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India - Current Energy Scenario and Strategies to Meet Future Energy Demands

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India is a country with a population of 1.30 billion which accounts for about 18% of the world's population, out of which about 32% is urban and rest is rural. Contemporarily, India is included in the trinity of top energy consumers along with China and the United States of America. Due to elevation of inhabitants and pecuniary expansion, the energy usage in India has been rising at a relatively faster rate. With meteoric rise in urbanization and revamping calibre of living for millions of Indian families, the demand shall probably be noteworthy. India faces a difficult challenge of not only just meeting the ever-growing energy demands but to ensure energy supply using different forms of energy i.e., conventional and non-conventional at minimal cost. This paper discusses the current energy scenario in India mentioning various energy sources, their potential as a viable energy source in the global market over a period of few years and for the future and also the challenges faced by India to keep up with the increasing energy demand in present date and possible solutions for the future to keep up with the demand with an economically viable and environmentally sustainable manner.

***Keywords*:** Renewable and Non-renewable Energy Sources, Environmental sustainability, Energy demand.

1. Introduction

The standard of living, world population, and global energy consumption has dramatically increased [1]. India has improved the availability of power in recent years, but the demand has consistently exceeded the energy supply and peak shortages. The India has installed capacity of 346 GW of energy with single National Grid system as on 30th November 2018. The India stands at third position in the world rank of production and consumption of electricity. The total electricity coverage of electricity in the country is 93 % with the 1149 kWh per capita energy consumption (in terms of electricity) during 2017-18 [1-4].

Approximately 80% of world power generation is contributed by power plants working with fossil fuel. The remaining is obtained from energy sources like hydropower, wind power, solar, nuclear power, geothermal power, and other energies. The major part of coal production (80 %) in India is consumed by the electricity sector [3]. India's economic growth potential has been led by coal which is used in powering multiple segments in the industry [4]. The average price of electricity in India is INR 5 per kWh [5]. Despite being low power tariff the per capita energy consumption in India is less. This is mainly due to lack of proper infrastructure for power supply. The Primary Energy Consumption of India has reached 753.7 MTOE (5.6 % of total world energy consumption) by 2017, whereas China and United States have 3132.2 MTOE (23.2 % of world) and 2234.9 MTOE (16.5 % of world) respectively [6]. India is 6th largest economic country in the world. The economy of the country is growing at the rate of 7.1 % and considered as fastest economic country in the world. India's per capita GDP is USD 2134 with 138th position in the

world as per the World Bank record [7]. India stands at 130th position (out of 189 countries) in Human Development Index ranking [6]. The International Energy Agency has estimated that India will increase power generation capacity from 600 GW to 1200 GW before 2050 [8].

Table 1: India Installed Power Station Capacity till 30th September 2018

Power Sector	Thermal Power from Conventional Energy Sources (MW)				Nuclear Energy Sources (MW)	Renewable Energy Sources (MW)			Total (MW)
	Coal	Gas	Diesel	Total Thermal Power		Hydro Power	Other Renewable	Total Renewable Energy Sources	
Central	56,955	7,237.91	0.00	64,192.91	6,780.00	12,151.42	1,502.30	13,653.72	84,626.63
State	63,596.50	7,048.95	363.93	71,009.38	0.00	29,942.00	2,004.87	31,946.87	102,956.25
Private	75,546.00	10,580.60	473.70	86,600.30	0.00	3,394.00	67,141.44	70,535.44	157,135.74
All India	196,097.50	24867.46	837.63	221,802.599	6780.00	45,487.42	70,648.61	116,136.03	344,718.61
Percentage	56.89	7.21	0.24	64.34	1.97	13.20	20.49	33.69	100

(Source: Central Electricity Authority, Ministry of power, Government of India)

