

INDIA'S ENERGY SCENARIO - CURRENT AND FUTURE

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ABSTRACT

The current population of India is 1.28 billion people accounting for more than 17.5% of world's population. Out of which, 32% is urban and rest is rural. It faces a formidable challenge in providing adequate energy supplies to users at a reasonable cost. India's energy challenge is of fundamental importance. In the last six decades, India's energy use has increased 16 times and the installed electricity capacity by 84 times. Overall generation in the country has been increased from 967.150 BU during 2013-14 to 1048.673 BU during the year 2014-15. In 2008, India's energy use was the fifth highest in the world. Nevertheless, India as a country suffers from significant energy poverty and pervasive electricity deficits. In recent years, India's energy consumption has been increasing at a relatively fast rate due to population growth and economic development, even though the base rate may be somewhat low. With an economy projected to grow at 8-9% per annum, rapid urbanization and improving standards of living for millions of Indian households, the demand is likely to grow significantly. The broad vision behind India's integrated energy policy is to reliably meet the demand for energy services of all sectors including the lifeline energy needs of vulnerable households in all parts of the country with safe, clean and convenient energy at the least-cost. This must be done in a technically efficient, economically viable and environmentally sustainable manner using different fuels and forms of energy, conventional and non-conventional, as well as new and emerging energy sources to ensure supply at all times with a prescribed confidence.

However, in the long run if we take the effect of the pollutants due to enormous use of fuels for power generation on human health and environment and cost as well as efforts needed to improve or alter the path of degradation, the initial higher cost of using renewable resources for producing energy may not be too big. A high degree of caution is also needed as emerging economies like India may not at present have financial resources to leapfrog directly to cleaner mechanisms of energy. Since global warming is an international

phenomenon and it has no boundaries there is an urgent need for the transfer of technology and development of appropriate financial instruments from developed the world to nations who are still trying to find their rightful places.

In this paper the various sources for power generation have been discussed with their part in total energy scenario of India and the appropriate energy mix for future so as to balance between satisfying the growing energy demand and their after effects.

Keywords: MW, RES, PLF, MU, LNG/CNG, LPG

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1. INTRODUCTION

In recent years availability of power in India has both increased and improved but demand has consistently outstripped supply and substantial energy and peak shortages. Electricity shortage is not the only problem. Its spread is an equally serious issue. In the past, the selection of an energy resource for electricity generation was dominated by finding the least expensive power generating plant. Although such an approach is essential, there is growing concern about other aspects of power generation such as social, environmental and technological benefits and consequences of the energy source selection. While comparing different energy sources for life cycle emissions, it is seen that coal has the maximum global warming potential followed by Natural Gas and others. Further, it needs to be re-emphasized that for India, like most developing countries, the cost of producing electricity is of paramount concern while planning for the type of plant to be installed and commissioned and more so with abundant supply of coal.

Power Sector at a Glance ALL INDIA (As on 09-07-2015, Source: OM SECTION)

(A) Table 1 Total Installed Capacity: (As on 30.06.2015):

Fuel	MW	%age
Total Thermal	1,91,264	69.6
Coal	167,208	60.8
Gas	23,062	8.4
Oil	994	0.4
Hydro	41,997	15.3
Nuclear	5,780	2.1
RES** (MNRE)	35,777	13.0
Total	2,74,818	

Renewable Energy Sources (RES) include SHP, BG, BP, U&I and Wind Energy

(B) Generation Performance**ELECTRICITY GENERATION PERFORMANCE**

The electricity generation target for the year 2015-16 was fixed as 1137.5 Billion Unit (BU) i.e. growth of around 8.47% over actual generation of 1048.673 for the previous year (2014-15). The generation during (2014-15) was 1048.673 BU as compared to 967.150 BU generated during 2013-14, representing a growth of about 8.43%.

Table 2 Program, actual achievement and growth in electricity generation in the country during 2009-10 to 2014-15

Year	Target (BU)	Achievement (BU)	% of target	% of growth
2009-10	789.511	771.551	97.73	6.6
2010-11	830.757	811.143	97.64	5.56
2011-12	855.000	876.887	102.56	8.11
2012-13	930.000	912.056	98.07	4.01
2013-14	975.000	967.150	99.19	6.04
2014-15	1023.000	1048.673	102.51	8.43

2. THE ENERGY SCENARIO**Energy Efficiency**

The primary energy demand in India has grown from about 450 million tons of oil equivalent (toe) in 2000 to about 770 million toe in 2012. This is expected to increase to about 1250 (estimated by International Energy Agency) to 1500 (estimated in the Integrated Energy Policy Report) million toe in 2030. This increase is driven by economic growth which lead to greater demand for energy services. This growth is also reflective of the current very low level of energy supply in India. The average annual energy supply in India in 2011 was only 0.6 toe per capita; whereas the global average was 1.88 toe per capita. Consequently, there is a large latent demand for energy services that needs to be fulfilled in order for people to have reasonable incomes and a decent quality of life.

Government of India has undertaken a two pronged approach to cater to the energy demand of its citizens while ensuring minimum growth in CO₂ emissions, so that the global emissions do not lead to an irreversible damage to the earth system. On one hand, in the generation side, the Government is promoting greater use of renewable in the energy mix mainly through solar and wind and at the same time shifting towards supercritical technologies for coal based power plants. On the other side, efforts are being made to efficiently use the energy in the demand side through various innovative policy measures under the overall ambit of Energy Conservation Act 2001.

The potential for improvement of energy efficiency of processes and equipment through awareness creation is vast. A sound policy for creation, retention and up gradation of skills of Human Resources is very crucial for penetration of energy efficient technologies and practices in various sectors.

The National Mission for Enhanced Energy Efficiency (NMEEE) is one of the eight missions under the National Action Plan on Climate Change (NAPCC). NMEEE aims to strengthen the market for energy efficiency by creating conducive regulatory and policy regime and has envisaged fostering innovative and sustainable business models to the energy efficiency sector. The Mission seeks to upscale the efforts to unlock the market for energy efficiency which is estimated to be around Rs. 74,000 crores and help achieve total avoided capacity addition of 19,598 MW, fuel savings of around 23 million tonnes per year and green house gas emissions reductions of 98.55 million tonnes per year at its full implementation stage.

