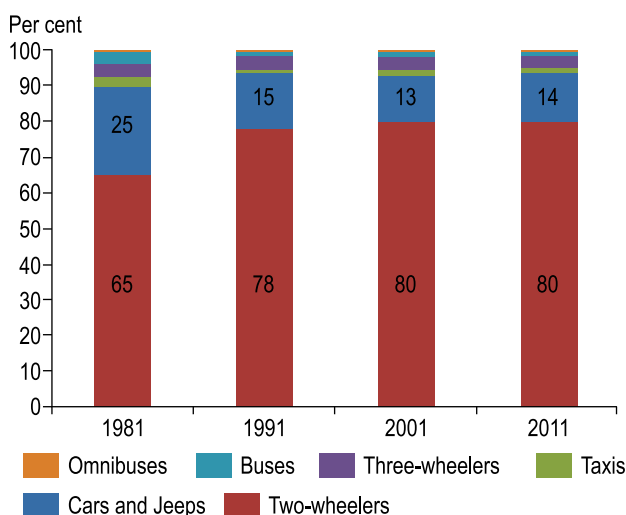


Figure 53: Share of different vehicle segments in the total registered passenger vehicles
Source: MoRTH 2012b

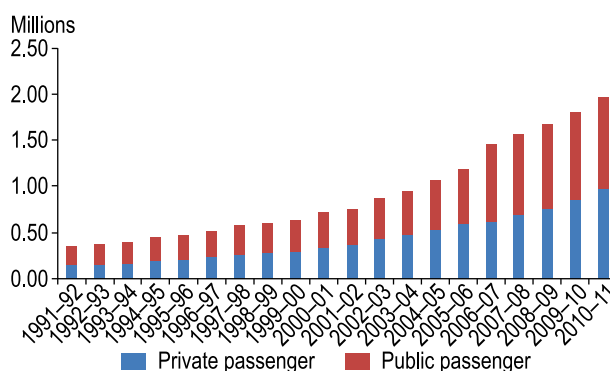


Figure 54: Share of different modes of road-based passenger transport
Source: TERI estimates

energy demand by transport in India has already been highlighted in the previous sections. As a result, issues related to the trucking industry have a huge impact on the overall energy footprint of the transport sector and total energy bill of the country. Unless adequate planning is undertaken to streamline this industry, commercial goods vehicles would require a large amount of imported petroleum and heavily burden the national exchequer.

But still the trucking industry in India compares poorly with international standards. Over 55% of the fleet of heavy commercial vehicles is estimated to be over 10 years old and on average they run only about 133 km per day. Even newer vehicles (i.e., those that are less than six years old) are estimated to be able to cover only about 267 km per day given the poor quality of roads, heavy nature of traffic, toll stations, and multitude of checkpoints. The average of 250 km per day distance covered

by trucks in India compares poorly to average global daily distances of trucks of around 400–450 km (Deloitte 2012).

Although there have been significant changes in trucking vehicle technology like introduction and use of multi-axle trucks, the largest share of trucks in India are two and three axle rigid trucks with low cubic capacity of 30 to 40 cubic metres and 135 to 165 horsepower engines. There is a need to increase the capacity of trucks to make them more efficient from the point of view of economies of scale. Every extra axle that a truck has can increase its capacity by approximately 5 to 7 tons and also increases fuel efficiency. There is a need to focus policy on introducing improved technologies and increase overall truck capacities.

Even with such improvements, the industry will benefit only if the road infrastructure in the country is brought up to higher standards. In India, it is estimated that an average truck driver cannot drive at more than 20 km an hour due to bad roads (Pradeep 2012). This reduction in speed is also related to the overloading tendency and delays at various tollbooths and checkpoints. It has been estimated that truck delays at checkpoints cost the economy INR 9–23 billion a year in lost truck operating hours (World Bank 2005). The quality of Indian highways has to improve to realize the benefits of improved vehicle technology in the future.

Limited penetration of alternate fuels

The last decade has also seen a push by the Government of India to promote alternate fuel vehicles across the country. Alternate

fuels, such as Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), and electricity are being promoted through various policy interventions. Auto Fuel Policy 2002 of the Ministry of Petroleum and Natural Gas (MoPNG 2003) was the first to propose diversification of fuel basket of road transport sector. Promotion of electricity as a transport fuel has received a boost due to the National Electric Mobility Mission Plan of the Ministry of Heavy Industries (MHIPE 2013). Although limited to a handful of urban centres, alternate-fuel vehicles are now available both for private and public transport. Most of the urban bus fleets and some of the intermediate modes of transport, such as taxis and auto-rickshaws across the country have seen significant penetration of CNG vehicles.

However, even with a distinct price advantage, these fuels have not gained much traction across the nation and conventional petroleum still continues to dominate sector's fuel mix.

This is mainly because of the lack of a well-developed infrastructure and a network for pan-India distribution of these fuels, specifically in the case of CNG and LPG. As a result, the penetration of alternate fuels for transport has been limited to a handful of the urban centres in the North-Western corridor and Southern states of India where pipelines are available to supply the fuels. For instance, CNG is the main alternative fuel in Delhi, Mumbai, and parts of Western India because of access to the CNG pipeline. Other major cities in the Eastern and Southern states in India that have air pollution issues have resorted to the use of LPG as the main alternate fuel. Electricity as an alternate transport fuel hasn't gained much popularity and faces infrastructure and

technology challenges, and without adequate Government handholding this segment of vehicles is not expected to make much headway in the Indian markets.

Rail transport

Reduced system efficiencies due to diminishing shares of rail-based transport

Between 1986–87 and 2007–08, freight moved by road increased from 224 Mt to 1,559 Mt (596%). During the same period, freight traffic carried by the railways went up from 255.4 Mt to only 768.72 Mt (201%) (Planning Commission 2009). This has been largely due to the rapid nation-wide development of India's National Highways network which has grown from 52,010 km in 2000–01 to 76,818 km in 2011–12, achieving a 48% growth (MoRTH 2012a). Compared to this, India's railway network grew at only 2.3% during the same period of time (Indian Railways 2013). The aggressive growth in the road sector, together with the slow growth of rail infrastructure, can be identified as some of the principle causes for the eroding share of the railways.

Estimates suggest that the share of the railways in overall passenger mobility has dropped from almost 85% at the time of independence to just about 13% at the beginning of this century. Although not as drastic as the passenger business, Indian Railways has also been losing its share in overall freight mobility. From 86% in 1950, the share of the railways in freight mobility came down to 34% by 2001 (Planning Commission 2007). This trend has become acute over the course of the last decade.

This continually declining share of railways in both the passenger and freight mobility is a cause of concern for a nation that is already grappling to meet its energy demands given that rail-based transport is almost 4, 19, and 21 times more energy efficient than bus, car, or air transport for passenger mobility (TERI 2013).

But these efficiencies are also dependent on the choice of traction used to drive the railways. In this regard electric traction is widely considered more efficient than diesel traction given that it does not require additional energy to pull an engine and the power plants generating the electricity. Further, whereas diesel locomotives are limited by the efficiency of the internal combustion engines, locomotives on electric traction could increase their efficiencies by economies of scale of electricity production. In the long run, the energy for electric traction could be produced from both renewables and nuclear to sustain the demands for railways. Given the several advantages of electric traction, it has been identified as the chosen traction, along the heavy traffic sections of the Indian Railways.

It should be noted that while moving to electric traction would reduce the dependence of the railways on diesel, an increase in electricity consumption has the potential of increasing the levels of greenhouse gas emissions as electricity in India is produced largely from coal-based thermal power plants. It is therefore imminent that the electricity generated for electric traction should be produced from renewable sources as far as possible.

Diminishing shares and average leads of freight mobility on railways

The railways have a comparative advantage in the movement of voluminous bulk commodities, such as coal, minerals, food grains, etc., given the natural economies of scale. This has been the main reason why bulk commodities have historically been moved on rail in most parts of the world. The last few years have, however, seen a depletion of railway shares even for commodities in which it had such an advantage. Better condition of roads, easy availability of trucks and trailers with heavy axle loads, longer transit times in movement by rail, and, most importantly, very high freight handling charges on railways are the reasons responsible for railways losing this share.

Apart from the convenience of door-to-door connectivity provided by road transport, the ever increasing freight-handling charges on the railways as a result of the practice of cross-subsidization of freight fares for passenger transport has been cited as one of the key reasons for the shift of freight movement from rail to road. This trend of larger shares of freight transport moving on road, consuming large quantities of the diesel used in the country, is not in the best interests of the energy security of the country. The creation of the Western and Eastern Dedicated Freight Corridors (WEDFC) connecting the industrial centres of the country with the Western and Eastern ports would help in the railways ensuring retention of some of its shares in total freight mobility in these regions. However, to ensure national energy security and make the most efficient use of the nation's resources, it is imminent

that adequate policies are directed to help the railways retain or increase its share in the overall mobility of both freight and passenger mobility.

Aviation

Given that the intensity of energy use by aircrafts is almost more than 20 times that by railways, an uncontrolled growth of the airlines sector seen over the last decade would lead to a manifold increase in the energy consumption by the sector as a whole.

To add to the growth in scheduled passenger traffic operations, the unfettered growth in the number and volume of non-scheduled chartered operations in India has also been increasing the energy demands by this sector. The total number of aircrafts with non-scheduled operator permits has grown by almost four times from only 107 in 2001 to 412 in 2012 (DGCA 2013).

Adequate policy measures are required to ensure that the international best practice in terms of energy efficiencies of aircrafts are enforced in India for its domestic operations.

Water transport

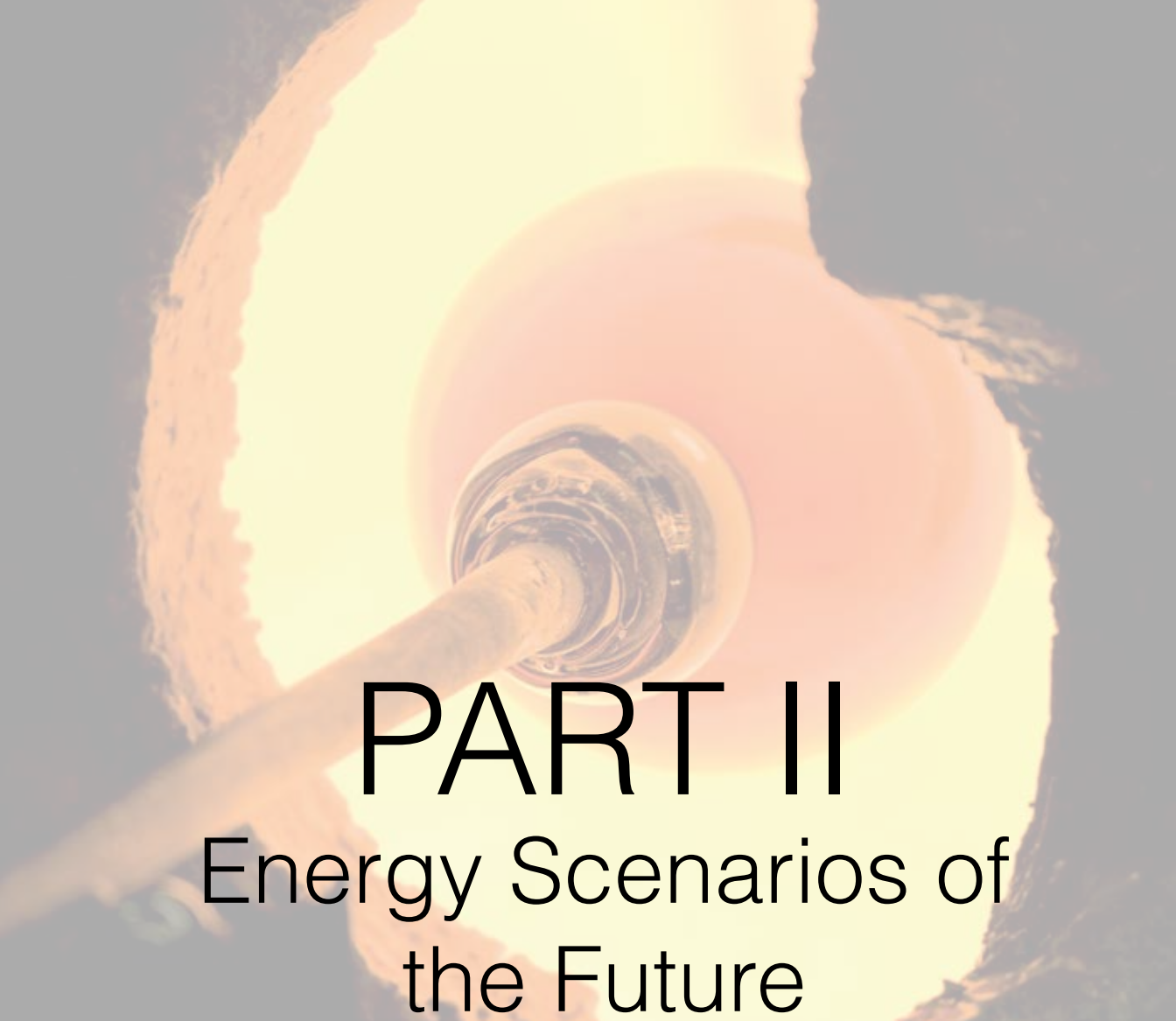
Since this mode of transport has a large number of advantages from the point of energy efficiencies, there is a need to direct more effective and integrated national policy packages to encourage more traffic shift from road to coastal shipping and other forms of water-based transport systems.

India is the largest peninsula in the world with over 7,500 km of coastline, 14,500 km of navigable waterways, and a very rich maritime history giving it a perfect environment to

have a robust water transport network. Along with these natural advantages, water-based transport has several other advantages, such as cheaper fuel costs, better economies of scale than road or rail, the ability to move bulk and high value goods, and environmental friendliness among others. With these advantages in mind, this mode of transport has the potential to become one of the principle modes of transport for the country. However, over the years, water-based transport in India has lost its overall importance in national mobility of both passengers and freight. At present, it occupies a very small and

insignificant share. A large number of critical issues have been plaguing the industry, hence limiting its growth.

The extensive network of perennial rivers criss-crossing the length of the country has a potential to serve as inland waterways. But, these have remained underutilized for transporting either passenger or freight traffic. Six sections of rivers have been identified as National Waterways in India (NWI) to serve this traffic (MoS 2012), but there is still no focused development to integrate inland waterways into the integrated transport planning in India.



PART II

Energy Scenarios of the Future



Chapter 10

Modeling Framework and Scenario Description

The scenario analysis for the Indian energy sector for this outlook has been carried out with the aid of the MARKAL (MARKet ALlocation) model. The following sections describe the modeling framework, the rationale for choosing this model, the scenarios that have been structured and the assumptions that they encompass.

Modeling Framework

MARKAL is a bottom-up dynamic linear programming model. It depicts both the energy supply and demand sides of the energy system, providing policy-makers and planners in the public and private sectors with extensive details on energy producing and consuming technologies. It also provides an understanding of the interplay between the various fuel and technology choices for given sectoral end-use demands. As a result, this modeling framework has contributed to national and local energy planning and the development of carbon mitigation strategies. The MARKAL family of models is unique with applications in a wide variety of settings and global technical support from the international research community.

