India's Energy Security: Overcoming Challenges through Technology

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Abstract. The increasing energy demand of India poses a great challenge to the policy makers as they are committed to the goal of providing energy to all. India has to achieve the twin goals of equitable development along with mitigation of climate change issues. This paper underlines the role of technology in enabling the policy makers to achieve comprehensive energy security while working towards sustainable development goals

Keywords: Energy, Technology, Sustainable

1 Introduction

The economic growth and energy demands are inexorably linked. As country gets richer, it consumes more energy. However, this relationship is not linear and its tends to follow S-curve[1]. Only when the average income reaches $4000, a person (in purchasing power parity or PPP),demand tends to accelerate, usually as the country enters its stage of industrialisation, as witnessed in China, Brazil, Thailand, Malaysia, etc. With a population of about 1.25 billion and purchasing power parity (PPP) GDP per capita of roughly $5,700, India is in the midst of a huge transformation across all sectors and so the energy demand is likely to increase manifold.

India's energy security, however, poses great challenge due to the complexities, ever increasing demand supply gaps, heavy dependence on oil imports, various security concerns, both domestic and external due to geo-political factors and hot spots in many energy exporting nations, multiplicity of agencies, etc. Moreover, expanding energy sector is likely to further exacerbate the already serious challenges with climate consequences, increasing land pressure, water stress, air pollution, etc. Also it will impact India's efforts to achieve the sustainable development goals, as enshrined in UN's Global Sustainable Development Report, 2015.

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India's deep divide on quantity and quality of energy across income groups, regions and rural-urban households continues and energy access remains grim. Nearly 20% household have no electricity, almost 94% of them in rural areas, and two-thirds households have no LPG, 85% of them in rural areas who all depend on traditional biomass, which has health hazards for GHG emission. An appropriate technology can make cleaner fuel which is accessible and affordable and can help in reducing energy disparity, poverty and bring social equity.

A reference to the Global Sustainable Development Report (GSDR) 2015 is relevant as it emphasises on a secure strong economic foundations for shared and sustainable prosperity, productive production systems and strong technological capabilities[2]**.** It also emphasises on more efficient energy and resource consumptions, recycling and reuse and shift to sustainable consumption and production (SCP) for reducing the environmental impacts.

India's development pattern has led to GHG emissions and climate issues, which is affecting all sections of society and has huge social cost. However, India is committed to "Sustainable Energy for All" of United Nations where 3 goals have to be achieved by 2030 on global space:

a) Universal access to electricity and clean cooking fuels;
b) Doubling the share of the world's energy supplied by renewable sources from 18 to 36 percent;
c) Doubling the rate of improvement in energy efficiency.

In this context, India will be on the watch list for its ambitious INDC (Intended Nationally Determined Contribution) as agreed in the United Nations Framework Convention on Climate Change (UNFCCC)[3].

A synergistic interdependence between different sectors and resources viz. energy, food, water, health is considered necessary as developments in any one sector would have a domino effect on the other**.** In view of this inter-relatedness,a visionary integrated energy *system* which is decarbonised will not only lead to overall development but mitigate climate change issues and ensure equity and empowerment to the marginalised. The article in its limited manner tries to identify some of the appropriate technologies which would enable the energy security to become efficient and resilient. The energy trilemma index formulated by World Energy Council, as stated below summarises the above challenges on the energy front[4].

Table 1 Energy Trilemma Index Ranking and Balance Score of India

	2013	2014	2015	Score (2015)
Energy Security	76	76	53	B
Energy Equity	110	105	104	D
Environmental Sustainability	121	123	122	D
Overall Rank and Balance Score	115	122	107	BDD

Table 1 brings out that during 3 years, India's rank has improved on two indicators and also on overall, from 115 to 107. Impressive improvement is noted on energy security front and marginal fall is noted on environmental sustainability front. Overall score BDD, however, leaves much room for improvement.

The technology and innovation policies, however, vary from country to country, with more advanced countries involved in advanced research and new products and less developed counties focussing on generating absorption capacity products. Dedicated R&D(70% of total business in R&D)should be supported through funds, tax support, so that technological investments in new products and processes, promoting eco-innovation and so-called "green" technologies are undertaken[5].

India continues to be energy dependent. Although it has abundant coal reserve and great potential in renewable energy, the country is heavily dependent on oil and gas import and uranium/nuclear fuel in particular, besides state-of-art technology required in several energy sectors, both in the supply and demand ends of energy sector.

The energy related infrastructure machinery and equipments have large gestation periods and with commensurate long economic lifetimes (minimum 25-30 years). Hence, the need to develop, adopt, customise and up-scale appropriate technologies ranging from clean fuel production to resource conversion and end-use technologies in a timely and well-planned manner. The role of technology is thus considered as one of the key elements in India's energy future[6].