Figure 1:



The NMEEE spelt out four initiatives to enhance energy efficiency in energy intensive industries which are as follows:

- **Perform Achieve and Trade Scheme (PAT)**, a market based mechanism to enhance the cost effectiveness in improving the Energy Efficiency in Energy Intensive industries through certification of energy saving which can be traded.
- **Market Transformation for Energy Efficiency (MTEE)**, for accelerating the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable.
- **Energy Efficiency Financing Platform (EEFP)**, for creation of mechanisms that would help finance demand side management programs in all sectors by capturing future energy savings.
- **Framework for Energy Efficient Economic Development (FEEED)**, for development of fiscal instruments to promote energy efficiency.

The per capita consumption of energy in India is one of the lowest in the world. India consumed 566 kgoe in 2008 compared to 1803 kgoe by the world, 4560 kgoe by OECD countries, 1600 kgoe by China. India's energy use efficiency for generating Gross Domestic Product (GDP) in Purchasing Power Parity (PPP) is better than many countries and even compared to the world average. It is expected that with a growth rate of 9% TPES requirement for India in 2021-22 will be around 1192 Mtoe which will further increase to around 2043 Mtoe by the year 2031-32.

Silent points of Energy scenario in India are as under:

- Rapid economic development & increasing population = High demand for energy
- A sustained 8% GDP growth of India requires an annual increase of:
 1. Commercial energy supply from 3.7% to 6.1%
 2. Total primary energy supply from 2.2% to 5.1%
- Limited supply of coal, coupled with its poor quality, low level of technologies advancements and high environmental hazards
- Limited domestic reserves and uncertain foreign supply of hydrocarbons

Power capacity has risen at a rate of 5.87% per annum over last 25 years. The total supply of electricity has risen at the rate of 7.2% per annum over the same period. This reflects an improvement in Plant Load Factor (PLF). However, the consumption is still constrained as power shortages continue to plague the country. Following table indicates the power supply & peak demand in India for April'2010 till February 2011. (Source: Central Electricity Authority, Government of India) Table 3:

Power Supply (in MU)			Peak Demand (in MW)		
Requirement	Availability	Surplus/Deficit	Requirement	Availability	Surplus/Deficit
783057	715795	-8.6%	120575	108212	-10.3%

The Planning Commission of India has set a target of adding more than 78000MW in a five year plan 2007-12. It's a fact that the plan targets have been missed earlier due to various reasons as under:

- Inadequate transmission and distribution (T&D) network
- T&D investments not kept pace with investments in generation
- Industrial and commercial establishments did not sought captive and standby generation to meet demand or provide quality supply on a 24X7 basis to support critical processes and provide peaking support
- Private distribution has been introduced but is limited to very few areas.

3. NON RENEWABLE ENERGY SOURCES AND THEIR LIMITATIONS

Strategies to meet India's energy requirement are constrained by country's energy resources and import possibilities. Unfortunately, India is not well endowed with natural energy resources oil, gas and uranium. Reserves of oil, gas and Uranium are meager though India has large reserves of thorium. While coal is abundant, it is regionally concentrated and is of low calorie and high ash content, though it has the advantage of low sulfur content. The extractable reserves, based on current extraction technology, remain limited. Hydro potential is significant, but small compared to India's needs and its contribution in terms of energy is likely to remain small.

1. Coal

It is the most important and abundant fossil fuel in India. It accounts for 55% of the country's energy need. The country's industrial heritage has been built upon indigenous coal. Commercial primary energy consumption in India has grown by about 700% in the last four decades. Considering the limited reserve potentiality of

petroleum & natural gas, eco-conservation restriction on hydro projects and geo-political perception of nuclear power, coal will continue to occupy centre-stage of India's energy. With hard coal reserves around 246 billion tonnes, of which 92 billion tonnes are proven, Indian coal offers a unique eco friendly fuel source for the domestic energy market for the next century and beyond. Lignite reserves stand at around 36 billion tonnes, of which 90% occur in the southern State of Tamil Nadu. Out of a total of 171926 MW of electricity generated, coal powered thermal power plants accounted for 92418 MW as of February, 2011 indicating that most of India's electricity needs are dependent on coal. It has been estimated that at current levels of consumption the proven reserves of coal will last for 80 years and if all the inferred reserves also materialize it can last for over 140 years at the current rate of extraction. If domestic coal consumption continues to increase at a rate of 5% the extractable reserve will run out in around 45 years. Further, it is difficult to predict the long term demand for coal owing to rapid changes in the prices and relative availability of other fuels as well as the technological advancements and new policies in the end use sector. The major coalfields in India are concentrated in eastern parts as shown under:

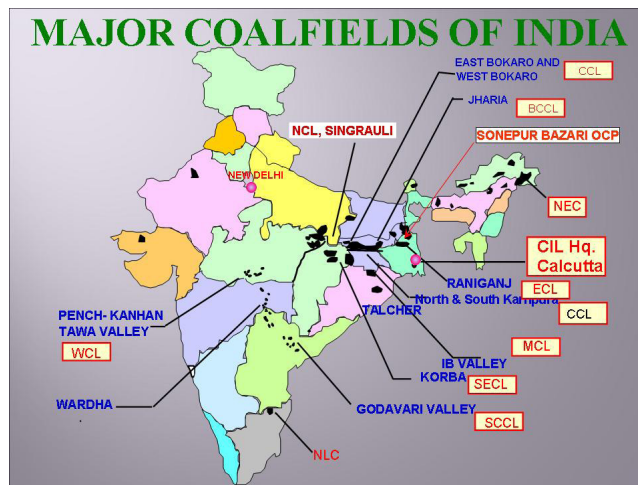


Figure 2

The setting up of a coal fired power plant in Western or North-west India, entails transporting coal over distances exceeding 1000 Km. and at such distances the economics of coal power become unfavorable. It is estimated that the coal deficit in India will increase to 400 million tonnes in Financial Year 2017 from around 50 million tonnes in FY11. Further, it is expected that demand for coal will rise to around 937 million tonnes by 2021-22 and to more than 1415 million tonnes by 2031-32. This will compel power generation companies to look at offshore coal, either through mine acquisitions or buying coal from international markets. Also the experts say offshore coal is not an easy alternative for power companies to meet their requirements. "Technically, the dependence on imported coal is not viable as old power stations cannot take the heat generated from more than 10-12% international coal blending". Besides, mines abroad, as in India, face government and environment clearance issues. Transportation of imported coal to the respective power projects has its own challenges as India does not have sufficient infrastructure such as ports and rail network. At present, the total cost of power generation using domestic coal is Rs 2.1 per kWh. But with imported coal, the cost shoots up to Rs 3.6 per kWh, due to high international coal prices, port handling charges, and customs duty. Many times