MARKAL interconnects the conversion and consumption of energy. This user-defined network includes:

- All energy carriers involved in primary supplies (e.g., mining, petroleum extraction, etc.)
- Conversion and processing (e.g., power plants, refineries, etc.), and
- End-use demand for energy services (e.g., automobiles, residential space conditioning, etc.)

These may be disaggregated by sector (i.e., residential, manufacturing, transportation, and commercial) and by specific functions within a sector (e.g., residential air conditioning, lighting, water heating, etc.).

The optimization routine used in the model's solution selects from each of the sources, energy carriers, and transformation technologies to produce the least-cost solution, subject to a variety of constraints. The user defines technology costs, technical characteristics (e.g., conversion efficiencies), and energy service demands.

As a result of this integrated approach, supply-side technologies are matched to energy service demands. Some uses of MARKAL include:

- Identifying least-cost energy systems and investment strategies
- Identifying cost-effective responses to restrictions on environmental emissions

and wastes under the principles of sustainable development

- Evaluating new technologies and priorities for research and development
- Performing prospective analysis of long-term energy balances under different scenarios
- Examining reference and alternative scenarios in terms of the variations in overall costs, fuel use, and associated emissions

A detailed representation of the modeling framework is shown in Figure 55.

The MARKAL database for this exercise has been set up over a 30 year period extending from 2001–2031 at five-yearly intervals coinciding with the duration of the Government of India's Five Year plans. The base year of the exercise is 2001–02 and the data for 2001–02, 2006–07 and 2011–12 has been calibrated and matched to the existing and published data. A discount rate of 10% has been considered.

In the model, the Indian energy sector is disaggregated into five major energy consuming sectors, namely the agriculture, commercial, industry, residential, and transport. Each of these sectors is further disaggregated to reflect the sectoral end-use demands. The model is driven by the demands from the end-use side.

On the supply side, the model considers the various energy resources that are available both domestically and from abroad for meeting various end-use demands. This includes both conventional energy sources, such as coal, oil, natural gas, hydro, and nuclear as well as the renewable energy sources, such as wind, solar, etc. The level of domestic availability of each of these fuels is represented as constraints in the model.

The relative energy prices of various forms and sources of fuels dictate the choice of fuels which play an integral role in capturing inter-fuel and inter-factor substitution within the model. Furthermore, various conversion

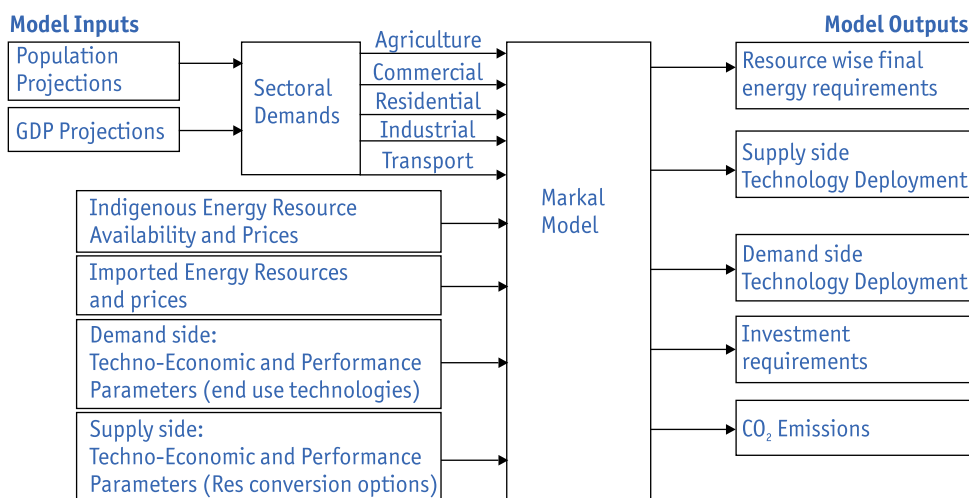


Figure 55: Modeling framework
Source: TERI

and process technologies characterized by their respective investment costs, operating and maintenance costs, technical efficiency, life span, etc., to meet the sectoral end-use demands are also incorporated in the model.

In this study, we have structured three different scenarios using a host of different assumptions on the supply of energy, end-use energy demand, and technology penetration. These are:

- Reference Energy Scenario (RES)
- Moderate Energy Security Scenario (ESM)
- Ambitious Energy Security Scenario (ESA)

The model run and analysis that has been carried out for these scenarios provides significantly different outcomes in terms of fuel mix, technology deployment, primary energy requirement, import dependence, and CO₂ emission levels. In order to understand the model results and compare the three scenarios, it is imperative to understand the assumptions made in each of them. These assumptions have been described in the following sections.

Scenario Description and Assumptions

Macroeconomic parameters

The energy demand of the end-use sectors are an exogenous input into the model. The calculation of each of these end-use energy demands is in itself an extensive exercise. The demands are primarily derived as a function of the Gross Domestic Product (GDP) and population. For this, both GDP and population have been projected and are taken to be the same across all three scenarios.

Gross Domestic Product (GDP)

The GDP is assumed to grow at a rate of 8% rising from INR 19.7 trillion in 2001 to INR 211.7 trillion in 2031. The sectoral GDP has been calculated based on a regression analysis that establishes the relationship between sectoral GDP and the total GDP. The share of agriculture, industry, and services GDP in the total GDP is seen to vary over the years. The share of agriculture falls from 26% in 2001 to 12% in 2031, while the share of industry rises from 23% in 2001 to 30% in 2031, and the service sector rises from 51% in 2001 to 58% in 2031.

Population

A number of organizations have projected the population of India. For our analysis, the population trajectory provided by the Population Foundation of India (Scenario B) has been used. This trajectory projects the population to rise from 1.03 billion in 2001 to 1.52 billion in 2031, growing at a rate of 1.3% and urbanization to rise from 28% in 2001 to 34% in 2031.

Prices of energy sources

The economic costs of energy resources have been considered in the model. Accordingly, taxes and subsidies are not considered so as to reflect the price differentiation across various consuming segments/uses. As such, Cost, Insurance and Freight (CIF) prices are considered for imported fuels, while Free-On-Board (FOB) prices are taken for domestic extraction and exports. For fuel prices in the future (till 2035), International Energy Agency's (IEA) projection of fuel prices under the current

policy scenario as published in *World Energy Outlook 2012* is used (Table 25).

Calculation of end-use demand

The end-use demands as described earlier are divided into five sectors; agriculture, industry, residential, commercial, and transport. Future demand for each of these sectors is calculated using different econometric methods and then is fed in to MARKAL as input.

The population and GDP projections are used as the main driving force for estimating the end-use demands in each of the energy consuming sectors.

Demand for the industry sector has been calculated for 10 of its most energy consuming sub-sectors; namely iron and steel, cement, brick, glass, aluminium, textile, fertilizers, chlor-alkali, petrochemicals, and paper. The other energy-consuming industries include small-scale industries, such as food-processing, ceramics, sugar mills, foundry, leather/tanning, etc., are grouped in a single sub-sector collectively called 'other industries'. Production (as a proxy of demand) in each of these industrial sub-sectors is projected using econometric techniques. Linear regression analysis is carried out for each of the major industry sub-sectors, taking production as the dependent variable and using various

macroeconomic indicators, such as GDP (aggregate), GDP of industrial sector, services, agriculture, etc., as independent variables.

Similarly, the transportation demand (disaggregated further into mode-wise passenger kilometre demand and freight kilometre demand) is projected using various socioeconomic indicators, such as per-capita income (indicator of purchasing power), percentage share of population residing in urban areas, population, and so on. To project the passenger and freight kilometres from each mode, their estimated vehicle population is multiplied with the occupancy rates and efficiency levels. The estimation of occupancy rates and efficiency for each mode of transport has been made after extensive stakeholder and expert consultation.

In the agriculture sector, demand is estimated for land preparation and irrigation pumping. Demand for land preparation is calculated by estimating the number of tractors and tillers that will be required in future. The demand for irrigation pumping is calculated by estimating the future water demand of the agriculture sector. This has been done in accordance to the current and expected cropping patterns.

In the residential sector, the demand is projected for lighting, space conditioning,

Table 25: Fuel prices

Fuel	Unit	2015	2020	2025	2030
Crude oil	US\$/barrel	118.4	128.3	135.7	141.1
Natural gas	US\$/MBtu	15.30	14.70	15.20	15.60
Coal	US\$/tonne	110.0	115.0	119.2	122.5

Source: IEA 2012

cooking, and refrigeration separately for urban and rural households to account for the differences in lifestyle and choice of fuel and technology options. Each of these end-use demands are estimated using a bottom-up methodology wherein they are calculated across different monthly per capita expenditure classes and then the sum total is taken as the final demand.

In the commercial building sector, the demand is projected for cooking, lighting, and space conditioning based on built-up area, energy performance index, and the value added by the services sector as an explanatory variable.

Reference Energy Scenario (RES)

This scenario is structured to provide a baseline that shows how the nation's energy trajectory would evolve provided current trends in energy demand and supply are not changed. It takes into account existing policy commitments and assumes that those recently announced are implemented. However, wherever necessary, a diversion from government projections and forecasts has been assumed. The key assumptions are described in the following sections.

Energy supply

On the supply side, the scenario comprises of assumptions which are input as constraints on the availability and level of domestic production of various resources.

As a result of problems currently constraining the production of coal it is assumed that the production of non-coking coal will reach a maximum of about 700 Mt

by 2021–22 (i.e., representing a CAGR of 3.7%) and increase by 3 Mt annually up to 2031–32. It is assumed that the present trend in the production of metallurgical coal will continue and the production will reach a maximum of 19 Mt by 2021–22 and stay at that level thereafter. We see that the overall constraints in production of coal will impact the production of non-metallurgical coal as well. Therefore, it is assumed that the production of non-metallurgical coal will peak at nearly 50 Mt by 2021–22 and increase by 0.5 Mt each year thereafter till 2031–32. For the production of lignite we take conservative estimates, with projections that the production will increase at a rate of 4% between 2011–12 and 2021–22, reaching approximately 63 Mt by 2021–22. Thereafter, it is assumed to grow by 2 Mt each year.

In order to estimate constraints on our domestic crude oil production for the RES, we assume that in the short term (up to 2021–22) ONGC's offshore crude output remains constant, and its onshore crude output continues to decline steadily. OIL's onshore crude production stays at around 4.5 Mt. Private/JV onshore crude output increases steadily up to 10 Mt in 2015–16 and offshore crude output by private/JV companies continues to decline as has been the case over 2000–01 to 2011–12.

In the medium to long term (2021–22 to 2031–32), assumptions are made on the total domestic crude oil production and not on production by individual companies. Total production remains relatively stagnant at a little above 40 Mt over after 2021–22.

Natural gas assumptions are based on a similar analysis. In the short term (up to

2021–22), we assume Reliance's KG-D6 gas output continues to fall steadily. Private/JV companies' production of natural gas remains constant at 11 billion cubic metre (BCM) from 2016–17. ONGC's gas output stays constant and increases moderately after 2015–16 due to new discoveries coming on-stream and OIL's natural gas output stays constant at 2.8 BCM.

In the medium to long term (2021–22 to 2031–32) assumptions are made on total domestic gas production and not on production by individual companies. If the natural gas scenario continues as usual, we do not consider a very significant rise in domestic gas production. Domestic production is assumed to be around 50 BCM in by 2031–32.

With regards to technology penetration in the power sector, large-scale deployment supercritical technology for coal-based generation is considered. Further, it is also assumed that ultra-supercritical technology would be available at commercial scale only by 2031. In view of increasing concern about rehabilitation and relocation issues, the capacity realizations of large hydroelectric plants to a moderate level of around 94 GW by 2031–32 is predicted.

Nuclear energy in the RES is projected to rise from an installed capacity of 5 GW in 2011–12 to 28 GW in 2031–32. Delays in land acquisitions, slow expansion and commercialization of Fast Breeder Reactor (FBR) technology, and uncertainties (from the supplier's perspective) surrounding the nuclear liability law are the major considerations for such modest projections.

As till now renewable energy capacity addition targets have always been achieved

in each of the Five Year Plans. This scenario assumes that this positive trend will continue and there will be no shortfall in targets. The targets of the Five Year Plans taken in to consideration are mentioned in Table 26.

Table 26: Tentative programme for capacity additions to grid-interactive renewable power under the 12th Five Year Plan (2012–17) and 13th Five Year Plan (2017–22)

Source/System	Capacity addition (MW), 12th Plan	Capacity addition (MW), 13th Plan
Wind power	15,000	15,000
Biomass power	2,100	2,000
Small hydropower	1,600	1,500
Solar power	10,000	16,000
Waste-to-Energy	500	
Tidal power	7	
Geothermal power	7	
Total	29,214	34,500

End-use energy demand

On the demand side, assumptions are made on the end-use technological levels. It involves inclusion of new technologies, efficiency improvements in the existing ones, and their changing penetration levels.

Energy in the agriculture sector is primarily needed for land preparation and irrigation. In the RES scenario, the share of efficient tractors in land preparation is assumed to be the same as the current levels with no improvement. The share of efficient electric pump sets in irrigation is assumed to rise from negligible levels in 2011 to about 18% in 2031. The efficient electric pump sets are about twice

more efficient than the ones currently in use. The end-use energy demand in the commercial buildings sector is divided into demand for space conditioning, lighting, cooking, public lighting, water pumping and sewage, and other electrical appliances. The commercial buildings sector's energy demand for the study was calculated using Energy Performance Index (EPI) numbers and the built-up area. The built-up area has been subdivided to cover the seven segments, viz. hospitals, hospitality, general offices, BPO, education, shops, and shopping malls. In the RES, we assume no improvement in the EPI of all the categories and limited GRIHA penetration in the new buildings (from 1% in 2011, 3% by 2021, and 6% by 2031).

Residential sector demand is calculated via a bottom-up exercise, where the cooking, lighting, space conditioning, water heating, and other end-use energy demands are calculated for each monthly per capita expenditure (MPCE) class (rural and urban). Various assumptions have been made on the level of penetration of efficient appliances in the RES. The share of efficient air conditioners, fans, coolers, and refrigerators is taken to rise in both the rural and urban households from about 9% in 2011 to 27% in 2031. An efficiency improvement in air conditioners and fans takes place at the rate of 1% per annum and 0.4% per annum, respectively. It is also assumed that 100% electrification will be achieved post 2016 with more efficient lighting equipment such as CFL trickling in to the rural households as well. By 2031–32, we assume that 90% of the lighting demand would be met by Compact Fluorescent Lamps (CFL). The share of LPG in rural cooking rises from 12% in 2011

to 23% in 2031 and urban cooking is taken to increase from 60% in 2011 to 72% in 2031 and share of improved cookstoves rises to 5% from negligible levels in 2011 by 2031 in the RES.