Since India's energy requirements for 2030-2050 cannot be met by a single energy source/fuel or technology, it will require variety of fuels and technologies across all links in the energy value chain i.e. from supply and production to transmission and distribution. However, the technology should meet three criteria viz. availability, cost-effectiveness and environmental sustainability[7].

The prevailing energy scenario underlines the challenges and the possible solution that technology can provide. The energy supply mix is primarily coal,followed by crude oil &natural gas, hydro, renewable and nuclear. A comparative figure of energy mix of 2014 &2040 is stated as follows[8]:

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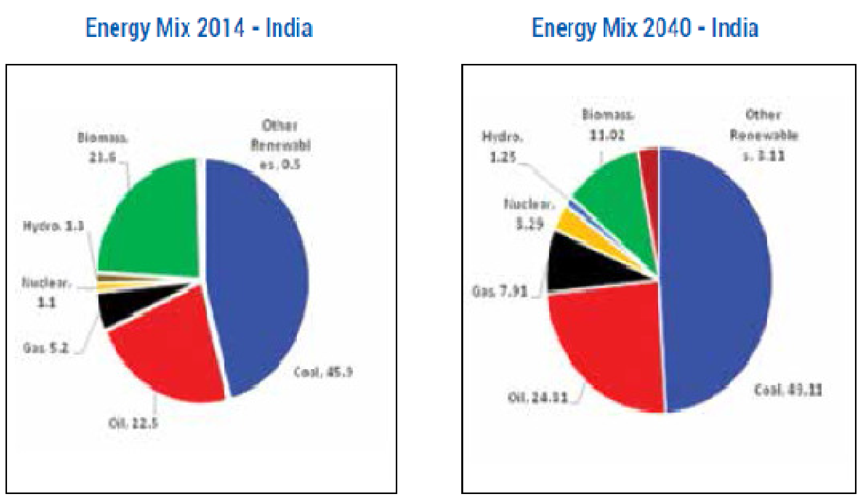


Use of biomass, a symbol of poverty in the economy will drastically come down from 24 % to 11 % by 2040. Growth of renewable sources in India is 11 % compared to 6.7 % at global level during the same period. Nuclear expansion program will cause growth of this source at 8 %.

Further, the tables below also reflect the multiple projection demands for India’s security in view of the growth in GDP, growing population, urbanisation and shifting economic activities from agriculture, lifestyle changes, “Make in India” programme, smart cities, preference for personalised automobiles, etc[9].

Table 2: Multiple projects of Demand for India's Energy (MTOE)

Agency	Edition / Year	2013	2020	2030
BP	February 2015	595	807	1160
BP	February 2016	637.8 (year 2014)	841.0	1505.3
IEA	Mid 2015	770	940	1182
IEA	November 2015	775	1018	1440

Table 3: Primary Energy Demand by Fuel – Project till 2040 (MTOE)

	2013	2040	Shares (%)		2013-2040	
			2013	2040	Change	CAGR (%)
Oil	176	458	23	24	282	3.6
Natural Gas	45	149	6	8	104	4.6
Coal	341	934	44	49	592	3.8
Nuclear	9	70	1	4	61	7.9
Renewable	204	297	26	16	93	1.4
Total	775	1908	100	100	1133	3.4

While renewables and other alternatives have to step in to meet India's energy requirements in the long run, improvements in efficiencies of extraction, resource assessments and supply of fossil fuels are required to support India's energy transition till 2040-2050.

2. Challenges

2.1 COAL

India's fossil fuels production has stagnated. The annual growth in coal production dropped from 6% to about 1.5% a year in 2013-2014, while consumption increased at an average of 7% a year. The coal reserves, despite its *volumes*, is of low quality and high in ash content (35% to 45%), which requires more washeries. 90% coal mines are open cast mines and cause air pollution health hazards. Coal section has several challenges viz. land acquisition, inadequate compensation to Project Affected People (PAP), coal mined storage issues, delays in getting environmental clearances, railways limitation in timely evacuation and transportation of coal leading to delays, etc. The underground mining demands better technology which would be mostly imported and will make mining costly and unattractive. Also the existing power plants can use only 10-15% of the imported coal due to design of the boilers.

2.2 Oil and Gas

The oil and gas sector accounts for about 39.38% and 9.07% respectively of primary energy[10]. India is heavily dependent on crude oil import which will continue to impactthe balance of payments. Domestic crude oil production has also stagnated at around 40 million tonnes a year due to ageing fields while consumption has increased by5% a year.

Similarly, there was decline (about 14%) in gas produced (40.68 BCM), primarily due to KG-D6 declining production. However, the oil and gas sector is indispensable for several sectors, especially transport. The various New Exploration Licensing Policy (NELP) roundshave also failed to significantly increase oil exploration and production. The survey/explorations of potential Hydrocarbon blocks, mostly now deepwater and in difficult areas demand high end technologies. NELP's replacement by the new Hydrocarbon Exploration Licensing Policy (HELP) is yet to be tested in terms of successfully attracting foreign oil companies.