power stations were down or had critical stock. This poses a challenge to the power industry to maintain capacity utilization at high levels. Further, The Directorate General of Hydrocarbons has estimated the country's resource base for Coal Bed Methane (CBM) to be between 1400 BCM (1260 Mtoe) and 2600 BCM (2340 Mtoe). To give impetus to exploration and production, the government has formulated the CBM policy.

2. Petroleum/Oil

India has total reserves (proved and indicated) of 1201 million metric tonnes of crude oil. Crude oil production during 2009-10 at 33.69 million metric tonnes was 0.55% higher than the 33.51 million metric tonnes produced during 2008-09. The consumption of petroleum products during 2009-10 was 138.196 million metric tonnes which is 3.60% higher than the sales of 133.400 million metric tonnes during 2008-09. Long-term growth in demand of petroleum products depends upon a number of factors such as economic growth (GDP), elasticity of demand for petroleum products with respect to GDP growth, relative price levels of substitute products particularly LNG/CNG, saturation of LPG demand, and the impact of energy conservation measures. The demand for petrol and diesel is dependent on the growth of road infrastructure, the price of oil, the future efficiency of vehicles, the growth of alternate modes of transport and the emergence of substitutes like bio-fuels and/or technologies such as hybrids. Naphtha demand is dependent on the growth plans for fertilizer and petro-chemicals and its price relative to the price and availability of natural gas. Requirement is expected to rise to more than 240 million metric tonnes by 2021-22 which will further increase to around 465 million metric tonnes by 2031-32 considering a high output growth. India has a total installed capacity of 1199.75 MW of oil based power plants which is not substantial and the price per unit of kwh ranges from Rs 7.60 to Rs 8.00. In 2009-10, the total expenditure incurred on import of 159.2 million tonne of crude oil was \$79,552 million and this is increasing each year putting substantial pressure on Indian economy leading to continuous increase in import dependence in this sector.

3. Natural Gas

India's total reserves (proved and indicated) of natural gas is 437 billion cubic meters as of 1st April 2010. Gross Production of Natural Gas in the country at 47.51 billion cubic meters during 2009-10 was 44.63% higher than the production of 32.85 billion cubic meters during 2008-09. The total installed capacity of gas fired plants as of February 2011 stood at 17706 MW. The flaring of Natural Gas in 2009-10 at 2.09% of gross production is lower than the 3.29% in 2008-09. Natural gas can replace existing fuels in various sectors both for feedstock as well as for energy purposes. However, this substitution will depend upon the relative price of gas with respect to other fuels. Therefore, it may be stated that the demand for gas will depend upon the price of natural gas relative to that of alternatives, mainly Naphtha for fertilizer and petrochemicals and coal for power. With domestic production of just over 140 million standard cubic meters per day meeting barely half the demand, India is importing 10 million tons of liquefied natural gas per annum and is looking at unconventional sources like shale gas. **Natural gas has been recognized as a bridge between the more polluting fuels based on hydrocarbons and cleaner renewable sources of energy.** It has been estimated that the demand for gas to be between 65 and 71 Billion Cubic Metres (BCM) for the year 2020. IRADe-PWC (Integrated Research and Action for Development) has projected demand of natural gas and natural gas

equivalent of Naphtha at 243 BCM under the business-as usual scenario and 405.7 BCM under a High Output Growth scenario for the year 2030.

4. Nuclear Energy

Nuclear power is the fourth-largest source of electricity in India after thermal, hydroelectric and renewable sources of electricity. As of 2013, India has 21 nuclear reactors in operation in 7 nuclear power plants, having an installed capacity of 5780 MW and producing a total of 30,292.91 GWh of electricity while 6 more reactors are under construction and are expected to generate an additional 4,300 MW. In October 2010, India drew up "an ambitious plan to reach a nuclear power capacity of 63,000 MW in 2032", but, after the 2011 Fukushima nuclear disaster in Japan, "populations around proposed Indian NPP sites have launched protests, raising questions about atomic energy as a clean and safe alternative to fossil fuels". There have been mass protests against the French-backed 9900 MW Jaitapur Nuclear Power Project in Maharashtra and the Russian-backed 2000 MW Kudankulam Nuclear Power Plant in Tamil Nadu. Despite this opposition, the capacity factor of Indian reactors was at 79% in the year 2011-12 compared to 71% in 2010-11. Nine out of twenty Indian reactors recorded an unprecedented 97% capacity factor during 2011-12. With the imported uranium from France, the 220 MW Kakrapar 2 PHWR reactors recorded 99% capacity factor during 2011-12. The Availability factor for the year 2011-12 was at 89%.