2. CONVENTIONAL ENERGY SOURCES

2.1. Coal

The India ranks 4th in case of coal production Whereas, it ranks 5th in terms of reserves of coal. The India coal reserves are mainly found in eastern and central part of country. The 98.20 % of the total coal reserves of the India are distributed in Jharkhand, Chhattisgarh, Odisha, Madhya Pradesh, West Bengal, Maharashtra and Telangana. The major lignite reserves (80 %) are found in Tamil Nadu. The total estimated coal reserves and lignite reserves as on 31st March 2017 are 315.14 billion tonnes and 44.7 billion tonnes respectively. [4]. The major part of Indian coal reserves is similar to Gondwana coal (250 million years old), which makes up to 98% of total reserves and 99 % of total production. The Gondwana coal field is source for coking, non-coking, bituminous and sub bituminous coal [10]. The characteristics of Indian coal are high ash content, low calorific value, low carbon content, and negligible toxic trace element. The average gross calorific value (GCV) of Indian coal is about 4500 Kcal/kg. The two major types of coal produced in India include coking coal and non-coking coal. Prime coking, medium coking, and semi-coking are the categories under coking coal. Lack of quality coal in country coal reserves forced to import high-quality coal to meet the energy demand of steel plants, electricity and cement which accounts for 29% of total consumption [10-12]. As per the Ministry of Coal, The Indian coal has classified based on the useful heat value (UHV) and ash content (AC) and it is listed in Table 2.

It is not possible to reduce the import of coal level to zero since the boiler technology requires a specific coal (blending/ imports). The Indian power plants consume 0.7 kg of coal to generate 1 kwh of power Whereas, United States power plant generate 1 kwh of power by consuming 0.45 kg of coal [14]. The thermal power generation capacity as on 31st March 2017 of conventional energy is 91,7305 MW. Combined with lignite, coal accounts for 59% of India's commercial power requirements. The total production of coal and lignite during 2007-08 were 457.08 MT and 33.98 MT respectively. The production rate of coal and lignite have increased at the rate of CAGR to 3.17% and 2.70% respectively. The total production of coal and lignite during the year 2016-17 were 662.79 MT and 45.23 MT respectively [4]. The coal export/import of India are given in Table 3.

2. 2. Oil and Natural Gas

India stands in third position of oil consumption in the world followed by USA and China [6]. India has deemed for 0.91% of world oil production during 2016-18. As per the estimation, the maximum crude oil and natural gas reserves are 604.10 MT and 1289.81 BCM respectively reported on 31st March 2017. The Maximum reserves of crude oil are unearthed from the western offshore (39.61%)

and Assam (26.49%), whereas the maximum natural gas reserves are located in the eastern offshore (39.39%) and western offshore (23.46%) reported on 31st March 2017 [4].

The oil demand of India is expected to be 458 MTOE BY 2020 at a CAGR growth of 3.6%. By 2040, gas production will approximately be 90 BCM, while demand for natural gas will also grow at a CAGR of 4.6% to reach 149 MT. India's LNG imports has increased at a CAGR of 8.14% during 2008-18 [4].

Table. 5. The crude oil and natural gas reserves in India (estimated as on 31st March 2017)

Region	Crude oil reserves (Million metric tonnes)	Share (%)	Natural gas reserves (BCM)	Share (%)
Coal Bed Methane	0	0	106.56	8.28
Tripura	0.07	0.01	36.1	2.8
Arunachal Pradesh	1.52	0.25	0.93	0.07
Nagaland	2.38	0.39	0.09	0.01
Andhra Pradesh	8.15	1.35	48.31	3.75
Tamil Nadu	9	1.49	31.98	2.48
Rajasthan	24.55	4.06	34.86	2.7
Eastern Offshore	40.62	6.72	507.78	39.35
Gujarat	118.66	19.64	62.26	4.85
Assam	159.96	26.48	158.57	12.29
Western Offshore	239.23	39.59	302.37	23.42
Total	**604.1**	**100**	**1,289.82**	**100**

(Source: Energy Statistics 2018." 25th Issue, Central Statistics Office, Government of India.)