In contrast to oil & gas extraction, there is significant increase in production of petroleum products by oil refineries since 2012-13 (about 7% increase), there by adding to country's net export. However, India is committed to better cleaner fuel and BS-IV norms by 2020 for which upgradation in the refinery technology is necessary. Problems like delayed clearance of hydrocarbon exploration blocks by concerned agencies, pricing issues of domestic gas, slow progress in strategic petroleum reserves (ISPRL), inadequate LNG import infrastructure, acquiring Right of way (RoW) for cross country pipelines, subsidies and fiscal balance issues continue to confront the oil sector.

2.3 POWER

The power sector achieved 54,963.9 MW in 11th Plan against set target of 78,700 MW, due to shortage of coal and gas, delay in obtaining clearances, old power plants having sub-critical technology, transmission and distribution losses. The Right of Way and land availability are major concerns impacting on new 55 projects (55,000 MW), including someultra-mega power projects (UMPP) located in Sarguja,Bedabhal (Odisha), etc.

Currently the average efficiency of coal and gas thermal plants in India is34% and 46% respectively, which is far lower than the OECD average,although the situation has improved in the 12th Plan due to installation of UMPP which are super critical technology plants. Nevertheless rapid improvement in efficiencies of coal and gas-based power plants is equally required in the short term as well as in the next couple of decades till the renewable energy picks up. Also a quick transition to more advanced clean coal technologies and more efficient gas-based generation technologies is desirable.

2.4 Renewable Energy

Renewable Energy potential is yet to be fully exploited due to multiple implementing agencies, no single window clearance, lack of evacuation facilities and energy storage, grid connectivity and gaps in implementation of renewable purchase obligation (RPO's) by the States, land issues, etc. Despite Renewable energy accounting for about 12% of total installed power generation capacity, only 5% *was* the total generation. India aims to reach renewable energy capacity to 175 GW by 2022 (Solar 100 GW, Wind 60 GW, Hydro 10 GW & Biomass 5 GW). Despite immense potential, wind power generation has been only 23.4 GW mostly due to hub-height of 30-50 metres, as against the assessed potential of 500 GW at 80-120 metres. Also solar energy production (5GW) is insignificant and the present Govt. under Jawaharlal Nehru Solar Mission programme has revised the target from 20GW to 100 GW by 2022. The other renewable resources like biomass, biofuels, hydrogen &fuel cells, etc. have so far remained largely untapped.

Given India's voluntary commitment to40% non-fossil fuel capacity by 2030by aggressively escalating renewable, R&D efforts need to be scaled up rapidly, especially with regard to batteries and storage capabilities for solar power, etc.

2.5 Nuclear

India has low quality of uranium. Further, land acquisition problems, environment and anti-Nuke protests (Jaitapur in Maharashtra,Kudan Kulam in Tamil Nadu, KhasiStudent's Unionprotest in Meghalaya to mention few), civil liability issues in view of Fakushima tragedy, high costs of foreign nuclear reactors, public perception continue to be the hindrances in the Nuclear sector.*Also critics point to the absence of independent regulator. The CAG report (2012) has raised questions about the legal status of the Atomic Energy Regulatory Board (AERB) as* *usually the senior formations of AERB and Department of Atomic Energy (DAE) are one and the same. Despite the much publicised treaties with the French and US companies, the installation and transfer of the nuclear reactors have not made any significant progress. Only Russia (KudanKulam Nuclear Plant) is an exception.*

3. Technological Intervention: *Energy Supply*

3.1 Coal Reserves and Production

Of 306 billion tonnes of coal resources, only 42% is proven and 21% of the proven resource was extracted using present mining technology, which is obsolete. Outof the total extractable coal, about 15 billion tonnes are power grade, which would last only 30 years at current consumption rates. With many green field power plants under construction, coal supplies will become even more critical. Hence, assessing reserves and quality of coal is of prime importance. By deploying appropriate methodology& technology the economically minable coal can be better identified and extracted.

Coal exploration technologies have become more precise. The imaging techniques provide higher resolution and coal seams under a high-density area can now be better detected. Further, a new technology allows direct estimation of ash and sulphur content in coal during geophysical logging. This will enhance domestic coal production from opencast mining (90%), and the remaining 10%from underground mining. Secondly, increasing production would require advanced but cost-effective underground mining technologies. Thirdly, it is essential to increase the present washery capacity (presently 145 Mt for coking coal) through better and green technology which decreases pollution.