The country is involved in the development of nuclear fusion reactors through its participation in the ITER project and is a global leader in the development of thorium-based Fast Breeder Reactors (FBR). India is poorly endowed with Uranium. Available Uranium supply can only fuel 10,000 MW of the Pressurized Heavy Water Reactors (PHWR). FBR technology is critical to developing stage two of India's nuclear power program. Without developing the wide-scale use of FBR technology, India will find it difficult to go beyond 10,000 MW of nuclear capacity based on known indigenous Uranium resources. India aims to supply 25% of electricity from nuclear power by 2050. Because India is outside the Nuclear Non-Proliferation Treaty due to its weapons program, it was for 34 years largely excluded from trade in nuclear plant or materials, which hampered its development of civil nuclear energy [production] until 2009. Due to these trade bans and lack of indigenous uranium, India has uniquely been developing a nuclear fuel cycle to exploit its reserves of thorium. Although the trade ban stopped India importing uranium it helped it to develop indigenous technology and trained a large manpower in the nuclear field. With the signing of a nuclear cooperation agreement it is anticipated that foreign technology and fuel will boost India's nuclear power plans considerably, however, the initial euphoria has somewhat ebbed as India failed to sign the Nuclear liability bill. The work of generating and maintaining nuclear power plant lies with "Nuclear Power Corporation India Limited" and it plans to build five nuclear power parks each with a capacity of eight nuclear reactors of 1000 MW. The nuclear power parks are planned at Kudankulam in Tamil Nadu, Jaitpur in Maharashtra, Mithi Virdi in Gujarat, Haripur in West Bengal and Kovvada in Andhra Pradesh.

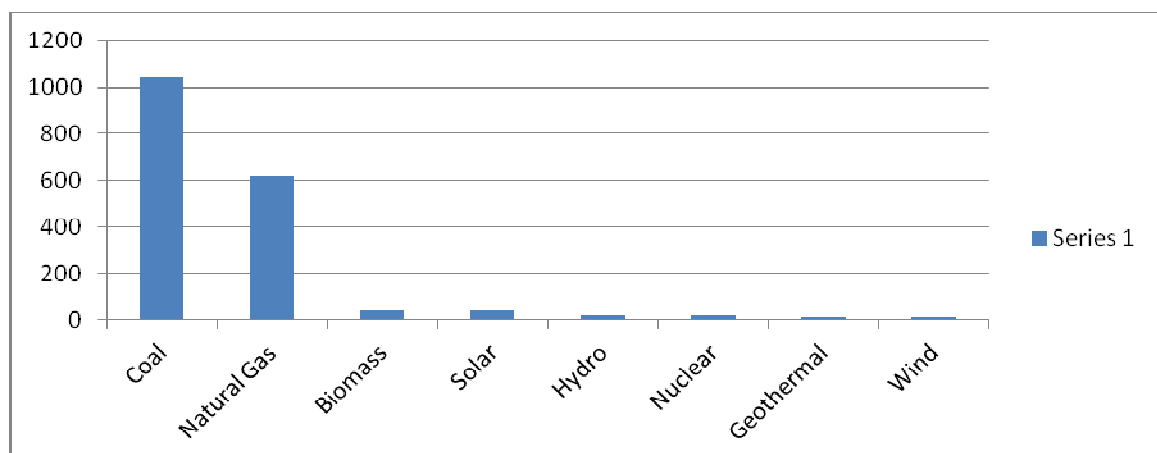
4. EVALUATING ENVIRONMENTAL IMPACT OF VARIOUS SOURCES OF ELECTRICITY GENERATION

Moreover, at projected usage levels, questions are also raised about the period India's extractable coal reserves could last. Environmental and climate change threats are

getting more severe and project clearances more difficult to obtain. In spite of many policy and infrastructural initiatives, it appears unlikely that quantities required to achieve projected conventional power capacity will be available. Large hydro projects are also facing problems – largely related to environmental issues and some to project execution in difficult areas along with attendant issues of building long transmission lines. Natural gas difficulties and its competitive usages also do not create optimism. Nuclear power capacity building continues to face its own problems, especially with the huge targets proposed. In the above backdrop, therefore, it could reasonably be expected that there could be substantial and worrisome slippages in creating conventional power capacities over the next two decades and even in the long term. It is almost inevitable that this would lead to more consumption of diesel, furnace oil and kerosene. It is, therefore, imperative that substantive measures be taken to reduce their consumption for energy purposes and also reducing consumption drastically in personalized urban and long-distance freight transport. If energy shortages persist it is difficult to expect much improvement in energy access. It is clear that India's need for secure, affordable, and environmentally sustainable energy mix has become one of the principal economic and development challenges for the country. It is also clear that while energy conservation and energy-efficiency have an important role to play in the national energy strategy, renewable energy will become a key part of the solutions and is likely to play an increasingly important role for augmentation of grid power, providing energy access, reducing consumption of fossil fuels and helping India pursue its low carbon developmental pathway.

By itself, electricity is an exceptionally clean form of energy – but we have to consider how it is generated. Today, about 70% of electricity is produced from fossil fuels (about 55% from coal, natural gas). Nuclear power accounts for another 20%, leaving about 10% coming from renewable resources like wind, water and solar. The result of this mix is that electricity generation is currently the largest source of energy-related CO₂ emissions. Figure 1 shows a comparison of different energy sources for life cycle emissions. It can be observed that coal has the maximum global warming potential followed by Natural Gas and others: Graph 1:

Comparison of Life-Cycle Emissions (Tons of Carbon Dioxide Equivalent per Gigawatt-Hour)



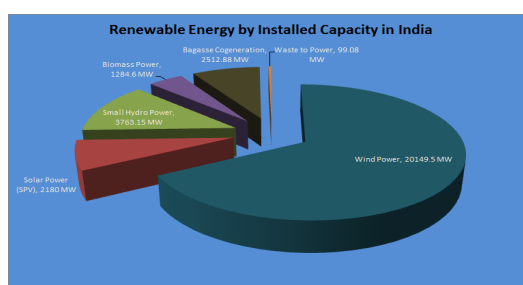
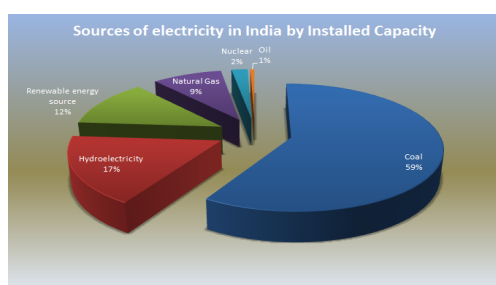
Each method of generating electricity has advantages and disadvantages, as well as significantly different effects on the environment. The chart below helps illustrate the differences between the various energy sources used to generate electricity: Table 4:

Fuel Type	Co2 Emissions per kWh	Power Availability	Ongoing Fuel Costs	Other Environmental Impact
Coal	About 200 pounds	24x7, 365 days per year	YES	Strip mining & groundwater contamination Airborne mercury contamination Non-renewable fuel source
Natural Gas	About 130 pounds	24x7, 365 days per year	YES	Non-renewable fuel source
Nuclear	zero	24x7, 365 days per year	YES	Extremely dangerous toxic waste Non-renewable fuel source
Wind	zero	Varies directly with wind speed	NO	Potential bird kill Highly visible Noise issues
Solar	zero	Daytime only, affected by clouds	NO	High energy used in manufacture Toxic silicon tetrachloride waste
Water (Reservoir Hydropower)	zero	24x7, affected by seasonal precipitation	NO	Flooding behind dam Impact on fish migration (if not mitigated)
Water (Streaming Hydropower)	zero	24x7, affected by seasonal precipitation	NO	Reduction in stream water flow

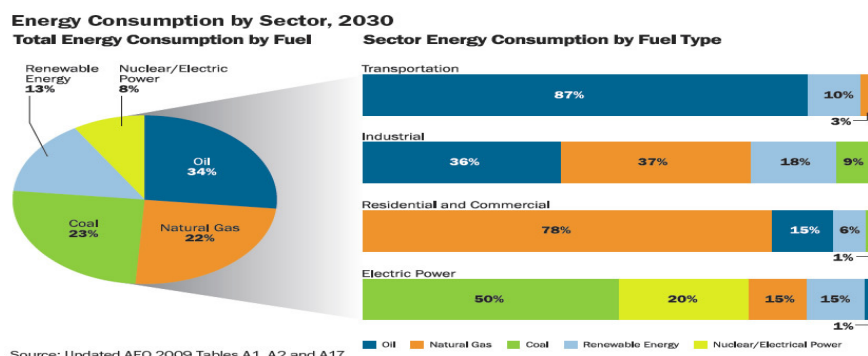
5. ROLE OF RENEWABLE IN ENERGY MIX

Renewable energy in India is a sector that is still in its infancy. India's electricity sector is amongst the world's most active players in renewable energy utilization, especially wind energy. As of 31 January 2014, India had an installed capacity of about 31.15 GW of non-conventional renewable technologies-based electricity, about 13.32% of its total.

Following graphs indicates the installed capacity of the sources of electricity and components of various renewable energy sources in stalled in India with their shares in percentage. Coal contributes major shares 59% followed by hydropower whereas among renewables major share is from wind, small hydropower and solar. Figure 3 & Figure 4



As it is envisaged that by 2030, the conventional energy sources like fossil fuels will be diminishing fast the renewable will have to compensate above gap and also to satisfy the increasing demand, the expected shares of the energy sources shown in Figure 5 below:



Today India's needs for electricity are supplied by Fossil fuels, Nuclear energy and Renewable energy sources. In the future (about 100 or more years from today), our supplies of fossil fuels will be essentially exhausted, and we will have to rely either on nuclear energy or on renewable energy sources or both. The focus is on electrical energy inputs, needed for activities grouped under broad headings like residential, commercial, transportation, manufacturing, agriculture, mining and construction, etc. The Average per Capita requirement of Electricity (ACE) would be 1840 kWh/year. Keeping in mind the need for frugality, it may be best for India to aim for the value of 1840 kWh/yr as calculated by Reddy et al. This would be adequate for providing a good standard of living. However, we should aim for a value of 4000 kWh/yr so that the HDI is 0.9.

As early as 1974, France adopted an energy policy of expanding its nuclear energy program so that it would eventually provide most of its electricity. In 1980 their energy mix for 251 TWH energy was fossil fuel as 47.0%, nuclear as 25.3% and renewable as 27.6% which has been changed in 2011 as 532 TWH 8.5%, 79.0% and 12.5% respectively.

In India also, there is Potential of Renewable Energy Sources for Generating Electricity and its Main contributors are Solar power (Photovoltaic conversion & Thermal energy), Hydroelectric power, Wind energy, Power from biomass etc. To estimate the capacity of renewable energy sources to generate electricity, the parameters to be considered are like- data on solar radiation, wind speeds, water flows, efficiencies of devices, etc. - requirements of space - degree of commercialization thus far and the rate at which it has occurred.

1. Solar Energy

Photovoltaic & Thermal installed capacity as on 31.12.2013: PV- 2647MW & Thermal-50MW

Ambitious plans to install 20,000 MW by 2022. Major issues are

- Initial cost – About Rs 15 crores per MW
- Need 2 hectares of open land per MW
- Limitation - Energy available for only 7 or 8 hours a day.

We expect to generate from solar energy (PV and thermal) can be evaluated as under:

Barren and uncultivated land = 200,000 sq km Assume 5% of this land is acquired. At 2 hectares per MW, installed capacity = 500,000 MW Annual plant load factor (APLF) = 0.18 Annual electricity production = 788.4 TWh

Small Capacity Roof-top Solar PV Systems Considering capacity of a typical roof-top system as 3 kW, the Electricity generated would be 4.5 MWh/year. In 2070, India will have 425 million households, half in urban areas and half in rural areas. Although it is difficult to install roof-top systems in urban areas, in rural areas, it may be possible at most to install systems in about 10% (i.e. 20 million) households and Electricity produced by solar roof-top PV systems 5, 10 & 20 million households the Annual production of electricity would be 22.5, 45, & 90 TWH respectively.

2. (a) Hydroelectric Power • Large units (> 25 MW)

- Total reserves = 148,700 MW
- Present installed capacity: About 25%
- Average APLF = 0.37
- Annual Electricity production of reserves exploited at 40%, 60%, 80% would be 193, 289 & 386 (TWh) respectively.

(b) Hydroelectric Power • Small units (< 25 MW)

- Total capacity available = 15,384 MW
- Present installed capacity: About 25 %
- APLF = 0.37

The Annual Electricity production of reserves exploited at 40%, 60%, 80% would be 20, 30 & 40 TWH respectively.