In the RES, efficiency improvement is considered as per the past trend and in line with commercially available technological options in the industry sector. Due to liberalization and opening up of domestic markets, large-scale industries, such as cement, iron and steel, petrochemicals, and other chemicals assumed to improve their energy efficiency levels by adoption of state-of-art technologies. Small-scale Manufacturing Enterprises (SMEs) adopt energy-efficient technologies at slower rate. This is mainly because the SMEs are constrained by the availability of adequate capital due to their small size. Furthermore, a low degree of creditworthiness of these enterprises makes it difficult for them to raise funds in the financial markets and invest in energy-efficient technologies. Most of these enterprises come under the domain of the unorganized industrial sector. Their fragmented nature, lack of expertise and technical know-how acts as a barrier to the uptake of energy-efficient technological options.

The demand for the transport sector is estimated via another model outside MARKAL. The energy demand is divided into passenger and freight movement. This is further disaggregated by modes—road, rail, air, and water. Assumptions regarding fuel and technology penetration in RES for the transport sector have been made keeping the present situation in mind. We consider that the share of CNG in cars and public transport rises to 4% and 2%, respectively, from present levels of 1%, by 2031. A fall in the use of public transport for

road passenger movement is assumed with its share dropping to 60% by 2031 (74% in 2011). Share of railways in passenger movement is taken to remain constant while that in freight is assumed to decrease to 30% (2031) from the 39% (2011). An increase in electric traction in freight movement from 65% (2011) to 70% (2031) and in passenger movement from 50% (2011) to 52% (2031) has been built in the model. Role of biofuels is minimal in the RES.

Moderate Energy Security Scenario (ESM)

This scenario is structured in a manner that enables one to visualize an energy trajectory of the nation that would ensure energy security in the future. This in broad terms implies reduction of imports and increased dependence on domestic production on the supply side; and more efficient consumption, fuel substitution, and increased energy access on the demand side.

Thus, the constraints that were assumed for domestic production of resources in the RES scenario are revised to more optimistic (but not overambitious) figures.

Energy supply

In this scenario, it is assumed that the total production of coal reaches 990 Mt by 2021–22 and about 1220 Mt by 2031–32. In order for this to happen, aggressive efforts are being made by the government and the private and public sector coal companies to meet these set targets. The efforts include installation of additional washery capacity to improve the quality of coal produced, increase in the share of underground coal mining, removal of

bottlenecks in setting up evacuation facilities to transport coal from mines, and increase in production of coal through the public private partnership route.

Also, in order to estimate the availability of coal in each of the three categories, the current composition of coking and non-coking coal in the total production basket is used. Currently, non-coking coal forms nearly 90% of the total coal production. This trend is expected to continue and efforts to enhance the quality of coking coal will be made. While the share of metallurgical coal in total coking coal output has declined from over 60% in 2000–01 to nearly 36% in 2010–11, it is assumed that efforts are being made to increase the output of metallurgical coking coal such that its share in total coal production increases to 5.5% by 2021–22, to 6% by 2025 and thereafter to 7% by 2031–32.

Since the estimates for production of non-metallurgical coking coal are not available, these are calculated as the residual production. In case of lignite, the production is assumed to reach the target of 69 Mt by 2021–22 and thereafter it is assumed to grow at 8% per annum up to 2031–32 to reach 123 Mt.

In the ESM, for estimating short-term (up to 2021–22) domestic crude oil production we assume ONGC is able to arrest the decline in production from the Bombay High and Heera fields and ramp up offshore production through its new discovery in the contiguous D1 field. ONGC's offshore crude oil production is assumed to increase to 18 Mt by 2015–16 and finally to 25 Mt by 2021–22. ONGC is able to keep its onshore production constant at the level reached in 2012–13 (7.2 Mt) till 2021–22. OIL's new discovery in Rajasthan, which is

slated to produce around 30,000 barrels per day (bpd), helps the company ramp up its onshore crude production to 5.5 Mt. Private/JV onshore production increases more than assumed in the reference scenario. The total private/JV onshore production is assumed to reach 10 Mt by 2015–16 and increase to 13 Mt by 2020–21 and 2021–22. While in the medium to long term (2021–22 to 2031–2032), assumptions are made on total domestic crude oil production and not on production by individual companies. The increase in production till 2021–22 will plateau at 66 Mt and decline by 2026–27. Aggressive private investment in domestic E&P (facilitated by enabling government policies), combined with some new oil discoveries, will allow India's domestic crude oil production to rise from a trough of 62 Mt in 2026–27 to reach a peak of 68 Mt by 2031–32.

Domestic natural gas production in the short term (up to 2021–22) will be more than that in the RES as we assume Reliance will be able to arrest decline in KG-D6 production and then turn around its production due to commercialization of new discoveries in this basin. Also the government's gas pricing policy will be reworked to encourage more competition and increase private investment. Therefore, overall private/JV production will increase to 17 BCM by 2016–17 and go up to 20 BCM by 2021–22. Also, ONGC's total production is projected to reach 30 BCM by 2016–17 and go up to 40 BCM by 2020–21 and OIL will be able to increase its production to 4 BCM as against 2.8 BCM assumed in the RES.

In the medium to long term (2021–22 to 2031–32) as in the RES assumptions are made on total gas availability for the period

2021–22 to 2031–32. We assume the Krishna–Godavari basin produces well above the current levels due to application of improved technology to enhance gas recovery, aggressive investment is undertaken by domestic private players (RIL, GSPC) and international players (British Petroleum) and significant increase in non-conventional gas (especially coal bed methane) production assists in taking domestic production up to 80 BCM by 2031–32.

In view of the possibility of greater technology transfer across countries and a greater thrust on indigenous R&D in the power sector in this scenario, all clean coal technologies are allowed to penetrate in an unconstrained manner to their maximum capacity from their year of introduction. For large hydroelectric plants a slightly higher deployment of over 105 GW by 2031–32 is assumed.

In the ESM, it is assumed that there are better and effective public engagement coupled with better R&R packages for the development of nuclear energy. On the international front, assuming greater clarity on the liability law and most of the nuclear supplier countries, those who have been given dedicated sites will decide to do business with India. However, because of the already lost time and issues faced in land acquisition at different places, commissioning and construction take time. It is also assumed that cost negotiations will be finalized faster. On the FBR technology front, while we have assumed that the commercial production starts sooner, a slow growth in their numbers is predicted. Thus the installed capacity will grow from 5 GW in 2011–12 to 41 GW in 2031–32 in the ESM.

For the renewable energy sector, in the ESM we assume renewable energy (RE) capacity addition is linked to Renewable Purchase Obligations (RPOs). RPOs specify that a percentage of electricity generation must be met by RE technologies. RPOs are extended beyond the mandate of 15% by 2021–22 and reaches 18% by 2031–32.

End-use energy demand

On the demand side, the ESM is structured to push the usage of more efficient technologies across all sectors.

In the agriculture sector, it is predicted that by 2031 the share of efficient tractors in land preparation will rise to 25%, as compared to the RES assumption of 10%. Around 50% of the irrigation needs will be met by efficient electric pump sets by 2031, bringing down the usage of diesel and inefficient electric pump sets.

In the commercial sector, an increase in GRIHA penetration (in new buildings) from 1% in 2011, 13% in 2021, and 26% in 2031 is considered. Also, after every five years, a 5% reduction in EPI is assumed for air conditioned buildings of the following segments:

- Hospitals
- Hospitality
- General offices
- BPO
- Education
- Shops
- Shopping malls

The share of efficient public lighting, public water works, and sewage pumping is taken to be 43% by 2031 compared to negligible levels in 2011.

In the residential sector, we assume the share of efficient air conditioners, fans, coolers, and refrigerators to rise up to 50% by 2031. Also, by 2031 it is assumed that 54% of the lighting demand in both the urban and rural sectors is met by CFLs and 40% by Light-Emitting Diodes (LED). For cooking, we assume that by 2031 the penetration level of improved cookstoves in rural areas would be 20%.

The industry sector boasts of measures that lead to significant energy-savings in the ESM. This includes adoption of energy-efficient technologies as well as uses of waste material such as higher share of blended cement in total cement production as compared to RES. SMEs will also have significant efficiency improvement over the time by means of removal of institutional barriers, availability of finance, capacity building, cluster level intervention, etc.

The transport sector in this scenario is structured in a way such that petroleum products are increasingly substituted by CNG, electricity, and biofuels. This includes shares of CNG in public transport and three-wheelers reaching 7% and 15%, respectively, by 2031 which is higher than RES levels. Electric two-wheelers and cars are also encouraged with their shares rising from negligible numbers to 20% and 10%, respectively, by 2031. Availability of biofuels for the sector is much higher in comparison to the RES. Along with the penetration of these alternative fuels in the sector; we have also assumed a 1% (per annum) improvement in the fuel efficiency of all the technologies. A road to rail shift is also envisaged in this scenario. We assume that the share of rail in freight and passenger movement does not drop from the present

levels as was the case in RES. Public transport is also encouraged and by 2031, 75% of the road passenger movement is via public transport modes. Share of electric traction in rail passenger and freight reaches 60% and 80%, respectively, by 2031.

Ambitious Energy Security Scenario (ESA)

In this scenario, energy security concerns are paramount. The main objective being to drastically reduce the energy imports of the country by 2031. This entails faster implementation of efficiency measures, rapid penetration of new technologies, and increased electrification of the economy. The role of renewables is crucial in this scenario.

Energy supply

In this scenario, the supply for conventional resources is taken to be at similar levels as the ESM scenario. It is assumed that the total production of coal reaches about 988 Mt by 2021–22 and about 1,200 Mt by 2031–32. Natural gas production reaches 80 BCM by 2031, which is similar to the ESM and crude oil production rises to 68 Mt by 2031.

For large hydroelectric plants, a slightly higher (in comparison to RES and ESM) deployment of over 105 GW by 2031–32 is assumed. Nuclear power capacity is assumed to grow from 5 GW in 2011 to 41 GW in 2031.

One of the main interventions in this scenario is the levels to which renewable energy development is pushed. In the ESA, we assume renewable energy (RE) generation capacity based on solar PV to be at least 200 GW by 2031, while that of wind to grow to 110 GW by 2031. These are almost thrice the

generation capacity that has been assumed for the RES and ESM.

End-use energy demand

In the agriculture sector, it is predicted that by 2031 the share of efficient tractors in land preparation will rise to 50%, as compared to the RES assumption of 10% and 25% in ESM. Sixty-five per cent of the irrigation needs will be met by efficient electric pump sets by 2031, bringing down the usage of diesel and inefficient electric pump sets.

In the industry sector, specific energy consumption of various technologies falls by plausible ranges in both the large-scale industries and in SMEs throughout the modeling period. A number of new and more efficient technologies are introduced, retiring the older ones. The share of scrap for the production is assumed to rise to 37% in 2031 (as compared 27% in ESM and 24% in RES).

In the commercial sector, apart from improvement in EPI, we assume that 100% of all new built area is compliant with GRIHA. The share of efficient public lighting, public water works, and sewage pumping is taken to be 60% by 2031 compared to negligible levels in 2011.

In the residential sector, we assume the share of efficient air conditioners, fans, coolers, and refrigerators to rise up to 60% by 2031. Also, by 2031 it is assumed that 18% of the lighting demand in both the urban and rural sectors is met by efficient CFLs and 80% by LEDs. For cooking, we assume that by 2031 the penetration level of improved cookstoves in rural areas would be 20%.

The transport sector in this scenario sees an increasing dependence on biofuels for meeting its energy demand. Share of CNG in public transport and three-wheelers reaches 10% and 15% respectively by 2031 which is higher than RES levels. Electric two-wheelers and cars are also encouraged with their shares rising from negligible numbers to 20% and 10% respectively by 2031. The share of public transport in road passenger movement is similar to ESM levels while movement from

road to rail is higher in this scenario. By 2031 it is assumed that 50% of the freight movement and 20% of the passenger movement would be via railways. Share of electric traction in both rail and freight by 2031 is same as in ESA. Availability of biofuels for use by the sector is much higher in comparison to the RES. A very optimistic assumption on the availability of biofuel has been made for this scenario.

The assumptions made for all scenarios are summarized in the table below.

Sector	RES	ESM	ESA
Coal	Maximum domestic production to reach 868 Mt by 2031–32	Maximum domestic production to reach 1,220 Mt by 2031–32	Maximum domestic production to reach 1200 Mt by 2031–32
Oil	Total domestic production remains relatively stagnant at a little above 45 Mt by 2031–32	Total domestic production reaches 68 Mt by 2031–32	Same as ESM
Gas	Total domestic production reaches 50 BCM by 2031–32	Total domestic production reaches 80 BCM by 2031–32	Same as ESM
Nuclear	Installed generation capacity rises to 28 GW by 2031–32	Installed generation capacity rises to 41 GW by 2031–32	Same as ESM
Renewables	Capacity addition according to the 12th and 13th Five Year Plans and then follows trend	RPOs are extended beyond the mandate of 15% by 2021 to reach 18% by 2031	Generation capacity based on solar PV to reach at least 200 GW by 2031 and that on wind energy to reach 110 GW
Agriculture	Share of efficient tractors in land preparation remains at the current levels. The share of efficient electric pump sets in irrigation is 18% by 2031	By 2031 share of efficient tractors is 25%, and the share of efficient pump sets rises to 50%	By 2031, the share of efficient tractors is 50% and the share of efficient pump sets to be 65%
Industry	Specific energy consumption of only large-scale industries to improve	Specific energy consumption of various technologies falls by 2031 by plausible ranges in both the large-scale industries and in SMEs. A number of new and more efficient technologies are introduced, retiring the older ones	Same as ESM and share of scrap in iron and steel production to be 37% (2031)

Sector	RES	ESM	ESA
Transport	Share of cars in private road transport would rise to about 49% in 20 years. Slight increase in the shares of vehicles dependent on CNG and electricity. Share of electric traction in rail passenger and freight movement rises to 52% and 70%, respectively, by 2031. Share of rail in freight and passenger movement to be 30% and 15% (2031). Share of public transport in road passenger movement is 59% (2031)	Shares of CNG in cars, taxis, and three-wheelers reaching 7% and 15%, respectively, by 2031. Electric two-wheelers, three-wheelers and cars are encouraged. Increased availability of biodiesel for the sector. Share of electric traction in rail passenger and freight movement rises to 55% and 80%, respectively, by 2031. Share of rail in freight and passenger movement to be 39% and 15% (2031). Share of public transport in road passenger movement is 75% (2031)	Shares of CNG in cars, taxis, and three-wheelers to reach to 7% and 15%, respectively, by 2031. Share of electric two wheelers and cars to rise upto 20% and 10% (2031). Increased availability of biodiesel for the sector. Share of electric traction in rail passenger and freight movement to rise upto 55% and 80%, respectively, by 2031. Share of rail in freight and passenger movement to be 50% and 20%, (2031), respectively. Share of public transport in road passenger movement is 75% (2031)
Residential	Share of efficient air conditioners, fans, coolers, and refrigerators rises to 27% by 2031. Hundred per cent electrification is achieved post 2016 with more efficient lighting equipment. Share of LPG in both rural and urban cooking increases and share of improved cookstoves rises slightly to 5% in 2031	Share of efficient air conditioners, fans, coolers, and refrigerators to rise up to 50% by 2031. More than 50% of the lighting demand is met by efficient CFLs, fluorescent tubes and LEDs by 2031. Twenty per cent penetration of improved cookstoves is assumed in rural areas by 2031	Share of efficient air conditioners, fans, coolers, and refrigerators to rise up to 60% by 2031. Eighteen per cent of the lighting demand is met by efficient CFLs, fluorescent tubes and 80% by LEDs in 2031. Twenty per cent penetration of improved cookstoves is assumed in rural areas by 2031
Commercial	No improvement in the EPI and level of limited penetration of GRIHA in new buildings from 1% in 2011, 3% by 2021, and 6% by 2031	After every five years, a 5% reduction in EPI is assumed for air conditioned buildings and an increase in GRIHA penetration (in new buildings) from 1% in 2011, 13% by 2021, and 26% by 2031	Improvement in EPI and 100% of all new built area is compliant with GRIHA. The share of efficient public lighting, public water works, and sewage pumping is taken to be 60% by 2031

Chapter 11

Model Results and Analysis

This chapter provides the key findings for the projection period based on the modeling exercise outlined in Chapter 10. The following sections describe the pathways in primary commercial energy supply, power generation, import dependence, and sector-wise final demand for the three scenarios. The emission trajectories and investment requirements are also discussed.