India should shift to super critical and ultra-super critical circulating pressurized fluidized bed technologies, which can be adapted to use low grade coal with high ash. The high ash content of Indian coal reduces boiler loading capacities since ash takes up space and increases handling costs. In this regard, Gasification is one of such technologies which can provide clean, abundant and affordable energy. Conversion of coal to lean liquid fuels is a proven technology and has been practiced extensively at Sasol in South Africa since more than 50 years. Essentially, it comprises two technologies, Gasification of coal to produce synthesis gas and conversion of syngas to liquid hydrocarbon through F-T process[11]. Indian Oil R&D has proactively initiated research in multi-feed gasification and further research is towards ‘Integrated Gasification’ or optimal use of the feedstock.

3.2 **Oil and gas reserves and production**

In the oil and gas sector, India's sedimentary basins (about 70%) are poorly or not completely explored. However, to enhance imaging interpretation, advanced technologies need to be deployed viz. Seismic acquisition, Micro-seismic remote sensing, Wire line telemetry and tools, Rock property and rock correlation tools, Basin and play insight tools, etc. Further, the 4D seismic technologies enable greater insight into the subsurface conditions and potential oil and gas reservoirs. To accelerate oil production from existing fields, five main techniques viz. thermal recovery, gas injection, chemical injection, water flood and hydraulic fracturing are being deployed.

Besides the above, there is shift from vertical drilling to horizontal drilling of wells as it enables better access of the oil wells and its hydro-fraction. Also hydrocarbon blocks in the deepwater and difficult areas would require state-of-the-art technologies encouraging foreign oil companies as the technology is capital intensive. The recent Hydrocarbon Exploration Licensing Policy (HELP) is expected to encourage foreign companies in oil exploration and production.

3.3 Power

About 71 % of India's current power capacity mix is thermal (coal, oil and gas). During the 12th Plan, 38% of the coal- based capacity is in the UMPP with super critical technology. However, it should be further integrated with gasification combined cycle technology in the immediate short term in a bid to prevent lock-ins to sub-optimal technologies.

About 9% of India's generation capacity is based on gas, The average net efficiency for gas fired power plants in India in 2009 was 42%, comparable to the world average in 2007. The 12th Plan envisaged developing 1,086 MW of gas-based capacity and at least 2,000 MW gas-based peaking power plants. According to TERI analysis, advanced gas (H-frame) turbines, having efficiencies of 60% or more in the combined cycle operation *need to* be adopted by 2016, to save energy and manage peak demands.

In June 2008, under the National Mission on Enhanced Energy Efficiency, the government launched the Perform Achieve Trade (PAT) scheme, to enhance the cost-effectiveness and energy efficiency in large energy-intensive industries and facilities by certifying the energy savings that can be traded. For the thermal power plant sector in this scheme, 144 high energy-consuming units have been notified as designated consumers by the Bureau of Energy Efficiency. By the end of the first PAT cycle (2015),energy savings of 3.211 Mtoe/year was expected, which is around 48% of total national energy saving targets under the PAT[12].

3.4 Renewable

Significant progress has been made in renewable energy due to increasing production from wind and solar energy and lowering of per unit cost (below Rs.4/-). India has planned renewable energy generation from 3l.5 GW in 2015 (mostly wind and solar) to 175 GW by 2022 (100 GW solar, 60 GW wind, 5 GW small hydro and 10 GWbiomass). Considering these targets, renewables will account for about 10% of the total energy mix, by 2022[13].

Notwithstanding the need for R&D for new products, the Renewable Electricity Futures Study found that 80% renewable future is feasible with currently available technologies, including in the solar and wind energy sectors.

3.5 Solar

The 100 GW target for solar in 2022 is to be achieved through decentralised rooftop projects (40GW), utility scale solar plants (40GW) and through ultra-mega solar parks (20GW). Most of these projects are in Gujarat, Rajasthan, Andhra Pradesh, etc. Of the two solar technologies-solar photovoltaic (SPV) and concentrated solar power (CSP), SPV remains the primary technology to harness solar power in India. Most manufacturing capacity in SPVs based on crystalline silicon manufactured as wafers. But thin film technology has an advantage, particularly in extreme temperature areas and where land is easily available. Solar PV and rooftop solar can provide both centralized and decentralised energy solutions. The CSP technologies can provide low level heating requirement in large industriesbesides generating power. They generate electricity by using mirrors to concentrate a large area of sunlight onto a small area. Heat is generated to produce the water to drive a turbine. Water is, thus, an important input to generate heat as well as a cleaning fluid for the solar collectors. Ironically the areas with high potential for solar power have water problems and deployment of this technology on a large scale would have to overcome this constraint. Technology should also overcome other issues of this sector viz. thermal and power storage through advanced batteries, power dispatchability and its grid integration to make solar power more competitive.

The MNRE has launched a comprehensive programme on "Research, Design and Development of Solar Photovoltaic Technology (SPV) and Solar Thermal Technology (ST)", during 2014-15. It has also recommended 500 R&D projects involving IITs, Universities, Industries etc. Further government has taken up steps to overcome the issues of standardization of systems and common specification to facilitate R&D in both solar and wind technologies. If achieved, India will witness a solar revolution.