3. (a) Wind Energy - on land

- Growth in capacity over the last 20 years has been spectacular.
- Installed capacity on 31-12-2013 = 21,136 MW
- Limitation: Available for only 4 or 5 hours a day.
- Latest findings indicate that the wind potential in India is much more than the value of 65 GW or so accepted earlier.

Annual Electricity produced by wind energy on land of potential exploited at 20%, 40% & 60% would be 703TWH, 1406TWH & 2108TWH respectively at 0.2 APLF. (Note: Potential = 2006 GW, hub height = 80 m APLF = 0.2)

(b) Wind Energy - off shore

There is Considerable scope for exploiting this resource. The Present installed capacity in India is Nil. However, Wind mapping is in progress off shore. The Potential estimated capacity would be 1100 TWH/year. As per Lu, McElroy & Kiviluoma, Proc. National Academy of Sciences of USA, 2009. it has potential of Annual production of electricity at 20%, 40% & 60% as 220TWH, 440TWH and 660TWH.

4. Power from Biomass

It needs trees, plants, bushes, grasses, algae, etc. and residues. Much of India's non-commercial energy required in the form of heat is obtained from biomass. Thus there are limitations to the availability of biomass which can be used for electricity production. Generally, biomass residues like rice husk, straw, coconut shells, saw dust, bagasse, molasses are used.

- Installed capacity on 31-12-2013 : 4000 MW
- Potential capacity (MNRE) : 23,000 MW
- Availability of biomass is seasonal. APLF = 0.3
- Annual production of electricity if potential is fully exploited = 60 TWh

Total Capacity of Renewable Energy Sources for Generating Electricity

Estimated annual electricity production (TWh/yr) Min Max

Solar power (PV + thermal)	810.9	3243.6 (incl. decentralized systems)
Hydroelectric power	213	426
Wind energy (on land & off shore)	923	2768
Biomass + others	77	77
TOTAL	2023.9	6514.6

On an annual basis, the estimated maximum production of 6514.6 TWh from renewable energy sources is reasonably close to the need of 6800 TWh. It is not enough to match demand with supply on an annual basis alone. Renewable sources must be able to meet the need for electricity continuously round the clock for all days of the year.

1. **Smart Grids Renewable sources** like solar and wind energy are intermittent sources with fluctuating outputs. If solar and wind energy are to supply the bulk of our electrical energy in the future, power grids will have to become smart grids.

Smart grids use information and communication technology to gather and act on information about the behavior of the supply and demand side in an automated fashion. Such grids help to improve efficiency, reliability and economics. Thus, 'smart' power grids should have the capability to

- Coordinate and control the supply of thousands of relatively small distributed and fluctuating solar and wind power sources.
- Take that supply with the help of an extensive and robust transmission grid from where it is produced to where it is consumed.
- Control and manage power consumption of thousands of consumers on the demand side.

2. **Energy Storage Systems** Develop energy storage systems for short-term and long-term storage (a) To even out the mismatch in diurnal variation. (b) To store energy on days when supply exceeds demand and to provide energy to match demand during days when there are lulls in wind speed or periods of cloudy weather. Recent simulation studies have shown that one can match the demand by over-sizing the

electrical capacity. Over-sizing by a factor of three is recommended to achieve reliability greater than 99.9 %.

6. GOVERNMENT POLICY FOR GRID RENEWABLE POWER

The development of grid interactive renewable power essentially took off with the Electricity Act 2003 –which mandates the State Electricity Regulatory Commissions (SERCs) to

- Promote cogeneration and generation of electricity from renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any person, and
- Fix certain minimum percentages for purchase of renewable power in the area of each Distribution licensee.

The National Electricity Policy 2005 has provided for progressive increases in these levels and purchases by distribution companies through competitive bidding processes. The Tariff Policy 2006 requires fixation by SERCs of a minimum percentage for purchase of energy from such sources taking into account availability of such resources in the region and its impact on retail tariffs and procurement by distribution companies at preferential tariffs determined by the SERCs. As of date, most of the SERCs have specified percentages for purchase of electricity from renewable sources of energy.

Incentives for Private Inv Investment in Renewable Energy

The Government has been promoting private investment for the setting up of projects for power generation from renewable energy sources through an attractive mix of fiscal and financial incentives, in addition to the preferential tariffs being provided at the State level.

Table 5 Trajectory of Growth of Installed Power Capacity in India

Period	Thermal		Hydro (>25MW)		Nuclear		Renewable Power	
	(%)	MW	(%)	MW	(%)	MW	(%)	MW
1.4.2002	70.85	74429	25	26269	2.59	2720	1.55	1628
1.4.2007	64.06	87015	25.51	34654	2.87	3900	7.55	10258
30.9.2010	63.95	106518	22.41	37328	2.70	4560	10.90	18155

(Source: Ministry of New and Renewable Energy, Government of India)

Table 6 Share of Different Renewable Sources in India

Resource	Potential (MW)	9 th Plan	10 th lan	11 th Plan Target	11 th lan Upto 9/10	11 th Plan Achivemt	12 th Plan Project	13 th Plan Projection
Wind	48500	1667	5427	9000	4714	12809	27300	38500
Hydro	15000	1438	538	1400	759	2823	5000	6600
Bio*	23700	390	795	1780	1079	2505	5100	7300
Solar		2	1	50	8	18	4000	20000
Total		3497	6761	12230	6560	18155	41400	72400

(Source: Ministry of New and Renewable Energy, Government of India)

* Includes biomass, bagasse cogeneration, urban and industrial waste to energy

During the last many years the share of renewable energy has steadily increased due to the initiative taken by Government of India and as indicated in above Table 5. The share of various types of renewable energy is indicated in the Table 6. It is estimated that total share of renewable energy will be 15.9% by 2022. In the larger perspective of grid power an innovative scheme is being tried in India called as tail-end grid. So far the emphasis has been on large plants whether they are wind, solar, hydro or biomass. Locations for wind and hydro are fixed. However, for biomass the difficulties of ensuring collection and transportation of fuel are leading towards smaller plants. For solar PV, a total of 100 MW capacity is being set up with smaller plants of 100 KW to 2 MW, which are connected to grid through 11 kV feeders. It is envisaged that hundreds of such plants will be built in the next few years thus improving the transmission infrastructure.