Primary Energy Supply

Figure 56 reflects the primary energy supply by fuel across scenarios. The primary energy supply in the RES grows almost three times over from 717 Mtoe in 2011 to 1,950 Mtoe by 2031 at a Compounded Annual Growth Rate (CAGR) of 5%. In the ESM scenario, it grows to 1,625 Mtoe and in the ESA scenario to 1,446 Mtoe

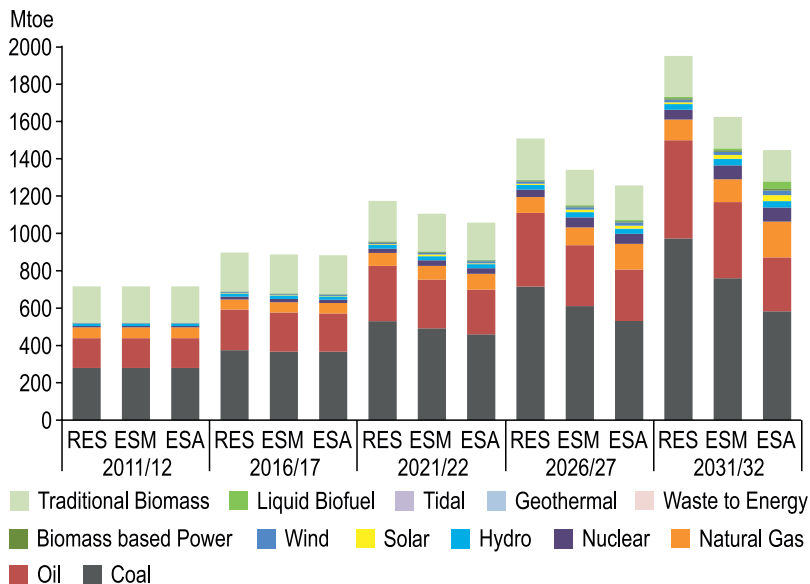


Figure 56: Primary energy supply, across scenarios

Source: Model results

Mtoe by 2031 at a slower growth rate of 4.2% and 3.6%, respectively.

In the RES scenario, coal continues to remain the dominant fuel in the supply mix throughout the modeling period with its share rising from 39% in 2011 to 50% by 2031, and supply from 280 Mtoe to 973 Mtoe. The share of oil in the supply mix rises from 22% in 2011 to 27% by 2031. Even though it is projected that the magnitude of natural gas in the supply mix will increase from 58 Mtoe in 2011 to 111 Mtoe by 2031, its share in the mix drops from 8% in 2011 to 6% by 2031. Share of nuclear energy is predicted to see a slight increase from 1% in 2011 to 3% by 2031. Thus by 2031, 83% of the commercial energy comes from coal, oil, and gas, 11% from traditional biomass, 3% from nuclear energy, 3% from renewables and large hydro.

Unlike the RES, in ESM we see a fall in the share of fossil fuels in the primary energy supply. The difference between the supply in RES and ESM by 2031 is 325 Mtoe which reflects a saving of 17%. This can be attributed to the reduction in the consumption of coal and oil by 213 Mtoe and 118 Mtoe, respectively, by 2031. These reductions are achieved on account of high efficiency measures taken across sectors. We see considerable growth of wind and solar energy raising the share of renewable energy in the primary energy supply to 3% by 2031. The share of traditional biomass in the primary energy supply reduces from 27% in 2011 to 10% in 2031, a drop observed due to higher penetration of improved cookstoves in the rural areas.

In the ESA scenario, the primary energy supply by 2031 is 26% lower than in RES and the share of energy from fossil fuels drops to

74% as compared to 79% in ESM and 83% in RES; thereby resulting in lower emissions. We see the share of renewables in the mix rise to 7%. Nuclear energy grows from 7 Mtoe in 2011 to 76 Mtoe by 2031.

Power Generation

Figure 57 shows the growth of power generation capacity (centralized and decentralized), across scenarios. In the RES scenario, the generation capacity grows almost three times over from 239 GW in 2011 to 821 GW by 2031. In 2031, 62% of this generation capacity is based on coal in comparison to 56% in 2011. The share of gas-based generation capacity is observed to fall from 11% in 2011 to 5% in 2031 in spite of increase in capacity, while diesel-based generation is seen to slowly disappear. Nuclear capacity grows almost 6 times from 5 GW in 2011 to 28 GW by 2031. It is also seen that even though the target potentials for hydro power are realized and its capacity grows from 42 GW in 2011 to 94 GW by 2031, its share declines from 18% in 2011 to 11% by 2031. In the RES scenario, targets set out in the 12th and 13th Five Year Plans for the development of renewable energy capacity have been assumed to be achieved, increasing the renewable energy-based capacity from 22 GW (sum total of solar, wind, biomass, waste, tidal, and geothermal energy-based capacity) in 2011 to 142 GW by 2031, and their share rising from 9% to 17%.

In the ESM, the power generation capacity grows to a magnitude of 778 GW by 2031, with a difference of 125 GW of coal-based generation capacity from the RES. In this scenario, we see a high growth of generation

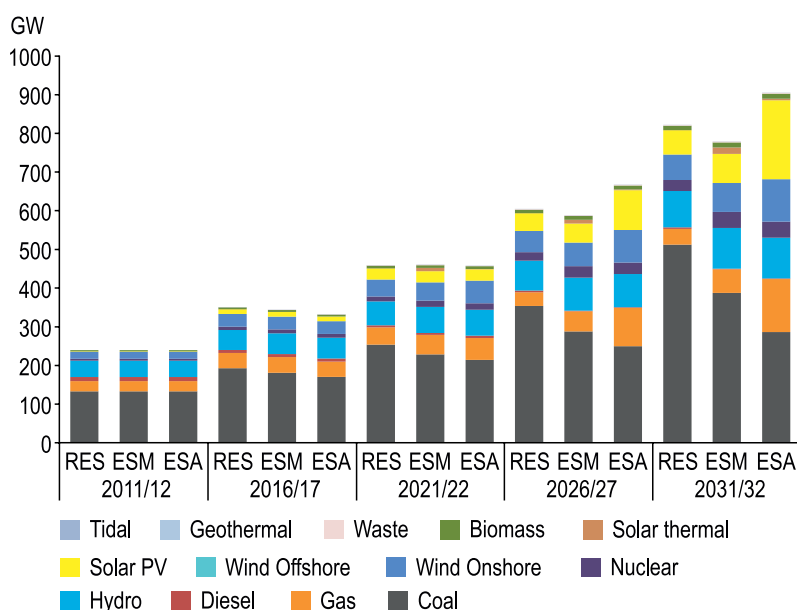


Figure 57: Power generation capacity, across scenarios (centralized and decentralized)

Source: Model results

capacity based on renewable energy. From a 22 GW of capacity in 2011 it grows to 182 GW by 2031, an increase of over eight times in 20 years. This is in line with the objective of the scenario; diversification of the fuels used, and thus helps analyse the requirements and consequences of such a situation.

In the ESA, also we see a considerable fall of share of generation capacity based on fossil fuels. From 71% in 2011, it drops to 47% by 2031 as compared to 68% in the RES. A major push is given to renewable energy-based capacity in this scenario. Solar PV-based capacity rises from 1GW (2011) to 204 GW (2031), while wind-based capacity rises from 18 GW (2011) to 110 GW (2031). Thus, the share of renewable energy-based generation capacity is 37% in 2031, a four-fold increase from 2011.

Import Dependence

Figure 58 depicts the fossil fuel import dependence of the country over the modeling period, across scenarios. In 2011, the import dependence of coal, oil and gas is 23%, 76%, and 21%, respectively. These escalate to worrisome figures of 66%, 91%, and 60%, for coal, oil and gas, respectively, by 2031 in the RES. These high numbers are a result of the increasing failure of domestic production to match the rising demands for these fuels. These also indicate to how unsustainable the energy scenario is going to be if the present trends of fuel usage are to continue. The fossil fuel import bill as a percentage of the export earnings has grown from 35% in 2001–02 to 60% in 2012–13. This is a major cause of concern especially with these projected import needs, rising and volatile fuel prices.

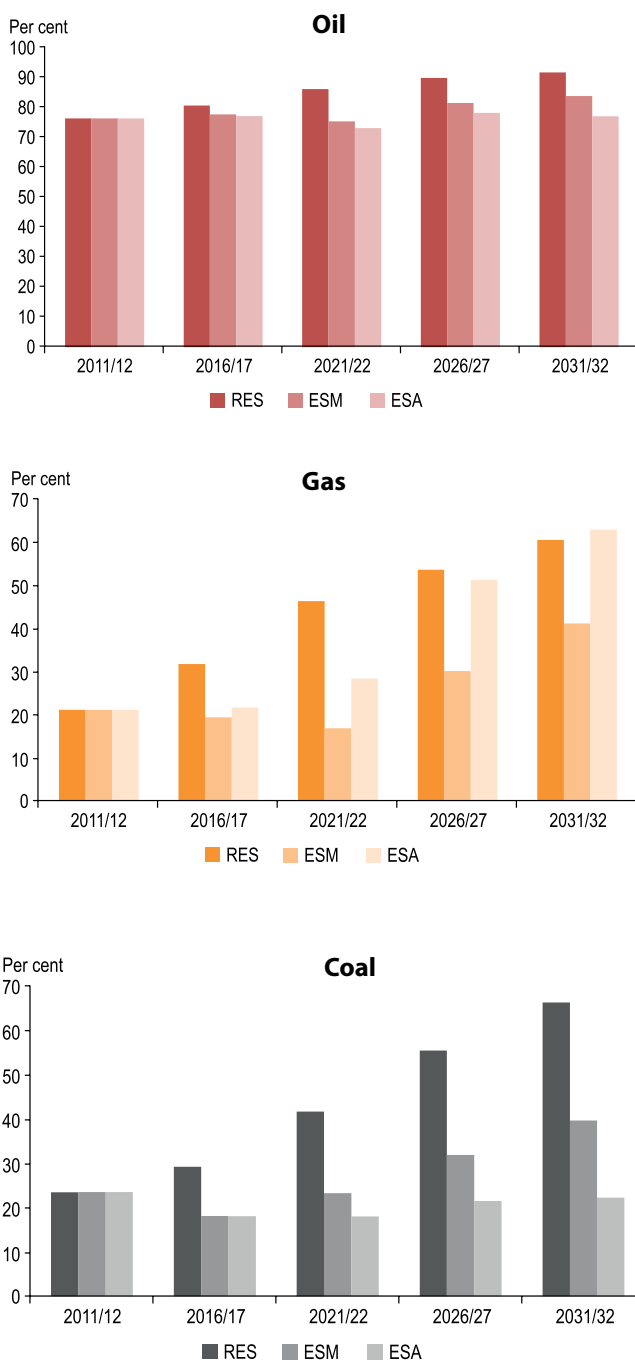


Figure 58: Import dependence of fossil fuels, across scenarios
Source: Model results

In the ESM scenario, given the stress on diversification of the fuel mix, our reliance on fossil fuel is projected to be lower when compared to the RES. The import dependence for coal, oil and gas, by 2031 stands at 40%, 84%, and 41%, respectively. This is much lower when compared to the RES, especially in case of coal. The lower levels of import in the ESM are a result of enhanced domestic production and lower demands due energy efficiency advances.

In the ESA, the import dependency of coal, oil and gas in 2031 is 22%, 77%, and 63%, respectively, which in physical terms implies that by 2031 the level of coal import would stand at 203 Mt, oil at 222 Mt and gas at 136 BCM. This scenario boasts of such low level of imports due to enhanced domestic availability of fossil fuels, a great use of renewable energy in the power sector, and also various efficiency measures across the demand sectors.

Final Energy Demand

Figure 59 shows the final energy demand by sectors over the modeling framework, across scenarios. Our energy demand in the RES grows from 549 Mtoe in 2011 to 1,460 Mtoe, increasing almost thrice in 20 years. Energy consumption of the commercial sector grows at the fastest pace, with a CAGR of 8%. In terms of magnitude, industry and transport sectors are the two main energy consuming sectors with the energy consumption of the transport sector increasing by about four times by 2031.

In the ESM, due to several demand management measures and fuel efficiency enhancements in the demand technologies, the final energy demand by 2031 is 1,252 Mtoe. This is a reduction of 17% from final demand in RES. This result helps us understand the demand management aspect of achieving an

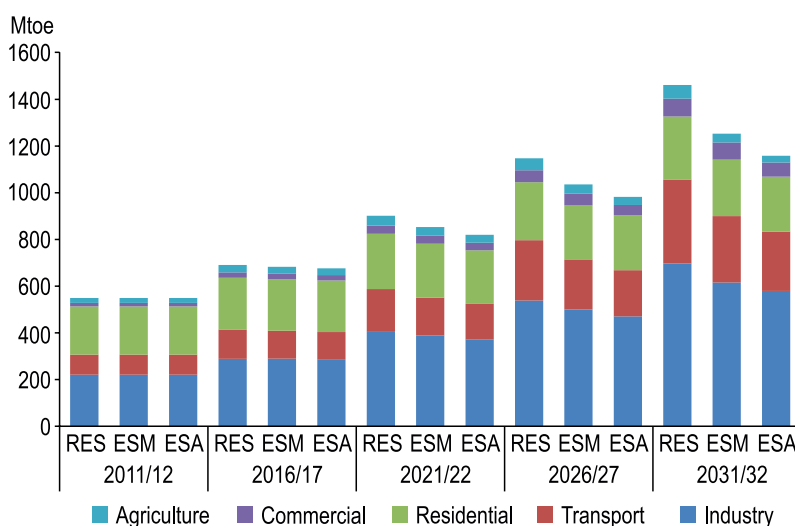


Figure 59: Final energy demand, across scenarios
Source: Model results

‘energy secure’ future and the important role that energy efficiency plays in achieving this.

In the ESA, the final energy demand by 2031 stands at 1,158 Mtoe, which is 21% lesser than the final demand in the RES and 8% lesser than the ESM. This reduction is achieved, as in this scenario we assume that energy efficiency improvements to some demand technologies are over and above the ESM improvement levels. Hence, it helps further curb wastage of fuel occurring due to inefficient usage.