2. 3. Nuclear Power

The India stands 13th position in the world ranking of nuclear energy capacity. The Indian nuclear power sector in the country stands 5th from the top in terms of electricity generation under conventional sources of energy. The country has total 7 nuclear power plants with the capacity of around 6,780 MW, which has 22 functional reactors [16]. All the nuclear power plants are operated by Nuclear Power Corporation of India Limited (NPCIL). As of today, 478 tonnes of uranium per year is consumed by the nuclear reactors. Due to meager uranium reserves and high thorium reserves, India has been forced to make an atomic reactor using thorium and low-enriched uranium which is the key part of India's three-stage nuclear power programme. The Indian reserves were small and country was dependent for nuclear fuel. The Russia play significant role in supplying the nuclear fuel to India since 1990. The new reserves of uranium have been excavated at Tummalapalle belt (Andhra Pradesh state) and Bhima basin at Gogi (Karnataka) in 2011. Nearly half a lakh tonnes of uranium has been unearthed at the Tummalapalle belt which is only one-third of the expected value. India also has large deposit of thorium nuclear fuel (518,000 tonnes) in monazite form [17].

India has planned of 63 GW of power generation by 2032 but the Fukushima (Japan) nuclear disaster has raised question of safety. India's installed nuclear power generation capacity is anticipated to escalate to 20 GW by 2020 [11].

3.NON-CONVENTIONAL ENERGY SOURCES

3. 1. Solar Power

The solar radiation received over the Indian geographical area is estimated to be about 5,000 trillion kWh/year. It is one of the best sources of energy available which is free energy and it also does not leave any residue, unlike conventional energy sources. India receives about 4 - 7 kWh/m2

of solar energy every day. India has ranked 7th in Solar Power generation as of 2018. Even on the hottest regions on our planet the ratio flux never exceeds 1 kW/m2, also its availability varies with time and place. It is higher during the daytime with radiation going up to 7 kWh/m2 and lesser at night. Hence, it is very difficult to harness solar energy continuously and it is intermittent [19].
The India solar energy generation capacity has expanded 8 times from May 2014 (2650 MW) to January 2018 (20 GW). The Government intends to increase the solar energy capacity to 100 GW by 2022 [20]. Currently installed capacity of solar projects in India is about 26 GW as of September 30th, 2018 [21]. The world's largest solar park Kurnool Ultra Mega Solar Park is located in Panvam Mandal of Kurnool district of Andhra Pradesh spreading over an area of 24.0072 km2 with a capacity of 1,000 MW.

The installed capacity of Solar thermal power plant in India is 227.5 MW (177.5 MW in Rajasthan and 50 MW in Andhra Pradesh) [22]. The power cost from solar thermal plant is INR 3.97 per kWh. The cost of electricity obtained from solar PV has dropped down to 73 % from 2010 to 2017. The power cost from solar PV varies INR 2.4 to 3.2 per kWh [23]. As of today, the average price of solar electricity is 18% lower as compared to coal-fired power plants.

3. 2. Wind Power

The ingenious domestic policies of India have led it to become the fourth largest installed wind power capacity in the world [24]. In spite of being a developing country, India ranks 4th in the Global Wind Power Installation capacity index. The total wind power installed capacity as of 31st March 2018 is 34.294 GW [25]. The wind power contributes 10 % of total India's installed power generation capacity. The total 52.68 TWh power produced during 2017-18. The cost of power has decreased and reaches record value of INR 2.43 per kWh. Mainly 7 states of India make significant contribution in harnessing wind power.

India has the second largest wind farm in Tamil Nadu. The total wind power installed capacity was 32.380 GW by March 2017. The Indian Government has targeted 60 GW of wind energy by 2022 [20].

3. 3. Hydro

India has large potential for hydropower. India ranks 7th relative to production of hydroelectric power in the world. India's installed capacity of hydropower is 45,487.42 as on 30th Sep. 2018 [4]. The Indian hydropower is viable and economically exploitable energy. The estimated gross energy potential is 148701 MW [26]. The 56 sites of pumped storage with 94,000 MW gross installed capacity has been recognized. Hydropower play vital role in turning India from deficit energy state to surplus energy state with the pumped storage system to meet peak load shortages. The average tariff for hydropower is INR 6 per kWh.

Undeveloped hydropower potential is immense in India, after Russia, China, and Canada. The total hydropower potential in India is 660,000 TWh/year, as estimated by The International Hydropower Association out of which 79% is still undeveloped [27].