7. BIOMASS POWER AND BAGASSE COGENERATION PROGRAM

This program aims at the utilization of biomass, such as agro-waste; agro-industrial processing residues, wood from dedicated energy plantations and bagasse from sugar mills, for power generation using combustion technology. The current potential for power generation from surplus agro and agro-industrial residues is estimated at 17000 MW. With efficient power cogeneration plants in new sugar mills and modernization of existing ones, the potential of surplus power generation through bagasse cogeneration in sugar mills is estimated at 5000 MW. Thus the total estimated biomass power potential is about 22,000 MW.

8. WIND POWER

The wind power program is the fastest growing renewable energy program and is almost entirely coming through private sector investments. India has a potential of around 48,500 MW. With a capacity addition of 12,800 MW, it contributes to around 75% of the grid-connected renewable energy power installed capacity. The major wind power capacity is in the states of Tamil Nadu, Gujarat, Maharashtra, Karnataka and Rajasthan. Wind electric generators of unit sizes between 225 kW and 2.10 MW have been deployed across the country. An ambitious target of 9,000 MW was set for 11th Plan, of which 5,715 MW had already been achieved by September, 2010. The main driving force for development of wind sector has been the provision of accelerated depreciation of 80%, an incentive also available to many other sectors. This provision has enabled large profit making companies, small investors and captive users to participate in the sector. However, Independent Power Producers (IPPs) and Foreign Direct Investment (FDI) were not able to benefit from the accelerated depreciation provision. In order to increase the investor base, the government has launched a scheme for Generation Based Incentives. The effort is to do 2000 MW or more annually.

9. SMALL HYDRO POWER

The estimated potential for power generation in India from small hydro plants is about 15,000 MW from 5718 identified sites. So far over 760 small hydropower projects aggregating to 2,803 MW have been set up in various parts of the country and 285 projects of about 940 MW are in various stages of implementation. At present, a capacity addition of about 300 MW per year is being achieved, of which about 70% is coming through the private sector. In order to accelerate the pace of small hydro

development, both public and private sector participation for commercial projects and decentralized micro hydro for remote village electrification are being encouraged. Attention is being focused on States with the maximum hydro potential and improving environment policies to attract private sector investments.

10. SOLAR POWER

Among the various renewable energy resources, India possesses a very large solar energy potential; most parts of the country are blessed with good amounts of sunshine. There are about 300 clear sunny days in a year in most parts of country. The average solar radiation incident over India varies from 4 kWh/day - 7 kWh/day. The solar radiation received over the Indian land area is estimated to be about 5,000 trillion kWh/year. National Action Plan on Climate Change included eight major national missions with the one on solar energy being the centre piece. This mission envisages a major step up in the utilization of solar energy for power generation and other purposes. The Jawaharlal Nehru National Solar Mission (JNNSM) had a target of 20,000 MW grid solar power (based on solar thermal power generating systems and solar photovoltaic (SPV) technologies), 2000 MW of Off-grid capacity including 20 million solar lighting systems and 20 million sq.m. solar thermal collector area by 2022. The Mission will be implemented in three phases. The first phase will be of three years (up to March, 2013), the second up to March 2017 and the third phase will continue until March, 2022. A new architecture has been designed for the 1000 MW projects. NTPC Vidyut Vyapar Nigam (NVVN) will sell the solar power to the State utilities after bundling solar power with the equivalent capacity of thermal power. This mission will help to reach grid parity by 2022 and to set up indigenous manufacturing capacity.

11. OFF-GRID RENEWABLE POWER PROGRAMS

Indian renewable energy priorities are different from those of developed countries. Firstly, and most importantly, it provides energy access to large rural populations including those in inaccessible areas and meets the unobtained demand in many other areas. Perhaps the remotest areas can get electricity only through renewable sources. Secondly there is another important, unrecognized consequence attributed to off-grid applications. In one way or the other, they replace fossil fuels and can make a significant contribution to reduction in their consumption which is so important from the point of view of energy security. It has a great strength in its ability to supply power in a decentralized and distributed mode which has the advantage of consumption at the production point and so reduces land and environmental concerns. Table 7 gives the achievements made in the off grid power program.

More stress needs to be given for tapping the potential of off grid energy in rural areas of India which are not connected by grid as it is economically unviable to extend the grid in each corner where there may not be positive economic returns. The JNNSM envisages up scaling "Solar water Heating – Collector Area" to 20 million sq m, deploying solar lighting systems in rural areas to 20 million and enhancing off grid solar application to 2000 MW by 2022. The greatest potential for off grid [energy production] appears to be in solar technology. The world's largest solar system for cooking in a community kitchen has been installed in Shirdi where food for 20,000 people is cooked daily and it saves 60,000 kg of LPG every year. Over 40% of the country's population currently does not have access to [grid] energy. Biomass based

solutions are possible as India generates about 600 million tonnes of biomass based on agriculture.

Table 7 Achievement in Off Grid Power System

S.No.	Resource/System	Achievement up to 30.09.2010
1	Biomass Power	263.1 MW
2	Biomass Gasifier	128.2 MWeq
3	Waste to Energy	60.8 MWeq
4	Solar PV Power Plants	2.9MWp
5	Hybrid Systems	1.1 MWp
6	Family type Biogas Plants	4.27 million
7	SPV Home Lighting system	6,19,428 nos
8	Solar lantern	8,13,380 nos.
9	SPV Street Lighting System	1,21,227 nos
10	SPV Pumps	7,495 nos.
11	Solar Water Heating - Collector Area	3.77 million sq m

(Source: Ministry of New and Renewable Energy, GOI)

These are relatively more commercially viable and can be implemented in market mode with some Government support. Similarly here is a huge potential for tapping family type Biogas Plants and the present number can be easily raised from 4.27 million to 8 million while there is the potential to raise biomass power to 22000 MW for grid as well as off grid power as discussed earlier. In Bihar state about 150 villages have already been powered by mini grids using rice husk based gasification systems. Pilot biomass projects are under preparation for using pine needles in Himalayan pine forests while Lantana weed in the forests areas of Central India and dedicated bamboo plantations are being examined as sources of biomass for energy production.