3.6 **Wind**

At present, India's wind energy capacity (23.4 GW) is based on on-shore technology[14]. The average capacity of wind turbinesis 20% due to low hub height (25-30 metres). The wind energy is projected to increase to 30% by 2030 by increasing the hub height of the shaft to 80-100 metres. Since, the capacity factor of an off-shore wind turbine is usually higher (40%-50%) than that of an on-shore turbine India needs to fruitfully exploit its vast coastline (about 7.500kw) and install wind turbines on offshore oil rigs (Bombay High, etc.). In this regard, effective coordination between concerned ministries viz. MoP, MoPNG and MNRE is required.

Although generation of power from wind is an established technology, a lot of incremental research with design modifications for existing small and medium turbines to optimise capacities and building up of next generation prototype, has been emphasized by MNRE and Department of Science and Technology (DST).

3.7 **Biomass**

The technologies used for biomass power are combustion and cogeneration. In the conventional Rankine cycle technology, the biomass is burnt in a high pressure boiler to generate steam to operate a turbine. The net power cost is about 23-25% less as compared to other energy.

Further the exhaust of the steam turbine can either be fully condensed or used partly as process heat in cogeneration. The sugar industry has traditionally been practising incidental cogeneration by using bagasse as a fuel for meeting its steam and power requirements. With advances in boiler and turbine technologies, the sugar industry can also produce electricity and steam for its own requirements and surplus electricity to be sold to the grid.

3.8 **Biofuels**

Biofuels are considered as a viable renewable energy transport pathway to reduce harmful air pollutants, combat GHGs, enhance energy, provide jobs, particularly to the poor. However, the first generation biofuels made with food crops like corn, sugar, palm oil, etc. led to resistance from the agriculture sectors. But the third generation biofuels have been found to create market for biofuels again. It is considered to be the best and most responsible option for policy makers according to an expert, Tammy W. Klein[15].

Hydrogen and Fuel Cells

Hydrogen is a clean energy carrier that can be produced from any primary energy sources, including fossil, nuclear and renewable energy sources. It is an energy carrier rather than a fuel, because like electricity, it takes energy from one source and delivers it to end-users/applications. Renewable energy industry can benefit from Hydrogenbecause it can serve as a means of securing electricity and reducing emissions. The Hydrogen market is expected to grow both as an industrial product as well as for fuel cell. Although at a very nascent stage in India, the Hydrogen & Fuel Cells hasgreat potential. Around one lakh mobile towers are expected to be converted to fuel cells based systems and thereby save energy to the tune of 50% diesel equivalent for the DG sets.

3.9 **Waste to Energy**

Energy from urban waste has great potential[16]. The urban population is likely to increase from 37.7 crores (2011 Census) to 60 crores (2030) and will create large waste. For sustainable environment solutions urban waste also need to be converted to energy. While in the developed countries, waste to energy is primarily for environment, in developing nations like India, energy from municipal solid wastes (MSW) in form of biogas can be used for heating and power generation also. While bio-methanation, refuse derived-fuel (RDF) and incineration are the most common technologies, pyrolysis and gasification are also preferred. The major benefits are 60%-90% net reduction in environmental pollutions and simultaneous reduction in demand for landfill sites as well as reduction in transportation cost to far away landfill sites.

The integrated hydro pyrolysis technology uses catalysts to convert forest, agricultural and sorted municipal wastes into fungible hydrocarbon transportation fuels. Although waste-to-energy technologies have the double benefit of generating electricity while taking care of urban waste, they face a major institutional hurdle. Waste segregation is an absolute requirement for waste-to-energy plants, but local bodies seem unable to segregate waste at the source. Because of the very high cost of facilities for sorting and separating waste, it is uneconomical and processing the unsegregated waste can also release toxins upon combustion. Besides, halogens, alkalis and heavy metals in unsegregated waste require expensive gas cleaning and residue management, pushing up the costs.

In this regard, the waste to Energy (WTE) plant for processing Municipal Solid Waste (MSW) at Timarpur, Delhi (imported technologies costing Rs.410 million) and the refuse derived fuel (RDF-WTE) plant at Hyderabad and Vijayawada, had limited success. Upgradation and effective customisation of WTE plant is necessary in view of the power potential of MSW / RDF assessed at 5,200MW by 2017. Besides being a renewable energy, the MSW can help India tide over fossil fuel demands.

Apart from such energy *being* consumed *it* will become part of integrated sustainable solutions focusing on waste to energy technologies, material recycling can increase energy efficiency in industry, particularly in the iron & steel and cement sectors. TERI analysis estimates that by enhancing the share of scrap-based steel production using the electric arc furnace route, energy efficiency in the iron and steel sector could improve by around 20%. Similarly, energy demand in the cement sector could be reduced by nearly 30% by enhancing the share of blended cements (Portland slag cement and Portland pozzolana cement). While PPC usespozzolanic material such as fly ash from coal-based power plants, PSC uses blast furnace slag. Such technological shifts will ensure energy saving and environmental sustainability and can be upscaled, if supported and backed by appropriate policies and regulatory mechanisms.