3. 4. Bioenergy

Bioenergy is the most promised energy source in India. The 70 % of Indian population is constitutes in rural area, where 75 % of their need is supplied by bioenergy. Tropical location, abundant sunshine, and rains are the factors that favor a high potential for biomass production. India has wide range of fertile land (394.6 million acres) [28]. As it has a large agricultural sector, it can provide a huge supply of biomass fuel which is an agricultural waste to meet the current energy demand. Biomass materials such as bagasse, rice husk, straw, cotton stalk, coconut shells, de-oiled cakes, jute waste, groundnut shells, and sawdust can be used for power generation. The total

bioenergy supply is 9837.43 MW of power from Grid and off-grid system [29]. To reduce the dependence on oil, India has concentrated towards the production of biofuel. The biofuel in India are majorly depend upon Jatropha seeds, which has high oil content (40 %) in it. Country has potential to produce 1.25 billion liters of ethanol [30].

3. 5. Geothermal Power

The Geological Survey of India has identified 340 geothermal energy locations in the country. The Himalayas, Sohana, West coast, Cambay, Son-Narmada-Tapi (SONATA), Godavari, and Mahanadi and the Puga Valley of Ladakh proved to be the most promising ones. The estimated potential of geothermal energy in India is about 10,000 MW [31].

However, the geothermal resources in India do not seem to be suitable for generating electricity and are being used only for taping small amounts of heat [32].

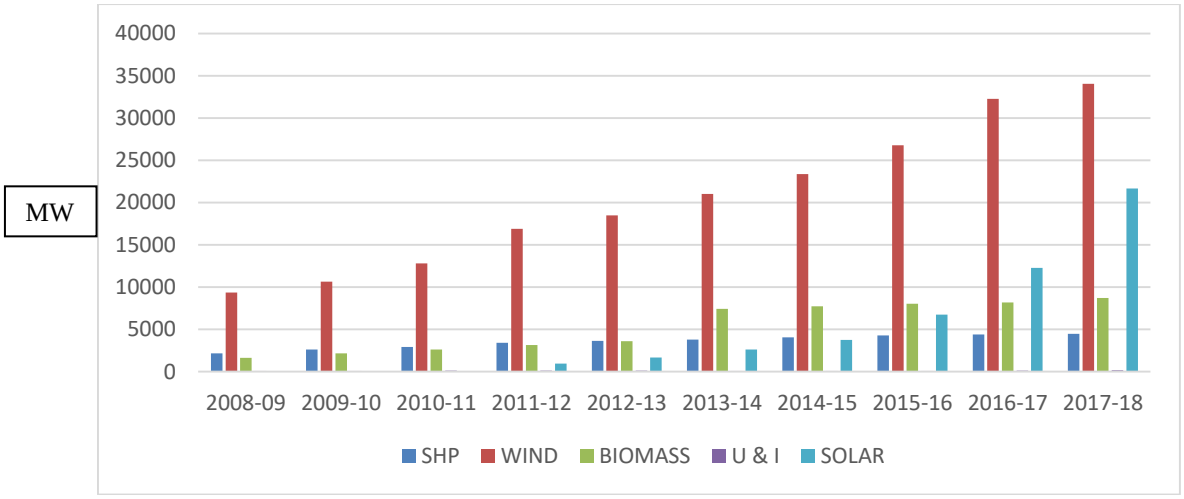

Fig. 2. This graph shows the Year wise Growth of Installed Capacity of Renewable energy during last 10 years.

4. IMPACTS OF CONVENTIONAL ENERGY SOURCES

The high fossil fuel consumption to fulfil the energy demand plays significant role in increasing the concentration of global house gasses like Carbon Dioxide (CO2) which is major reason for global warming. The high ash content in Indian coal cause high impact emission. As per the estimation, nearly half of the CO2 is emitted by power sector in India. The CEA annually estimates the total CO2 emission from power stations connected to grid system [33]. The CEA report of emission of CO2 from 2009 to 2017 is given in the Table 9. The India stand in top 5 countries list for high emission level. The total emission level of India and comparison with the other countries is given in table 10 [34]. Coal produces the maximum amount of greenhouse gases. Analyzing a thermal power plant can be effectively done by considering the 3 key limiting factors which include duration of the plant along with its design & operating efficiency [7]. Performance characteristics of an operating plant are scaling down with respect to both energy and exergy due to diminution of yield from generator. This infers that operating a power plant at its assessed power is more cost effective than operating at part loads [35]. Exergy analysis is of utmost importance due to insufficient performance of first law analysis [36]. The inflated exergy losses in the power plants given by the exergy loss distribution point out to the fact that they are imparted by boiler and turbine's irreversibility. Illicit power connections, meager billing, and defectively functioning meters along with low-tension distribution network and moderate load denseness are some of the factors contributing to high turbine & distribution losses [35]. Practically, a thermal power plant