In all the three scenarios, we see that the percentage share of industry sector in the final energy demand is the highest from 2011 onwards, accounting for around 40%–50% of the total demand. Furthermore, the share of the transport sector in final energy demand is observed to increase from 16% in 2011 to 22–25% by 2031. The share of residential sector is seen to diminish over time since the magnitude of its consumption grows slowly,

while that of commercial and agriculture sector remains constant.

The energy consumption trajectories, by fuel and scenario, of each demand sector are discussed in details below.

Industry Sector

Figure 60 shows the final energy demand by the industry sector by fuel, and across scenarios. Industry demand has been projected to grow from 221 Mtoe in 2011 to 697 Mtoe by 2031 at a CAGR of 6% in the RES. This rapid growth in energy consumption in the industrial sector is largely on account of the growth in infrastructural demands of the country (steel, cement, and brick demands). Coal is used to meet more than half of the sector’s energy demand and its consumption increases by four times over in 20 years. Coal in this sector is mostly used to generate decentralized electricity. Petroleum products and natural gas

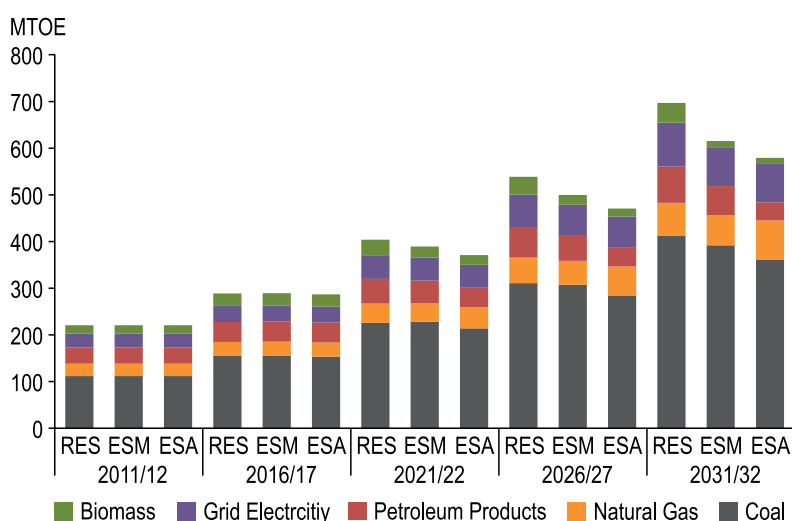


Figure 60: Final energy demand by the industry sector, across scenarios
Source: Model results

are the next most popular fuels that are used in the sector. The share of petroleum products however, is seen to decrease slightly from 16% in 2011 to 11% by 2031, while that of natural gas from 12% in 2011 to 10% by 2031.

In the ESM, the final energy demand by 2031 is 615 Mtoe, which is about 12% lesser than that in the RES. Even though, coal continues to be the dominant fuel, its consumption drops marginally in this scenario when compared to the RES. This scenario encompasses various measures taken to help reduce the Specific Energy Consumption (SEC) of all the technologies especially in SMEs. The reduced SECs also lower the consumption of petroleum products by about 19% by 2031 in comparison to the RES. The use of gas and grid electricity is also seen to be lower than that in the RES.

From 221 Mtoe in 2011, the final energy consumption in the sector rises to 579 Mtoe by 2031 in ESA. This is lower than the final

energy consumption in the RES by 17%, and in the ESM by 6%. The use of scrap for steel production in ESA is considered to be higher in comparison to the other two scenarios.

Transport Sector

Figure 61 reflects the final energy demand by the transport sector by fuel, and across scenarios. The energy demand of the transport sector in the RES grows from 86 Mtoe in 2011 to 360 Mtoe by 2031. This sizeable growth in the transport sector can be attributed to a shift towards more energy-intensive modes of transport for both passenger and freight movement. This four-fold increase is mainly due to the rapid growth in the consumption of petroleum products the transport sector, which has grown at a by CAGR of 7%. In 2011, petroleum products are used to meet over 97% of the sector's energy demand which drops to 91% by 2031. There is a slight increase

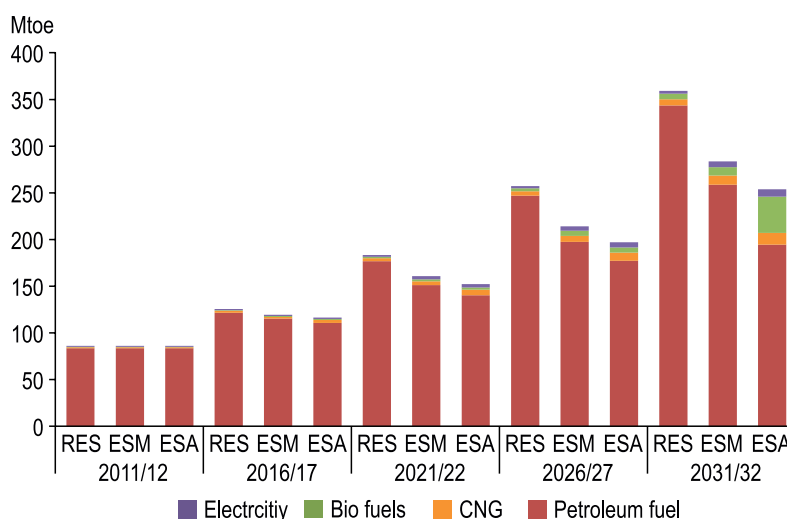


Figure 61: Final energy demand by the transport sector, across scenarios
Source: Model results

in the use of CNG and electricity in RES. Role of biofuels in this scenario is minimal.

In the ESM, the energy demand rises to 284 Mtoe by 2031, which is lower than the RES by 21%. The consumption of petroleum products by 2031 goes down to 259 Mtoe as compared to 344 Mtoe in the RES. This denotes a saving of about 25%. In the ESM, we assume the share of CNG use in public and private transport to increase, rising number of electric two-wheelers in use, greater share of electric traction in both passenger and freight rail movement, use of biofuels to penetrate slowly in the sector and efficiency improvements in the technologies. Thus, in the scenario petroleum products usage is substituted by CNG, electricity, and biofuels.

In the ESA, the final energy consumption of the sector by 2031 is 254 Mtoe, which is 29% lower than the consumption in the RES. The

use of petroleum fuel in 2031 falls to 195 Mtoe, 43% lower than the RES value. This scenario shows a picture wherein the transport sector in India isn't entirely dependent on petroleum products to meet its energy demand and about one-fifth of its energy comes from alternative fuels. From having a negligible share in the fuel mix in 2011, the share of biofuels rises to 15% in 20 years. Electricity and CNG, which in 2011 met about 2% of the energy demand rise to a share of 8% by 2031.

Residential Sector

Figure 62 depicts the final energy demand by the residential sector by fuel, and across scenarios. The final energy demand of the residential sector increases by only 1.3 times from 206 Mtoe in 2011 to 269 Mtoe by 2031 in the RES scenario. A major portion of the demand continues to be met by traditional

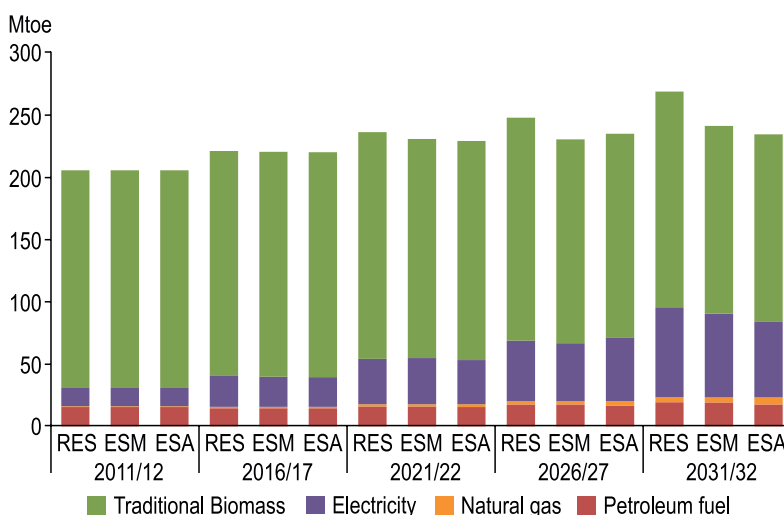


Figure 62: Final energy demand by the residential sector, across scenarios

Source: Model results

biomass even in 2031. Traditional biomass is an important fuel used for cooking and water heating in the residential sector. Also due to greater appliance penetration and electrification, the electricity consumed by the sector rises over four times from 15 Mtoe in 2011 to 72 Mtoe in 2031.

In the ESM, the final energy demand of the residential sector grows to 242 Mtoe by 2031, which is about 10% lower than the demand in RES. The difference can be seen in the electricity usage which by 2031 is 7% lower when compared to the RES scenario. This reduction occurs due to higher penetration and use of efficient household appliances such as air conditioners, refrigerators, etc. However, traditional biomass continues to be the most popular fuel choice, especially in the rural households though the penetration of

improved cookstoves in ESM is more than in the RES (20% by 2031). Improved cookstoves are upto five times more efficient than the traditional cookstoves.

In the ESA, the final energy demand in 2031 is 235 Mtoe, which is a saving of 13% and 3% when compared to the RES scenario and ESM. In this scenario, we see a drop in the use of electricity to 61 Mtoe in 2031, which is 16% lower than the RES and about 10% lower than the ESM. This is possible because of the extensive usage of efficient household appliances and the efficiencies of which also increase at an annual rate of 1–2%.

Commercial Sector

Figure 63 reflects the final energy demand of the commercial sector by fuel, and across scenarios. The final energy demand of the

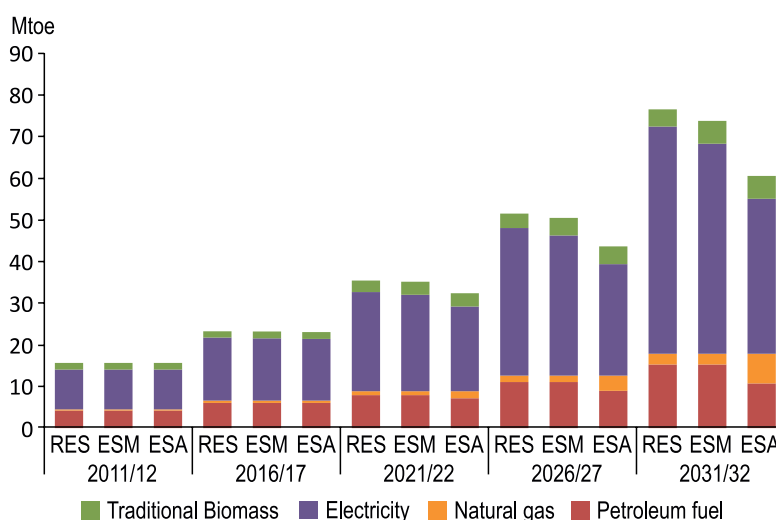


Figure 63: Energy demand of the commercial sector, across scenarios
Source: Model results

sector grows five times from 16 Mtoe in 2011 to 77 Mtoe by 2031 in the RES scenario. Petroleum products and electricity are the two most popular fuel choices of the sector. It should be noted that in the RES no reduction of EPI of commercial buildings is considered and limited penetration of GRIHA rated buildings is assumed in new buildings. Thus, we see that the use of electricity grows by about six times and its share in the sector's fuel mix grows from 61% in 2011 to 71% by 2031.

In the ESM and ESA, the final energy demand rises to 74 Mtoe and 61 Mtoe by 2031, which is a slight fall when compared to the RES. A drop is observed in the usage of electricity in these scenarios and a saving of 8% and 32% is reflected compared to RES. The reductions in ESM occur due the assumption of a 5% reduction in EPI in every five years starting from 2011 for air conditioned buildings. Also, an increase in GRIHA penetration in new built

area (from 1% in 2011, to 13% in 2021, and 26% by 2031) is considered. In the ESA, along with EPI improvements what also helps in the reduction of energy consumption is that we have assumed that 100% of the new built-up area complies with GRIHA standards by 2031.

Agriculture Sector

Figure 64 depicts the final energy demand of the agriculture sector by fuel, and across scenarios. The final energy demand of the sector rises almost three times over from 21 Mtoe in 2011 to 58 Mtoe by 2031 in the RES. Electricity and petroleum products are the only two fuels used to meet the energy demand of the sector, with diesel being used mainly for land preparation and electricity for irrigation purposes. Overtime, the share of petroleum products is seen to fall while that of electricity rises.

In the ESM and ESA, the final energy demand by 2031 is 37 Mtoe and 29 Mtoe which

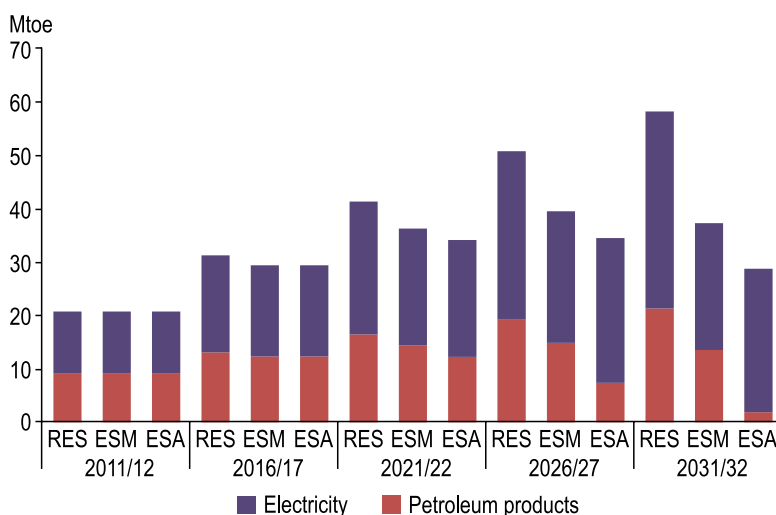


Figure 64: Energy demand of the agriculture sector, across scenarios

Source: Model results

is a saving of 36% and 51% when compared to the RES. This saving is brought about by various energy efficiency measures. In both scenarios, it is assumed that there is a greater penetration and usage of efficient tractors and replacement of more and more diesel pump sets by efficient electric pump sets over the years.

To summarize, the scenarios and their respective trajectories discussed in the

preceding sections provide a comprehensive assessment of the energy pathways and opportunities that lie ahead. Referring to the dashboard presented in the introduction chapter, Table 27 provides the projected trajectory of India's energy sector on various energy security parameters under the three scenarios.

For detail scenario trajectories please refer to the Annexure.