3.10 Nuclear

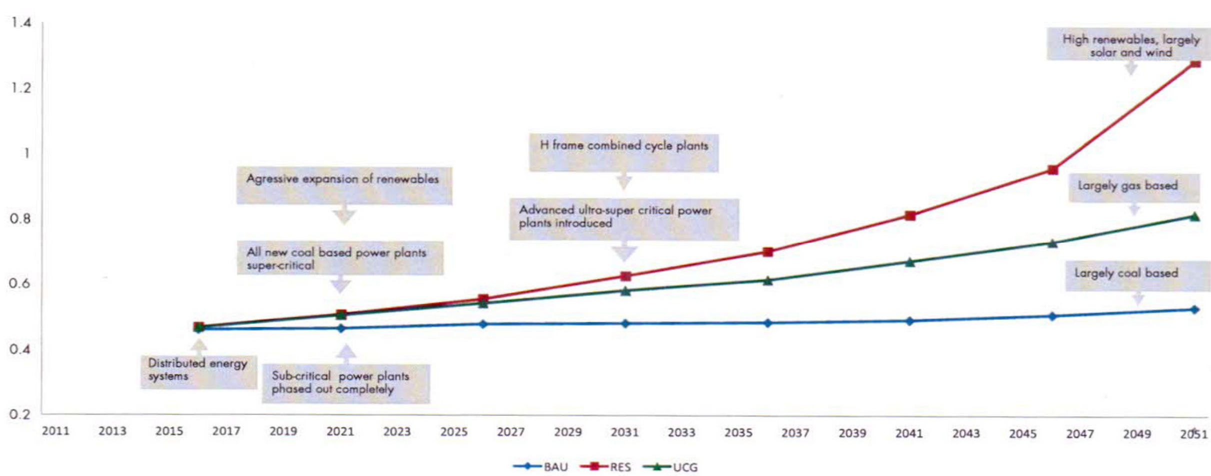
The present generating capacity of nuclear plants (5,780MW) is expected to escalate to 275 GW with Fast Breeder Reactors (FBR) contributing 262.5 GW. India has 19 pressurized heavy water reactors (PHWR) and two boiling water reactors mostly indigenous in nature, which are in operation. A three-stage strategy based on a closed nuclear fuel cycle has been developed. The first stage is fuelled by natural uranium to produce plutonium. The plutonium is used in the second stage in Fast Breeder Reactors (FBR) to convert thorium and uranium into fissile material. In the third stage the fissile uranium and plutonium are combined with thorium in advanced heavy water reactors.

However, nuclear reactors have been operating at 45% to 55% of capacity, due to a shortage of uranium and nuclear fuel. Significantly, India has large thorium reserves but it requires a more complex chain of nuclear technologies to exploit thorium as a fuel. Also since USA and French FBR reactors are costly India should strive to enhance its indigenous reactors as well as expedite technological solutions for thorium exploitation.

As regards power generation from different energy sources, the policy makers can focus on the broad technology progress in three scenarios, 2011-2050 as depicted by Suman Berry & others, as stated below:

Figure 3.2.

Broad technology progress in three scenarios, 2011–2050



Note: Efficiency is calculated as total generation to total energy consumption. Since the supply of renewables is abundant, the conversion losses of renewables have not been considered in the calculation. As a result, very high renewable efficiency may go over 1, as in RES.

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3.11 **Transmission and distribution**

The long power lines result in high technical losses and low voltage distribution. By reconfiguring the existing network to high voltage distribution system (HVDS), long length mains can be converted into 11Kv mains, and the appropriate capacity distribution transformer can be installed as close as possible to the end-user. As a result, the current Rowing through the lines may come down to almost a 30th, reducing the technical losses drastically. Energy-efficient transformers, advanced metering technologies and reactive power correction near load centres can bring down losses further[17].

4. Energy demand & Consumption

4.1 Residential & Commercial

The energy basket in residential and commercial sector is primarily from electricity, lighting, heating and space conditioning LPG, kerosene, biomass, coal for cooking. In 2012-13, it accounted for 6.5% in household expenditure in urban and 8% in rural areas (NSSO 2013). About 80% of households still depend on traditional biomass which is about 33% of total primary energy supply for heating and cooking, and nearly 300 million people in India lack access to electricity. Despite increase in LPG distribution in the rural areas, a significant share of people would continue to rely on biomass-based cooking even in 2050. Therefore, it is essential to enhance the improved cook stoves, biogas utilization and other affordable technological solutions. In this regard, National Programmeon improved cook-stoves and National Programme Biogas development *has to* be sincerely implemented and monitored.