12. INVESTMENT IN RENEWABLE ENERGY

Renewable power generation capacity in India has been set up largely through private sector investments and has been possible due mainly to a conducive, strong and clear policy framework and investor friendly environment. New investment is the most potent indicator of growth of the sector. It is estimated that, in 2009 the total financial investment in clean energy in India was at US \$ 3.2 billion out of which more than US \$ 1 billion is in the form of FDI. Ernst and Young ranked India the fourth most attractive country for renewable energy investment in the world, only behind the United States, China, and Germany. Broad estimates indicate that mitigation from the existing renewable energy portfolio is equivalent to around 4-5% of total energy related emissions in the country. Further, the vast market potential and well developed industrial, financing and business infrastructure, has made India a favorable destination for Clean Development Mechanism (CDM) projects, with renewable energy projects having the major share. National renewable energy plans offer ample opportunity for CDM projects and technological innovations. The Government of India has also created a "Clean Energy Fund" by imposing a surcharge of Rs 50 on the sale of every tonne of coal to finance clean energy projects.

The renewable energy has vast potential in terms of creating new job opportunities in India where there is high rate of unemployment and disguised employment. The report estimates that implementation of the National Action Plan on Climate Change

could create an additional 10.5 million direct green jobs and India's share of US \$ 2.2 trillion can be US \$ 135 billion. Further, global expansion of wind power could create 288,500 Indian jobs if Indian firms were able to penetrate 10% of the global market.

13. CONCLUSION

Energy is vital for development and this means that if India is to move to a higher growth trajectory than is now feasible, it must ensure the reliable availability of energy. The present energy scenario in India is not satisfactory. The power supply position prevailing in the country is characterized by persistent shortages and unreliability and also high prices for industrial consumers. Electricity is produced domestically but its supply depends upon the availability of coal, exploitation of hydro power sources and the scope for expanding nuclear power, and there are constraints affecting each source. Energy is central to achieving the interrelated economic, social, and environmental aims of sustainable human development. It is necessary to examine the kinds of energy India produces and the ways it uses them otherwise, environmental damage will accelerate, inequity will increase, and economic growth will be jeopardized. All energy sources are having advantages as well as certain disadvantages but resources are not an end in themselves, and their attractiveness must be seen in the context of societies' energy service needs, of the technologies that convert resources into energy services, and of the economics associated with their use. These analyses have shown that India will have to plan for the fulfillment of its energy needs based on a judicious mix of the natural resources endowed to it, keeping sustainable development in focus and having a minimum carbon foot print. India, with its vast population and limited natural resources for meeting its energy requirements, needs to maintain its momentum of growth and this can be made possible only with a clear strategy for use of best possible energy options available. India needs to have a long term strategy for meeting its energy needs by 2050 and a short term goal of 2020 which can be small steps towards attaining energy security by 2050. The broad vision behind energy policy must be to meet energy demands reliably with energy which is clean and affordable and this must be done in an environmentally sustainable manner using different fuels and forms of energy, conventional and non-conventional, as well as new and emerging sources to ensure supplies at all times. It is imperative for India to have a consistent energy policy, together with relentless pursuit of energy efficiency and conservation, maximizing coal production and improving the rail and port infrastructure as well as development of alternative infrastructure for coal transportation such as coastal rivers because coal, being the cheapest form of energy, will be the flag bearer of India's energy needs. There is also an urgent need to fully exploit the hydro and nuclear potential of the country but here it is important that inhabitants of a particular area are taken into confidence so they do not feel alienated from the project. India needs to step up its effort in the direction of coal gasification, carbon sequestration and undertaking projects for bio fuels. It is not possible for India to achieve energy security by concentrating on non renewable sources like coal and oil as the world does not have enough of such resources to meet demands which are continually increasing. India needs to look increasingly towards renewable energy for attaining energy security by 2050 and India's target of getting around 15.9% of total energy need from renewable sources by 2022 is too modest. India being endowed with year round solar radiation must exploit this source to the fullest extent as it is abundant and will remain as long as Earth is in existence irrespective of the cost involved today. As rightly said by a renowned nuclear scientist in India, expensive energy is still better than having no

energy. Further, India needs to fully exploit the potential of other renewable energy sources like bio fuels, wind, hydro and even nuclear energy. It means that India needs to increase the share of renewable energy substantially as non renewable sources of energy are just not available and India will risk losing growth momentum leading to wide spread inequalities which can have serious social and political ramifications. Finally, India needs to wake up and respond by improving efficiency, boosting infrastructure development and promoting private equity participation. India needs to realize the vast potential of renewable energy and need to step up effort for attaining the goal of “20 11 20 20” by 2020 i.e. 20% reduction in GHG, 11% reduction in consumption of energy by bringing about attitudinal changes, 20% share of renewable energy and 20% conservation of energy from the year 2011 till 2020. These targets are attainable and not only provide cleaner energy but also open a new field for providing employment opportunities to millions of people who are unemployed or disguised employment. This momentum then needs to be maintained so that India attains a target of having 70% renewable energy use by 2050.

ABBREVIATIONS

SHP= Small Hydro Project , BG= Biomass Gasifier, BP= Biomass Power, U & I=Urban & Industrial Waste Power, RES=Renewable Energy Sources, TWh- Trillion Watt Hour, GDP- Gross Domestic Product GHG- Green House Gases, NMEEE - National Mission for Enhanced Energy Efficiency, MTEE- Market Transformation for Energy Efficiency, EEFP -Energy Efficiency Financing Platform, FEEED- Framework for Energy Efficient Economic Development, ABT- Availability Based Tariffs, AT&T-Aggregate Technical & Commercial, T&D- transmission and distribution, CBM- Coal Bed Methane, IRADe -Integrated Research and Action for Development, PHWR- Pressurized Heavy Water Reactors, FBR -fast breeder reactors, SERC- State Electricity Regulatory Commissions, IPP- independent power producers, FDI- Foreign direct investment, NVVN- NTPC Vidyut Vyapar Nigam, CDM- Clean Development Mechanism,

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