Table 27: Energy security indicators

	Parameter	Current Status (2011)	2021			2031		
			RES	ESM	ESA	RES	ESM	ESA
Supply side			RES	ESM	ESA	RES	ESM	ESA
	Import dependence—Oil	76%	86%	75%	73%	91%	84%	77%
	Import dependence—Coal	23%	42%	23%	18%	66%	40%	22%
	Import dependence—Natural Gas	21%	46%	17%	28%	60%	41%	63%
	Total energy import dependence for fossil fuels	40%	57%	39%	36%	74%	54%	44%
	Share of fossil fuels in the commercial energy supply energy mix	69%	76%	75%	74%	83%	79%	74%
Demand side	Net energy intensity (ktoe/INR)	0.0120	0.0098	0.0093	0.0088	0.0082	0.0069	0.0060
	Average consumption of energy per capita (ktoe/capita)	435	698	659	627	1,137	956	840
	Access to electricity	67%	100%	100%	100%	100%	100%	100%
	Use of improved cookstoves	0%	1%	5%	5%	5%	20%	25%
	Access to modern cooking energy fuels—Rural	29%	30%	30%	30%	34%	34%	34%



PART III

Way Forward for an Energy Secure India



Chapter 12

Recommendation

The analysis provided in Energy Sector Analysis and the results of the modeling exercise, highlighting the complex inter-linkages of the different sectors on each other. There is a need to encourage both, supply, as well as, demand sector management to ensure that the sectors perform efficiently and optimally. This requires forward thinking and visionary planning that takes into account current technology advances and the possibilities they could hold for the future. This would also require manifold increase in R&D both at the technical and policy levels to support desired transitions. There is synergistic interdependence between different sectors and resources such as energy, food, water, health; developments in any one sector have a domino effect, affecting others. These need to be recognized to help undertake holistic planning. Setting up a committee to review options for phasing out obsolete, inefficient infrastructure; for preparing and planning for the future infrastructure; and for undertaking integrated management of energy should be considered.

The key areas for improvement for each of the supply and demand sectors are summarized in the following sections. These recommendations provide a way forward and help address the key energy security issues

that were identified and developed on in the preceding chapters.

Energy Supply Sectors

Coal

Considering the issues that affect the availability of coal in the country, the following key recommendations have emerged.

Enhancing production of domestic coal

The most critical area of improvement relates to the production of coal in the country. The current production level is not in tandem with the reserves that India boasts of. A mix of initiatives needs to be implemented here including—encouraging underground coal mining, facilitating participation of more players in order to increase the production capacity and also to foster competition and enhancing efficiency in the sector should be adopted.

Facilitating imports

Given that the projected dependence on imports in the near to medium term is set to increase, it is essential to facilitate the import of coal by creating adequate facilities and entering into contracts with large coal supplying countries. These efforts will be

aimed to ensure that the domestic demand, at least in the short term, is met.

Providing clearances and removing bottlenecks

Provision of clearances appears to be the major hindrance in ramping up domestic production of coal. A single window mechanism has been suggested in order to streamline the process of allocation of coal blocks and enhance the production of the resource in the country. This process has, to some extent, already commenced and regular meetings between the Ministries of Coal, and Environment and Forests organized to provide environmental clearances to coal mines (Lok Sabha 2013).³⁵ However, the process needs to be systematized and regular follow-ups are needed to ensure that approvals proceed on track.

Establishing infrastructure capacity to remove evacuation and transport bottlenecks

Infrastructure for transportation of domestically produced coal needs to be enhanced significantly. The construction of washeries, creation of storage facilities for mined coal, expansion of railway network and addition to port facilities are all needed to ensure that the mined coal is transported to the major demand centres.

Improvements in technology

A large number of initiatives need to be taken to mitigate the environmental implications of

coal mining in the country. One of the most important efforts is to increase the share of underground mining in the total mining technology mix. Coal India Limited (CIL) have already circulated an Expression of Interest to examine the latest available technology in coal mining and identify gaps and areas of improvement.

Independent and effective regulation

The first step needed towards this is the introduction of a regulator that works independently of government controls. While this recommendation has been made in several reports, its implementation is yet to come into force. Any new regulator will have to be autonomous with adequate powers to regulate pricing and allocation as well as enhance transparency in the sector.

Improvements in the R&R policy

The land acquisition policy needs to be more participatory in nature. Various mechanisms have been suggested in this regard; including sharing of resource revenues, leasing of land, and providing regular incomes rather than one term payments.

Restructuring to enhance competition in the coal sector

In the long term, restructuring of the coal sector is essential to enhance competition to facilitate improvements in the technology employed. Short- and medium-term measures such as introduction of an autonomous regulator and improvement in the pricing

³⁵ Lok Sabha 2013. Environmental Clearance to Coal Mines, Unstarred Question No. 2402, Answered on March 12, 2013. Available at <http://164.100.47.132/LssNew/psearch/QResult15.aspx?qref=136343>, accessed on April 25, 2013

mechanism will facilitate a move towards this long-term measure.

Oil and gas

A large number of committees and reports have examined the various issues in India's oil and gas sector. Most of them have argued for deregulation and subsidy removal, although the specific modalities for such reforms have been looked into only recently. Some of the main recommendations for improving the performance of the petroleum and natural gas sector in the country are given below.

Petroleum product pricing reforms

In 2012, the Kelkar Committee's report on a 'Roadmap for Fiscal Consolidation' recommended that the government should increase the price of diesel by INR 4 per litre, the price of kerosene by INR 2 per litre and that of LPG by INR 50 per cylinder, with immediate effect. Subsequently, smaller and more frequent price revisions should be left to the discretion to the OMCs, who should be duly empowered to make these revisions. It was estimated that this move would reduce the projected under-recovery by INR 20,000 crore for the next half year.

The 'Expert Group on a Viable and Sustainable System of Pricing' for Petroleum Products headed by Kirit Parikh strongly recommended deregulation of petroleum product prices (See Chapter 2 reference MoPNG 2010c). Soon after publication of the report's findings, the government decided to deregulate petrol prices.³⁶

Diesel price deregulation was to follow soon. However, it was only in September, 2012, that the government announced the first significant hike in diesel prices (by INR 5 per litre). Thereafter, the government has been committed to carrying out a phased deregulation of diesel by raising prices in small amounts at frequent intervals.

Taxation regime

Regarding the taxation regime on oil and gas, the Report of the 13th Finance Commission recommends that transport fuels including High Speed Diesel (HSD), Motor Spirit (MS), and Aviation Turbine Fuel (ATF) should be brought under a dual levy, of GST and an additional levy, with no input tax credit available on the additional levy. This would protect the existing revenues from these sources. However, all other petroleum products should be brought within the ambit of the GST, as should natural gas.

Independent estimation of reserves and resources

Emphasis needs to be laid on collecting and providing accurate data on reserves held. Significant acreages of the sedimentary basins of the country are still unexplored. Efforts need to be made to enhance the exploration of the yet unexplored basins and perhaps, leasing out these acreages to specialized exploration agencies on contractual basis will help in accessing the data. Further, the work on the National Data Repository needs to be taken up in earnest in order to provide access to all the existing basin data in the country.

³⁶ Although the government has approved deregulation of petrol prices, oil companies still seek tacit approval from the government before changing prices

Production sharing contract mechanism and natural gas prices

In December 2012, the Rangarajan Committee on the Production Sharing Contract (PSC) Mechanism in the Petroleum Industry recommended sweeping changes in the current PSC mechanism. The committee proposed that the cost recovery mechanism should be replaced by a revenue-sharing mechanism in future PSCs in order to avoid gold-plating of costs by E&P companies and to cut down the administrative cost of monitoring upstream companies' operations.

On natural gas pricing, the Rangarajan Committee recommended that an unbiased arm's length price should be estimated based on an average of two indicators. One of these would be derived from the volume-weighted net-back price to producers at the exporting country well-head for Indian imports for the previous 12 months. The other indicator would be the volume-weighted price of US's Henry Hub, UK's NBP, and Japan Custom Cleared (on net-back basis, since it is an importer) prices for the previous 12 months. The arm's length price thus computed as the average of the two price estimates would apply equally to all sectors, regardless of their prioritization for supply under the Gas Utilisation Policy (GUP).

In March, 2013, the petroleum ministry asked a committee headed by Dr Vijay Kelkar to review the formula suggested by the Rangarajan committee. After initial assessments, Dr Kelkar stated that doing away with the cost recovery model would be detrimental to E&P companies and hence impede investment in domestic oil and gas production (See Chapter 2 reference Economic

Times 2013). It seems that there is still a considerable difference of opinion within the government regarding the proposed change in the PSC mechanism.

This uncertainty needs to be addressed and removed in order to encourage participation and competition within the sector. Further, the difference in treatment of oil and gas produced under the New Exploration Licensing Policy (NELP) blocks and uncertainty over charging differential income tax under different NELP rounds needs to be addressed.

Nuclear

For a fuel constrained nation like India, every option for energy needs to be exploited. For strategic reasons as well, it is difficult to assume a complete withdrawal from nuclear power. However, social costs should also be taken into account.

This section looks at some broad recommendations for taking into account the views of the people and for a better governed nuclear power sector.

Independence of the regulator

Financial, administrative, and most importantly, statutory independence is absolutely essential for the regulator. To some extent, this will be achieved by the 'Nuclear Safety Regulatory Authority Act' draft legislation that was tabled in the Parliament in September 2011. This will help with statutory independence. However, the debate and decision on it needs to be expedited. Specific and published timelines should be set up to look into and implement the Comptroller and Auditor General (CAG)

recommendations. Regular reviews like the one conducted by the CAG as well as the international peer review and appraisal by the IAEA (also recommended by the CAG) should also be undertaken. A transparent and efficient regulator, which is also perceived as one, will help build greater confidence about the establishment and perhaps about the technology as well.

Increased transparency in decision-making, costs, functioning, and laws

A distinction has been made between the civil and defence use of nuclear energy. However, this distinction needs to permeate in the activities as well. One of the widely talked points in the nuclear sector recently has been the lack of transparency. A detailed engagement and clause by clause clarification of the liability laws should also be done to dispel any apprehensions both domestically and internationally as well as to make the government's position more clear.

Better public engagement and public debate on proposed and existing nuclear sites

A public communications strategy that involves local and regional people, local businesses and organizations in the decision-making process is essential. There are good examples of public engagement best practices and strategies followed in different countries. For instance, Finland follows a pre-defined timetable based on step-wise decision-making process for establishing a nuclear power plant. More significantly, the decision-making process takes into account local views and

gives the municipality, where a power plant could be located, a veto power as well (See Chapter 4 reference Tigerstedt 2012; World Nuclear Association 2013). The Environmental Impact Assessment (EIA) forms a critical part of the process which aims to take into account both positive and negative opinions of the stakeholders.

Strengthening and building related institutional infrastructure to cope with a growing industry

The Indian nuclear industry has been functioning under enforced isolation for many years. Opening up of this sector will require simultaneous reforms and strengthening of laws governing and affecting related industries as well. This should be done not only to promote investments but also to protect domestic interests. Strengthening this sector is especially important in the light of the specificities of India's position in the world nuclear industry.

For instance, in case of the insurance industry, the capacity of domestic insurance companies to insure a nuclear power plant; the requirement for independent inspection of such a plant by insurance companies, and the possible conflict therein, etc., should to be taken into account and laws to facilitate them should be expedited. How these affect the public and what happens in a case where the claim is larger than the capacity of the insurers?

Thus, the various implications of regulatory decisions need to be studied and the supporting infrastructure built, before, or at least faster, than the growth of the industry.

Social impact assessments

The government needs to undertake a social cost-benefit analysis and evaluate the extent of damage possible in the worst-case scenario taking into account the seismicity of a region, propensity to natural disasters, and unforeseen incidents. This forms a part of the design-basis of a plant but the possible impact of multiple systems failure on the people around also needs to be considered. The methodologies and assumptions and the results of such an assessment, should be made public (See Chapter 4 reference Srinivasan, Rethinaraj, & Sethi 2012). Each fuel source has risks associated with it but a comparative assessment helps understand the choices. Such an assessment should be mandated for other fuels as well, but it becomes particularly important in the case of nuclear energy.

Renewable energy

Technology

For wind energy, development of high efficiency wind turbines is needed so that they produce higher amounts of electricity in low wind regime (this is mostly the case for Indian wind potential sites). For solar plants, efforts need to focus on increasing the level of efficiency, inverter quality, lowering costs, addressing non-surety of crystalline vs. thin film, etc. There needs to be a focus on developing appropriate energy storage solutions. Energy storage helps to accommodate large-scale renewable energy injection by addressing issues, such as uncertainty of output and variability. It can utilize excess renewable energy produced

during off peak demand period and can provide this energy during peak hours.

To achieve low-cost manufacturing and therefore lower capital costs, and capitalize on its inherent advantages in the solar sector, India needs to consider revamping and upgrading its solar R&D and manufacturing capabilities. In this regard, the government may consider promoting a core company to produce wafer and silicon that will enable substantial reduction in the costs of solar technologies.

Policy

The government must formulate a comprehensive policy or action plan for all-round development of the sector, encompassing all the key aspects. An action plan must be prepared in consultation with state governments. It is understood that the Energy Coordination Committee (ECC) has approved the preparation of an umbrella renewable energy law to provide a comprehensive legislative framework for all types of renewable energy technologies, their usage and promotion. However, the government has fixed no timeframe for the formulation and enactment of such a law and thus it must expedite this task and ensure that the desired law be enacted quickly.

Regulatory

While setting state-wise RPOs, there must be a standardized RPO target formulation; with a standard procedure applied across states to determine the targets. The underlying principles and approach in breaking down

the national RPO target into state-wise RPOs can consider factors, such as GDP or financial health, renewable resource potential and consumer profile of the state, etc. These targets should then be made mandatory and enforced. State Electricity Regulatory Commissions (SERCs) should be responsible for monitoring annual compliance with RPO targets by state distribution utilities; penalty mechanisms should be introduced as a deterrent for non-compliance.

A number of states do not allow the procurement of renewable energy-based power from outside the state. This is an artificial barrier in the way of renewable energy-based power generation and investment across the country. Instead, regulators can identify ways and means of selling this power to neighbouring states that are short on renewable energy resources or through RPOs at a mutually agreed upon rate.

Renewable energy forecasting is required for grid security. However, due to lack of quality data and insufficiently developed forecasting tools, accurate renewable energy forecasting is difficult. Renewable energy forecasting for wind and solar power is critical for large-scale grid-integration of renewable energy. Currently, scheduling is required for wind power projects but developers are opposing this due to possible penalties that may be imposed due to deviations from schedule. The Government must look into removing penalties in the initial stages until forecasting tools become sufficiently advanced. Significant amount of generation integration will depend on the accuracy of the forecast.

Transmission and infrastructure requirements

Investments must be made to support infrastructure and renewable energy evacuation should be accorded high priority. Grid connectivity to renewable energy generation should be provided by state transmission utilities. Transmission system plans prepared by STUs should cover evacuation and transmission infrastructure requirements for renewables.

There is a greater need for coordination and consultation between the state transmission utility and the nodal agency responsible for development of renewables at the state level for the development of transmission infrastructure for renewable energy projects that are in the process of being allotted or development or are likely to be bid out in the near future.

To absorb higher renewable energy, short-distance intra-state transmission network as well as Renewable Energy Certificates (REC) mechanism needs to be strengthened. There should also be focus on setting up long inter-regional corridors in RE rich states as better integration of high renewable energy penetration would require balancing at the regional and national level.

Capacity building and information dissemination

There is an urgent need for technical assistance programmes designed to increase the planning skills and understanding of renewable energy technologies by electricity utilities, regulators, local and municipal administrations, and other

institutions involved. Information specific to viable technology options needs to be made easily accessible both to increase general awareness and acceptability as well as to aid potential investors and sponsors of such projects.