4.2 Commercial

Energy consumption in the commercial sector has grown 11-12% in 2011-12 which is much faster than average electricity growth, primarily due to increasing number of Buildings (14%) in different sub-sector i.e. hospitality, hospital, commercial complexes, education sector and overall urbanisation. In this regard the best practices and technology innovation like energy efficient Green Buildings*need to*be further incentivised and the energy auditing as laid down in Energy Conservation Building Code (ECBC), Green Rating for the Integrated Habitat Assessment (GRIHA) and environment clearness of Building projects through Environment

Impact Assessment (EIA), *has to* be strictly implemented. To meet the growing demands of white-goods and other electrical appliances,improvement in energy efficient technologies is to be *given priority*. Already star rating appliances are being popularised. However, due to specific issues of climate, cultural and socio-economic conditions, many of the technologies from abroad need to be customised to the Indian environment.

The government measures to popularise efficient appliances, lighting systems, efficient Green buildings, etc. can help in reducing the energy demand by around 26% by 2050.

4.3 **Transport**

In 2010-11, transport sector accounted for 28% total commercial energy with 7% Compound Annual Growth Rate (CAGR/TERI, 2014). The privatized transports with personalized vehicles are increasing at an alarming rate. By 2050 the demand of the Indian transport sector alone may equal that of India's total energy demand of 2011. More important, railway has lost its passenger and freight share to the more energy intensive road-based transport. However, there is considerable scope for energy efficiency in the transport sector which will bring down energy demand.

In this regard, special emphasis be given to public and mass transit systems as the privatised transport sector is increasing at an alarming rate. Since two wheelers (70% of India's vehicle), are mostly used for short distances, electric two wheelers with average range of up to 140 km on a charge could be a suitable substitute. Hybrid cars with electric motors viz. Nissan leaf and the Toyota Prius make can push their fuel efficiency around 70% higher than that of petrol or diesel counterparts[18]. Electric and Hydrogen hybrid and electric vehicles, as well as advanced alternative fuels like third generation biofuels and integrated hydro- pyrolysis and hydro conversion could make significant impacts in curbing dependence on petroleum products as transport. Improved energy efficiency across the end-use sectors can bring savings of 25-35%.

The third generation algal biofuels can also help reduce dependence on oil. Unlike the use of first and second generation biofuels where it competes with food crops and was being resisted by some stakeholders, in contrast, microalgae can be grown on degraded and non-arable land and thus do not compete directly with the food crops. They can also begrown on land with saline water. The potential for biodiesel production from microalgae is 15 to 300 times more than that for traditional crops and has very short harvesting cycles, allowing multiple or continuous harvesting[19]. Although the technology is currently in R&D phase, algaeis projected to become commercially viable in some OECD countries around 2030 for some applications, such as biojet fuels. Due to economies of scale,such technologies can enable the transport sector to save 30% energy.

4.4 Industry

Out of the total energy consumed in 2016,Industry is the largest consumer of energy in India, consuming nearly 40% of the total demand which increases to more than 57%, if non--commercial biomass is excluded from the energy mix. Industrial sector, which also constitutes about 30% of the GDP, is also responsible for carbon emissions due to a large number of industries being energy intensive. The demand for industrial energy is driven and shared by Designated Consumers (DC), usually 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, Fertilisers, Aluminium, Textile, Pulp & Paper, and Chlor-alkali. These DCs account for about 60 million tonnes of oil equivalent (MTOE) of energy consumption annually (Energy Security Outlook, TERI Report 2015, page 87). Apart from these DCs there are several other large industries that are energy intensive in nature viz. glass, metals, food processing, vegetable oils, automobiles, dairy, sugar, distilleries, petrochemicals, etc. The MSME sector which provides large scale employment is spread (2,400 clusters) throughout the country, manufacturing different products that are energy intensive.