scores only 23% where ideally it can score 80%. Inefficient use of resources and technological backwardness leads to high level of pollution; CSF study has found. India has one of the lowest efficiencies among major coal-based power producing countries with an average value of 32.8%. Average CO2 emission was 1.08 kg/KWh, 14% higher than that of China's [37].

The India's Ministry of Environment and Forests has taken a step towards reducing the emission from coal by implementing the to use beneficiated coals (ash content 34% or lower) in power plants near to urban and other ecologically sensitive and critically polluted areas. The thermal power plant in India has to undergo extensive review process (environment impact assessment) before being approved for construction. The India's Ministry of Environment and Forests has provided a manual for pollution level [4].

5. FUTURE ASPECTS AND STRATEGIES TO FULFILL ENERGY DEMAND

The India's contribution to the global GDP is forecast to increase 16 % by 2040. The India's energy demand will grow at the fastest rate and electricity consumption is forecast to reach 15,280 TWh by 2040. The growth rate forecast to be 3 times than that of China. The main reason behind this, the country has different stages of development. As per the IMF (2013 report) the 30 % of people are still living below the poverty line of country. This will lead to less energy consumption per capita with average increase in demand by 2040. As per the forecast of world oil outlook report (2017), The India will be second largest oil demand country adding 5.9 million barrels per day (MB/d) between 2016 to 2040. The demand growth will increase at fastest average rate of 3.6 % per annum. The demand for gas is expected to be increase 1.2 million barrels of oil equivalent per day (mboe/d), 2.1 mboe/d and 3.3 mboe/d by 2020, 2030 and 2040 respectively. The country will witness the gas demand growth at the rate of 5.2 % per annum. The fastest growth of energy source in India is forecast to be renewable energy and nuclear energy with the growth rate of 11.1 % per annum to 7.4 % per annum respectively. The Biomass energy growth forecast to fall from 23 % in 2015 to 11 % in 2040 [39]. This is because of policy maker's intention to move away from Indian traditional stove (Chullah) towards other fuel stoves (LPG).

Table 11. India's primary energy demand.

Sector	Increase level with the Year (mboe/d)				Growth rate percentage p.a.
	2015	2020	2030	2040	2015–2040
Oil	3.9	4.9	7.5	9.9	3.8
Coal	7.5	9.6	14.6	19.1	3.8
Gas	0.9	1.2	2.1	3.3	5.2
Nuclear	0.2	0.4	0.8	1.3	7.4
Hydro	0.2	0.3	0.4	0.6	3.6
Biomass	3.9	4.1	4.3	4.3	0.4
Other renewables	0.1	0.2	0.7	1.2	11.1
Total	16.8	20.6	30.4	39.7	3.5

6. CONCLUSION

This paper discusses about the present energy scenario and future energy demand of India. The energy consumption has increased drastically with the increase in standard of living and population of the country. India's energy installed capacity has reached 346 GW by 2018. India

stands at 3rd position in the world rank of energy consumption and production. The government of India's efforts to provide electricity to all will definitely lead to seeking more energy, where coal will play major role to fulfill the energy demand of the country. India's less reserves of oil and natural gas lead to the dependency on other country for the same. This may arise serious problem of energy security. The diminution of hydro-projects to safeguard environment and environmental hazards due to nuclear power plants limit their growth in installed capacity. The India has wide scope for renewable energy and significant growth has been observed since 2013. India has already achieved major part of the Paris agreement and set a new target of 227 GW of power from RES by 2022. They are only replacement over conventional energy sources considering environmental sustainability and energy security point of view. There is an urgent need to improve the equipment of India's thermal power plant with updated technology since they make major role in greenhouse gas emission.

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