Power

Electricity generation

Power sector utilities that have been allocated captive blocks should be advised to enhance their production through some incentive oriented strategy and surplus production after meeting their own requirement may be supplied to power stations. In order to ensure the availability of coal to the power plants, the Ministry of Power has undertaken the some measures. However, there still exists a strong need to develop a sustainable strategy to ensure coal supply to power plants in the long term. There is also an urgent need to strengthen the logistics for coal movement and transmission infrastructure for gas to ensure reliable fuel supply to thermal power plants.

The designing of the standard bidding documents should account for factors, such as fuel price hikes, providing sufficient security on project assets to the lenders and clearance delays that are beyond the control of developers. In view of the increasing requirement of capacity addition to meet the demand, the capacity for manufacture of main plant equipment has to be increased with the formation of several Joint Ventures (JVs) for manufacture of main plant equipment in India.

There is need for fast track development of clean coal technologies with higher

efficiencies and low emissions in India (*See Box 2 for more details*).

Transmission

Higher deployment of advanced technologies, such as the Thyristor Controlled Series Compensation (TCSC), High Surge Impedance Loading (HSIL) lines, high temperature high capacity conductors, multi-circuit towers, mono pole towers, etc., is essential to optimize Right of Way (RoW) and enhance the power transfer capability of existing and new transmission lines.

With scarce land availability, there is a growing need for reduction of land area used for setting up of transmission systems, Power Grid Corporation of India Limited (PGCIL) has established state-of-the-art Gas Insulated Substations (GIS) which requires less space (about 80% reduction), i.e., 5–6 acres as compared to conventional substation which generally requires 30–40 acres areas.

Increase in the transmission system at higher voltage levels and sub-station capacities to support transmission network to carry bulk power over longer distances and at the same time optimize right of way, minimize losses and improve grid reliability.

Open access in transmission and distribution

There is an urgent need to have a strong transmission and distribution system, to cope with the dynamic requirement. Therefore, strengthening of inter-state and inter-regional transmission capacity for optimum utilization of available power is necessary. It is essential to encourage use of modern project management tools followed by timely

BOX 2: CLEAN COAL TECHNOLOGY DEVELOPMENT IN INDIA

Since coal is the most abundant fuel available domestically, close to 56% of the installed capacity in India is coal based. As the demand for electricity grows, the role of coal would remain undiminished. The adoption of super-critical technology in thermal power plants has become very crucial. It has become all the more important especially when we consider the fact that coal, a rapidly depleting resource, is the mainstay of thermal power generation in our country. The indigenous production of coking and non-coking coal has not increased significantly over the years; therefore, the existing resources need to be utilized more efficiently in future for addressing energy security concerns of the country. Also, Indian coal however has a high ash and mineral content while cleaner imported coal is very costly. Hence, the focus is on development of clean coal technologies which is of paramount importance for a country like India.

While many developed countries adopted the super-critical technology about 40–50 years back, India lags behind. It is only recently that the government has become serious about adopting this technology. India is targeting 50% addition to installed capacity through super-critical technology by the end of 12th Five Year Plan and 100% addition by the end of 13th Five Year Plan. Apart from being less polluting and consuming lesser fuel, super critical are nearly 25% more efficient as compared to conventional sub-critical power plants. Coal-based units of higher size (660 and 800 MW) with super-critical technology have been introduced in the country and state owned NTPC is proposing to set up nine units of 800 MW (totalling 7,200 MW) during the 12th Plan (2012–17). Also, all Ultra Mega Power Projects being implemented are necessarily to adopt super-critical technology.

With the commercial introduction of new steel alloys with higher allowable stresses and longer life at elevated temperatures, a number of power plants with USC parameters have come up in developed countries like Japan, EU, and the USA. In September 2010, the Indira Gandhi Centre for Atomic Research (IGCAR) announced the development of an advanced ultra-supercritical boiler with steam capacity of 350 bar and 700 °C for an 800 MW coal power plant. This will be undertaken in cooperation with BHEL and the National Thermal Power Corporation (NTPC), the largest and state-owned power utility in India. Construction of the plant will start by 2018 (IEA 2011). Therefore, with the growing concern for carbon emission, energy efficiency, and cleaner power, there is a need to assess the availability of different (and evolving) technology options. It is of prime importance to assess their suitability in the context of existing and expected future challenges which has highlighted the need for a systematic and careful technology decision-making process to develop suitable technology policies in this sector.

monitoring and corrective actions to avoid delays and the consequential losses.

Transmission development should be done in a phased manner to avoid the bottling up of power. It is, therefore, imperative to establish sound project management principles for the sector to help ensure timely completion of projects so as to commensurate with generation/load growth.

Distribution

Improving the financial health of utilities

To enable the turnaround of the State Distribution Companies (DISCOMs) and ensure their long-term viability, a scheme for financial restructuring of state-owned DISCOMs has been notified by the Government of India. The scheme contains measures to be taken by the state-owned DISCOMs lender banks and state governments for achieving financial turnaround by restructuring their debt with support through a Transitional Finance Mechanism by the Central Government. However, the proposal to restructure debt of state-owned DISCOMs will only be a short-term solution and for the restructuring package to yield results. It has to be supported with regular tariff hikes, a timely and adequate financial support by the state governments, and better regulatory process and disclosures.

In order to enable a unified approach by Financial Institutions (FIs)/banks for funding state distribution utilities, Ministry of Power (MoP) has developed an integrated rating methodology for state distribution utilities. The overall objective of the integrated rating methodology is to devise a mechanism for

incentivizing/ disincentivizing the distribution utilities so as to improve their operational and financial performance, enable regulatory compliance and influence respective state governments to fulfil commitments on subsidy, equity support including transition funding support to achieve self-sustaining operations.

The long term, measures, such as elimination of the gap between revenues and cost of electricity supplied, reduction in distribution losses, and automatic pass-through of fuel costs will enhance the profitability of operating in the sector.

Improving the operational performance and reduction of losses

Since the financial viability of the power sector as a whole depends on the revenues collected at the distribution end, it is vital that the distribution system is made financially viable. This can be made possible by improving the operational performance by achieving 100% metering (metering of feeders, distribution transformers and consumers), to achieve 100% billing/collection efficiency and to reduce the commercial losses. The Government of India approved Restructured Accelerated Power Development and Reforms Programme (R-APDRP) in 2008 with the focus on a positive performance in terms of Aggregate Technical and Commercial (AT&C) loss reduction recognized the critical need for distribution reforms. This includes preparation and validation of base-line data, establishment of IT applications for energy accounting, and auditing and strengthening of distribution and transmission systems. The Indian Government has proposed to continue the R-APDRP during

the 12th Plan and the completion period for Part A extended by another two years for all states for conversion of loan into grant (R-APDRP 2013).

Tariff rationalization and encouraging competition in the sector

The Act and the Policies require the Regulatory Commissions to ensure that the tariff progressively reflects the cost of supply. High level of cross subsidy is not desirable as it discourages competition and efficiency in operation. Therefore, it is essential to rationalize the tariff in a time bound manner.

Energy efficiency and Demand Side Management (DSM)

SERCs should mandatorily consider appropriate tariff interventions (like Time of Day tariff, incentive for energy-efficient buildings/appliances, etc.) to support DSM. This should also be supported by institutionalizing energy efficiency in the organizational structure of distribution utilities and providing special measures for promoting energy efficiency in pumping groundwater for agricultural use since DSM and energy conservation are as important as capacity addition to tide over shortage.

Encourage private participation in the sector

It is essential to have a reasonable cross-subsidy surcharge and additional surcharge for the open access as the new capacities are being set up in different states. Although the introduction of open access has been

mandated in the Electricity Act 2003, there has been reluctance in the states to give freedom to the customers having requirement of 1 MVA and above to choose their own sources of supply. This should be expedited so that power markets are broadened and developed. Competition in the distribution sector needs to be enhanced by issuing parallel distribution licensees in select areas and implementing open-access regulations.

Energy Demand Sectors

Agriculture sector

Despite the challenges posed by the energy-intensive nature of agriculture, prudent use of resources and judicious application of technology has the capacity to significantly improve the long-term sustainability of food production. Possibilities to shift to a more rational energy system in view of energy security, access to energy, and environmental sustainability include:

- Minimum tillage, use of crop residue and better matching of tractor and attachments would help to conserve energy.
- Micro-irrigation technology: Micro-irrigation allows application of water to root zone of the crops through specially designed equipment known as emitters. It has already been adopted by some countries for transforming their agriculture. India introduced this technology on a commercial scale in the 8th Five Year Plan. However, the coverage so far has been minuscule in the face of the fact that almost 69 million ha could be covered through this improved system.

- Research and development in use of alternative energy forms to petroleum and renewable energy sources: biodiesel, biogas, producer gas, solar operated pump sets, etc.
- Policy and regulations: Metering of electricity, tariff revisions, restructuring

MSP to promote crop diversification, long-term agricultural mechanization policy at national and state levels, promoting farmers' machinery cooperatives to provide an efficient network of custom-hiring services (Figure 66).

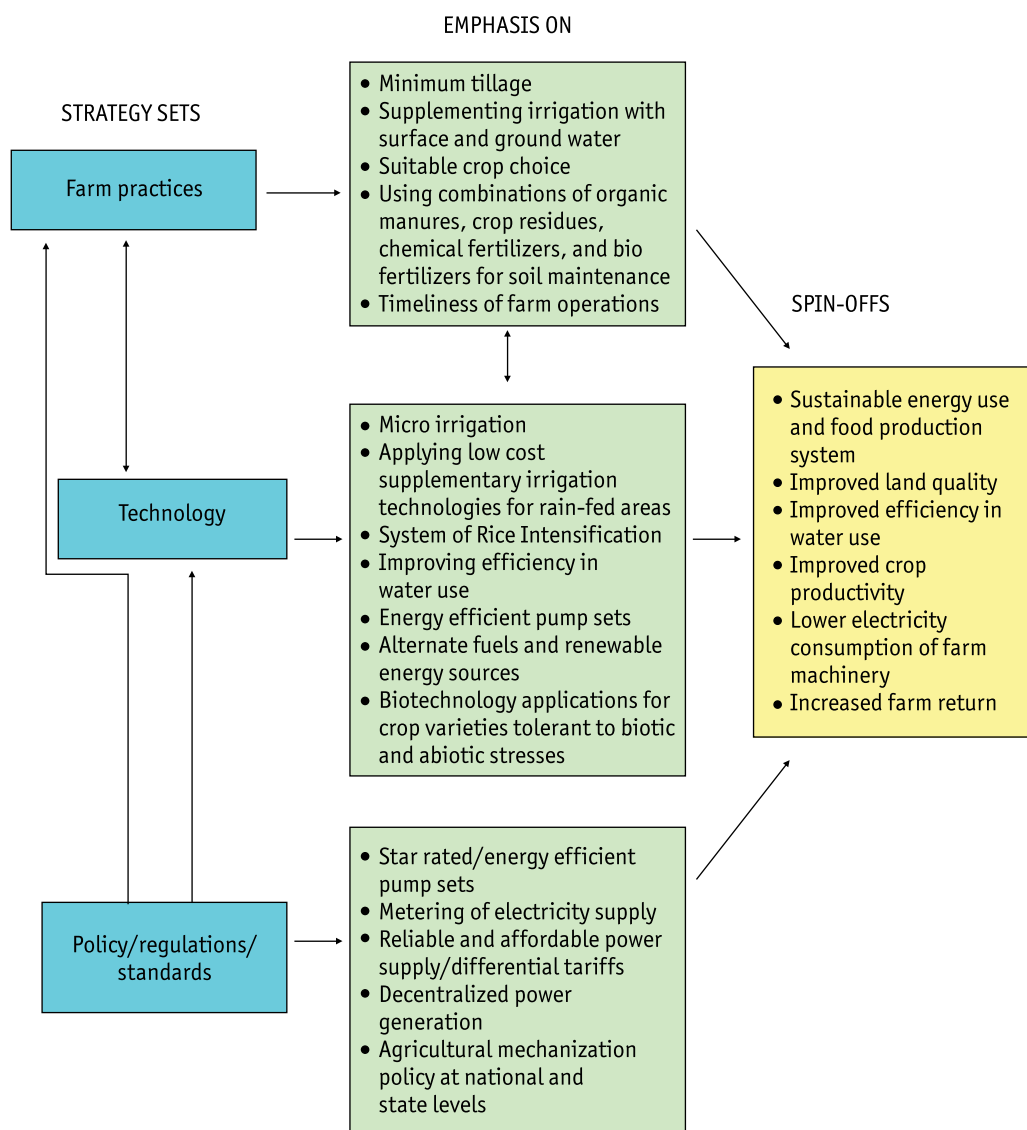


Figure 66: Framework for improvements in agricultural sector

Industry sector

There is urgent need for improvements in policies, regulations, and measures in order to meet the twin objectives of energy security and climate change mitigation.

Technology innovation

Creating altogether new technology development platforms is an elaborate process. While this should be initiated for certain regions and sectors, policies must also look at expanding/strengthening any existing facilities. There are various testing centres that exist across the country and efforts can be made to expand these into technology incubators and/or research centres. Technical assistance needs to be provided to the existing centres through institutional capacity building, expert training, equipment up-gradation, and business model development. Targeted programmes aimed at facilitating manufacturing of highly efficient pumps and providing support for disseminating these pumps (including capacity building of the users on selection and installation) should be planned on a massive scale.

Energy performance standards

There is an opportunity for energy savings by establishing minimum energy performance standards for various equipment/appliances, such as pumps, compressors, fans, air conditioners, etc. The existing performance levels of star rated equipment can also be strengthened further in this regard. Furthermore, current norms must be re-visited to study ways in which energy-efficient technologies can be promoted in public procurement.

Data collection and benchmarking

Collection and compilation of energy-related data in a systematic manner is a major intervention that can form the basis for targeted policy action. For large industries, an extension of PAT beyond DC can be a source for further data collection and benchmarking. However, the process may be more complicated for the MSME sector that is highly diverse and fragmented. A possible option could be to incorporate energy-related data in the existing MSME census conducted by the Ministry of MSME. Furthermore, cluster-specific programmes could also be undertaken for detailed cluster analysis covering data collection, technology development, and demonstration, capacity building and implementation assistance.

Capacity building and awareness

Awareness, capacity building, and implementation assistance of industries on technologies, such as waste heat recovery systems, best operating practices, and financing can be strengthened through:

- large awareness campaigns
- multi-stakeholder training programmes
- supplier-industry-bank networking

The current financial incentives/subsidy programmes for technology upgradation also need to be complemented with technical assistance and implementation support. While there are more holistic capacity building needs for the MSME sector, large industries require more specific sensitization. For example, ISO 50001 energy management standard is a relatively new concept to enter

the Indian industry and can be promoted actively. There is a lack of sensitization regarding energy management at the entrepreneurial level and a dearth of trained experts to implement the standard. Work in this area offers immense scope for energy conservation in a sustainable manner.