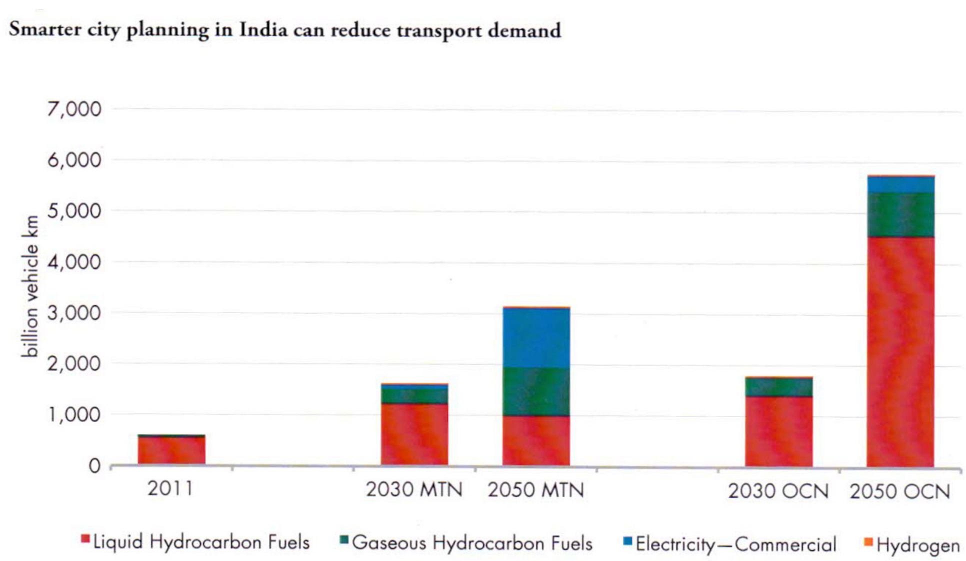
Although, the various sectors in industry are using their specific R&D to attain energy efficiency and reduce operational costs,the government has also initiative several policies to encourage energy saving and reduce GHG carbon emissions. Some of these key policies to encourage the energy efficient technologies are enshrined in National Mission for Enhanced Energy Efficiency (NMEEE), 2008, Energy Efficiency Financing Platform (EEFP), Framework for Energy Efficient Economic Development (FEEED), Integrated Energy Policy (IEP), National Manufacturing Competitiveness (NMC) Programme, Technology and Quality Upgradation (TEQUP) Support to MSMEs etc.

4.5 **Agriculture**

In the agriculture sector, there is increasing consumption of energy due to farm mechanisation, diesel operated pump sets, transportations, etc. The energy intensive agriculture sector also requires a prudent use of resources and judicious application of technology to improve long term sustainability of food production and mitigation of climate issues. Besides, energy efficient equipment's and pump sets, minimum tillage, use of crop residue and better matching tractor and attachments, micro irrigations with emitters to provide water to the root zone so as to save water energy be made mandatory. However, more focussed R&D is required in the agriculture sector to save energy and reduce pollution.

4.6 **Smart Cities initiative**

Urbanisation being inevitable and the fact that urban centres are fast growing in India, the Smart Cities initiative (100 cities in different phases) must focus on evaluating integrated and innovative solutions through technologies and best practices in spheres of building, rail-road engineering and transport including mass transit systems, waste disposal etc. Further there should be dedicated funds and tariff incentives for energy saving technologies and equipments, etc., as discussed above. The Smart Cities programme will ensure that the inhabitant live closer to their work place or use fully integrated public transport systems. This lowers the vehicle kilometres driven by around 2000 km per person a year. The figure below is illustrative[20]:



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5. Conclusion

India needs to invest in the diverse technologies both on the supply and demand chain with equal intensity. Once tested and commercially viable, such technologies *can* be deployed simultaneously. To avoid lock in and problem of the *stranded* assets, India needs to decide whether to develop through a clean or Business As Usual (BAU) trajectory[21]. Since India is poised to make huge green field investments in various sectors to meet its growing energy needs, it needs to make some of these decisions rather quickly. The life span of technologies is usually 20 to 30 years while that of infrastructure is even longer. Hence, investment in energy technology has to be long-term, keeping in view the energy demand of India in 2040-2050.

More important India should prioritise R&D in renewable technologies, particularly solar, wind, biofuels, biomass gasification, and clean coal technologies, RDF-WTE technologies, smart grids, GRIHA (Green Buildings), hybrid vehicles, *solar buses, etc.* Similarly for rural and far away and backward areas, R&D for improved cook-stoves, solar lanterns, solar home lighting, off-grid solar technologies, which are financially viable alongwith appropriate market mechanism be put in place. India needs to customise transformational technologies of the developed nations as in case of CFL and LED-based lighting systems.

The government through various policies has already put in place mechanism to enhance energy efficiency and conservation and environmental sustainability. Some of these missions worth mentioning are National Mission on Enhanced Energy Efficiency and Performance-Achieve-Trade (PAT), National Electricity Mobility Mission, National Mission on Agriculture Mechanisation, Energy Conservation & Building Code (ECBC), National Manufacturing Competitiveness Programme, Technology and Quality Upgradation (TEQUP) support to MSMEs, standard and labelling schemes under the motto “more stars, more savings” for appliances, Jawaharlal Nehru National Solar Mission, AMRUT, National Mission on Sustainable Habitat, etc.

A clear, transparent, long-term technology, vision, also grounded in short and medium policies, dedicated R&D manpower and infrastructure, internalizing true costs and benefits and incentivising alternatives, *needs to* be undertaken. Besides, ‘Make in India’ programme, the education system should align with R&D and younger generation should acquire the requisite skills for technological collaboration with the developed nations. The need of the hour is to harness, develop, demonstrate and deploy alternative energy and cleaner technologies through innovative products, processes & people. A concerted R&D will not only ensure a decarbonised and efficient energy system but also ensure equity and ending energy priority besides, enabling India to attain its sustainable development goals.

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