Residential and commercial sector

Streamlining government initiatives

Several mechanisms and policies have been made by governments at both levels, the state and the centre. In order to ensure reliability, access to energy sources at household level, the government has introduced policies ranging from provision of subsidies to establishing off-grid energy solutions. However, there appears to be a lack of integration among the policies introduced, the implementation of various schemes and sometimes even amongst various government departments.

Increasing awareness

There is an opportunity to develop a large-scale knowledge and awareness programme, including construction of demonstration projects and conducting project level design workshops for a common understanding of the subject. Lessons from successful examples (at project and policy level) may be disseminated at a national level to enhance uptake of energy efficiency in the built environment. At the household level too, awareness about energy-efficient appliances must be increased. One such mechanism could be involvement of local governments in the villages and resident welfare associations in urban areas.

Encouraging research and development

In order to achieve cost parity of various materials and technological solutions, there is an opportunity for more research and development on solutions that may enable energy efficiency in buildings.

Financing

Support from the banking sector can also be used in enhancing energy efficiency initiatives. Some of these initiatives may be in the form of favourable lending structures that include enhanced moratorium period, reduced interest rates on loans, waiver of loan processing fees, and increase in the timeframe of loan repayments.

Banking and non-banking financial corporations need to work together to ensure that credit linked to energy efficiency measures is easily available to loan beneficiaries.

Transport sector

The current trends of transport in India make it highly energy intensive. Given the lack of an integrated approach towards mobility planning, the energy demands for transport in India are only going to rise exponentially in the near and distant future.

For passenger transport, increased efforts would be required to move a greater share of people on the more energy-efficient mass transport systems, such as railways, metro rail systems, bus rapid transit systems, etc. This can be done only by inducing more investments into these inter- and intra-city systems through innovative financing solutions. A push towards providing better and more accessible modes of public transport in both large and

medium cities and towns would be essential to ensure increased energy efficiencies of passenger traffic.

In terms of freight traffic, creation of more dedicated freight corridors (DFC) in addition to the Western DFCs and the Eastern DFCs coupled with an integrated logistic planning by the railways backed by rationalized freight pricing would be critical to ensure that the railways retain and better their shares in total freight transport in the country. However, this can only be achieved through appropriate changes in the regulatory and operational structure of the railways. A movement to electric traction accompanied by adequate volumes of power generation through renewable sources would help in ensuring long-term energy security in the transport systems in the country.

The greatest efficiencies in national transport can only be achieved when there is an integrated mobility plan prepared for the country. Under the present setup, where the different modes of transport are headed by different ministries with independent agendas, transport planning has always been taken up in a piecemeal fashion, resulting in sub-optimal outcomes both in terms of operations as well as energy efficiencies. It is, therefore, in the best interests of the country to take up transport planning in an integrated approach and by promoting the planning of mobility rather than only the planning of

transport modes to ensure optimal use of energy for transport in the country.

Conclusion

This publication provides a detailed analysis of the key issues and a long-term perspective on energy scenarios in the country. As noted in the Introduction, it is necessary to examine all the major indicators that determine and affect the energy security of the country. The findings of the modeling exercise also identify the impact various options on the overall energy scenario of India in the future. There is a need to remain continually engaged with some of the key issues and analyse in greater detail some of the major factors determining the energy pathways of India today and in the future. With this aim, the forthcoming issues of this publication will look at some of the major issues and will delve deeper into analysing their impacts on the economy in general and on the country's energy security in particular.

One of the major consumers of commercial energy in India is the transport sector. The sector is also the largest consumer of petroleum-based fuels. This is a particular cause of concern owing to the large dependence of the country's refining sector on imported crude oil. The next edition of the *Energy Security Outlook* will focus on the transport sector in India, its major areas of lacunae and the potential for reform and reduction of energy consumption.

Annexure

RES	2011	2016	2021	2026	2031	Shares (%)		CAGR (%) 2011–31
						2011	2031	
Primary Commercial Energy Supply (Mtoe)	522	688	955	1,284	1,725	100	100	6
Coal	280	375	530	716	973	54	56	6
Oil	159	217	297	394	526	31	30	6
Natural Gas	58	54	69	85	111	11	6	3
Nuclear	7	16	23	40	52	1	3	10
Hydro	13	16	20	25	31	2	2	4
Solar	0	2	4	7	9	0	1	22
Wind	3	5	8	11	15	1	1	9
Biomass for power	2	3	4	5	7	0	0	7
Waste-to-energy	0	0	1	1	1	0	0	*
Geothermal	0	0	0	0	0	0	0	*
Liquid biofuels	0	0	0	0	0	0	0	*
Final Energy Demand (Mtoe)	549	690	901	1,147	1,460	100	100	5
Agriculture	221	289	404	539	697	40	48	6
Commercial	86	126	184	258	360	16	25	7
Industry	206	221	236	248	269	37	18	1
Transport	16	23	35	52	77	3	5	8
Residential	21	31	41	51	58	4	4	5
Agriculture Sector (Mtoe)	21	31	41	51	58	100	100	5
Petroleum Products	9	13	17	19	21	44	37	4
Electricity	12	18	25	31	37	56	63	6
Residential Sector (Mtoe)	206	221	236	248	269	100	100	1
Traditional Biomass	175	181	182	179	173	85	64	0
Petroleum Fuels	15	14	16	17	19	8	7	1
Natural Gas	1	1	2	3	4	0	1	9
Electricity	15	25	36	49	72	7	27	8

RES	2011	2016	2021	2026	2031	Shares (%)		CAGR (%) 2011–31
						2011	2031	
Commercial Sector (Mtoe)	16	23	35	52	77	100	100	8
Traditional Biomass	2	2	3	3	4	10	5	5
Petroleum Fuels	4	6	8	11	15	27	20	7
Natural Gas	0	1	1	2	3	2	3	12
Electricity	10	15	24	35	55	61	71	9
Transport Sector (Mtoe)	86	126	184	258	360	100	100	7
Petroleum Fuel	84	122	177	247	344	97	96	7
CNG	1	2	3	5	7	1	2	9
Biofuels	0	1	2	3	6	0	2	15
Electricity	1	1	2	2	3	1	1	6
Industry Sector (Mtoe)	203	262	371	500	655	100	100	6
Coal	112	155	226	311	412	55	63	7
Natural Gas	26	30	41	55	71	13	11	5
Petroleum Products	35	43	53	64	78	17	12	4
Grid Electricity	30	34	51	71	94	15	14	6
Biomass	0	0	0	0	0	0	0	*
Power Generation Capacity (GW)	239	350	459	604	821	100	100	6
Coal	133	192	254	353	512	56	62	7
Gas	27	40	45	36	41	11	5	2
Diesel	11	8	5	4	4	4	1	-4
Hydro	42	51	62	77	94	18	11	4
Nuclear	5	9	12	22	28	2	3	9
Wind On Shore	18	33	44	55	66	7	8	7
Wind Off Shore	0	0	0	0	0	0	0	0
Solar PV	1	12	29	46	63	1	8	22
Solar Thermal	0	0	0	0	0	0	0	0
Biomass	3	5	7	9	11	1	1	7
Waste	0	0	1	2	2	0	0	*
Geothermal	0	0	0	0	0	0	0	0
Tidal	0	0	0	0	0	0	0	0
Emissions (Billion Tonnes)	1.7	2.2	3.0	4.0	5.5	*	*	6
Fossil Fuel Import Dependence	40%	47%	57%	67%	74%	*	*	*
Coal	23%	29%	42%	55%	66%	*	*	*
Oil	76%	80%	86%	90%	91%	*	*	*
Gas	21%	32%	46%	53%	60%	*	*	*

Note: * Not applicable

ESM	2011	2016	2021	2026	2031	Shares (%)		CAGR (%) 2011–31
						2011	2031	
Primary Commercial Energy Supply (Mtoe)	522	677	901	1,147	1,447	100	100	5
Coal	280	367	492	611	761	54	53	5
Oil	159	210	261	326	408	31	28	5
Natural Gas	58	55	73	96	121	11	8	4
Nuclear	7	18	30	54	76	1	5	12
Hydro	13	17	22	28	34	2	2	5
Solar	0	2	9	13	21	0	1	27
Wind	3	5	9	12	17	1	1	10
Biomass for power	2	3	4	6	8	0	1	8
Waste-to-energy	0	0	1	1	1	0	0	8
Geothermal	0	0	0	0	0	0	0	*
Liquid biofuels	0	0	0	0	0	0	0	*
Final Energy Demand (Mtoe)	549	682	853	1,035	1,252	100	100	4
Agriculture	221	289	389	500	615	40	49	5
Commercial	86	120	161	214	284	16	23	6
Industry	206	221	231	231	242	37	19	1
Transport	16	23	35	51	74	3	6	8
Residential	21	29	36	40	37	4	3	3
Agriculture Sector (Mtoe)	21	29	36	40	37	100	100	3
Petroleum Products	9	12	14	15	14	44	36	2
Electricity	12	17	22	25	24	56	64	4
Residential Sector (Mtoe)	206	221	231	231	241	100	100	1
Traditional Biomass	175	181	176	164	151	85	62	-1
Petroleum Fuels	15	14	16	17	19	8	8	1
Natural Gas	1	1	2	3	4	0	2	9
Electricity	15	24	37	47	67	7	28	8
Commercial Sector (Mtoe)	16	23	35	51	74	100	100	8
Traditional Biomass	2	2	3	4	5	10	7	6
Petroleum Fuels	4	6	8	11	15	27	21	7
Natural Gas	0	1	1	2	3	2	3	12
Electricity	10	15	23	34	50	61	68	9
Transport Sector (Mtoe)	86	120	161	214	284	100	100	6
Petroleum Fuel	84	115	152	198	259	97	91	6
CNG	1	2	4	7	10	1	3	11

ESM			2011	2016	2021	2026	2031	Shares (%)		CAGR (%) 2011–31
								2011	2031	
Biofuels	0	1	2	5	9	0		3		17
Electricity	1	1	3	5	6	1		2		10
Industry Sector (Mtoe)	203	263	365	479	602	100		100		6
Coal	112	156	228	307	392	55		65		6
Natural Gas	26	30	40	51	64	13		11		5
Petroleum Products	35	43	48	55	63	17		10		3
Grid Electricity	30	34	49	65	83	15		14		5
Biomass	0	0	0	0	0	0		0		*
Power Generation Capacity (GW)	242	343	460	588	778	100		100		6
Coal	133	181	228	288	387	55		50		5
Gas	30	41	51	52	61	12		8		4
Diesel	11	8	5	1	2	4		0		-9
Hydro	42	54	67	86	105	17		14		5
Nuclear	5	10	17	29	41	2		5		11
Wind On Shore	18	33	47	61	75	7		10		7
Wind Off Shore	0	0	0	0	0	0		0		0
Solar PV	1	12	29	49	75	0		10		23
Solar Thermal	0	0	9	10	17	0		2		0
Biomass	3	5	7	10	13	1		2		8
Waste	0	1	1	2	2	0		0		*
Geothermal	0	0	0	0	0	0		0		0
Tidal	0	0	0	0	0	0		0		0
Emissions (Billion Tonnes)	1.7	2.1	2.8	3.5	4.3	*		*		5
Fossil Fuel Import Dependency	40%	38%	39%	47%	54%	*		*		*
Coal	23%	18%	23%	32%	40%	*		*		*
Oil	76%	77%	75%	81%	84%	*		*		*
Gas	21%	19%	17%	30%	41%	*		*		*
Note: * Not applicable										

ESA	2011	2016	2021	2026	2031	Shares (%)		CAGR (%) 2011–31
						2011	2031	
Primary Commercial Energy Supply (Mtoe)	522	673	856	1,066	1,240	100	100	4
Coal	280	367	460	531	583	54	47	4
Oil	159	205	239	276	289	31	23	3
Natural Gas	58	56	85	137	192	11	15	6
Nuclear	7	18	30	54	76	1	6	12
Hydro	13	17	22	28	34	2	3	5
Solar	0	2	5	16	32	0	3	30
Wind	3	5	11	17	25	1	2	12
Biomass for power	2	3	4	6	8	0	1	8
Waste-to-energy	0	0	1	1	1	0	0	*
Geothermal	0	0	0	0	0	0	0	*
Liquid biofuels	0	0	0	0	0	0	0	*
Final Energy Demand (Mtoe)	549	690	901	1,147	1,460	100	100	5
Agriculture	221	289	404	539	697	40	48	6
Commercial	86	126	184	258	360	16	25	7
Industry	206	221	236	248	269	37	18	1
Transport	16	23	35	52	77	3	5	8
Residential	21	31	41	51	58	4	4	5
Agriculture Sector (Mtoe)	21	29	34	35	29	100	100	2
Petroleum Products	9	12	12	7	2	44	7	-8
Electricity	12	17	22	27	27	56	93	4
Residential Sector (Mtoe)	206	220	229	235	235	100	100	1
Traditional Biomass	175	181	176	164	151	85	64	-1
Petroleum Fuels	15	14	15	16	17	8	7	1
Natural Gas	1	1	2	4	6	0	2	11
Electricity	15	24	35	51	61	7	26	7
Commercial Sector (Mtoe)	16	23	32	44	61	100	100	7
Traditional Biomass	2	2	3	4	5	10	9	6
Petroleum Fuels	4	6	7	9	11	27	18	5
Natural Gas	0	1	2	4	7	2	12	17
Electricity	10	15	20	27	37	61	61	7

ESA	2011	2016	2021	2026	2031	Shares (%)		CAGR (%) 2011–31
						2011	2031	
Transport Sector (Mtoe)	86	117	153	197	254	100	100	6
Petroleum Fuel	84	111	141	177	195	97	77	4
CNG	1	3	6	9	13	1	5	12
Biofuels	0	1	2	5	39	0	15	26
Electricity	1	1	4	6	8	1	3	11
Industry Sector (Mtoe)	203	260	350	453	568	100	100	5
Coal	112	154	214	283	360	55	63	6
Natural Gas	26	30	45	63	85	13	15	6
Petroleum Products	35	43	43	41	39	17	7	0
Grid Electricity	30	34	48	65	84	15	15	5
Biomass	0	0	0	0	0	0	0	*
Power Generation Capacity (GW)	242	332	457	666	904	100	100	7
Coal	133	170	214	249	286	55	32	4
Gas	30	39	57	99	137	12	15	8
Diesel	11	8	6	2	2	4	0	-9
Hydro	42	54	67	86	105	17	12	5
Nuclear	5	10	17	29	41	2	5	11
Wind On Shore	18	33	59	84	110	7	12	9
Wind Off Shore	0	0	0	0	0	0	0	0
Solar PV	1	12	29	103	204	0	23	29
Solar Thermal	0	0	1	2	4	0	0	0
Biomass	3	5	7	10	13	1	1	8
Waste	0	1	1	2	2	0	0	*
Geothermal	0	0	0	0	0	0	0	0
Tidal	0	0	0	0	0	0	0	0
Emissions (Billion Tonnes)	1.7	2.1	2.6	3.1	3.5	*	*	4
Fossil Fuel Import Dependency	40%	38%	36%	42%	44%	*	*	*
Coal	23%	18%	18%	21%	22%	*	*	*
Oil	76%	77%	73%	78%	77%	*	*	*
Gas	21%	22%	28%	51%	63%	*	*	*
Note: * Not applicable								

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