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India's Electricity Sector: Surging Growth, Sustainability Issues and Policy Alternatives Ahead

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Abstract

India's surging economic growth in the post-reforms era created unprecedented demand for electricity. India has become 4th largest consumer of energy inputs in the world and a net importer of energy inputs (coal, oil, gas, uranium, etc.) and cutting-edge technology. The study unravelled that these costly imports not only raised the electricity costs, but also put pressure on India's scarce foreign exchange; which adversely impinged her economic sovereignty. Further, most of thermal plants using fossil fuels are small-sized, used outdated technology and notorious for uncontrolled emission of harmful gases (GHG and CO2) that caused severe environment pollution in India. The study, while analysing surging gaps in the demand/supply of electricity, builds a strong case for technological up-gradation of thermal plants and greater investments in renewable energy resources. It also emphasizes upon radical reforms in India's electric sector including (i) reduction in transmission and distribution losses and theft of electricity; (ii) allow non-price initiatives to promote energy efficient equipments/appliances; and (iii) encourage investments in the R & D for bringing new innovations such as cutting-edge technology.

Keywords: Energy Inputs, Electricity, Thermal Plants, Installed Capacity, Peak Load, T&D Losses.

Introduction

Electricity is one of the most powerful, safe and reliable sources of energy. It has become a central point to measure the quality of life as everything we do depends upon it one way or another. On domestic front, it lights the houses, buildings, and streets/pathways etc.; protects the human beings from unbearable heat/cold; and empowers them to run machines/equipments used in the fields, industries, homes, offices, etc. Electric power has also become most critical input for raising production, bringing speed and automation across all major sectors of an economy - agriculture, industry, transport, communications, business/commerce, etc. Electricity can be produced from a variety of energy sources such as oil, coal, hydro, natural gas, nuclear, wind, solar, and stored hydrogen. Most of these inputs, particularly the coal, oil and natural gas are not only exhaustible, scarce and depleting, but these inputs are also subject to the price shocks, supply interruptions and causing severe pollution (Government of India, 2015; 2017). All these factors demand optimum uses of these energy inputs; which, in turn, require proper planning and strategy for electricity production, transmission and distribution. Further, for the proper planning and optimal uses of electricity, an integrated and updated database of electricity production and consumption is not only necessary, but also demands a scientific analysis of various competing inputs, technological up-gradations and alternative uses. There is need to examine electricity generation, its different uses, T&D losses and damages it done to the environment. At the time of India's Independence (1947), electric supply was very limited as the installed capacity of electricity generation was just 1360 MW (Central Electricity Authority, 2014; 2018).Since the 1950s, a large number of hydro and thermal plants were constructed in India under state sector, which enjoyed nearly a monopoly power over the production, transmission and distribution of electricity till 1991.

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Under the NEP-1991, however, this sector was opened to the private sector for investments by giving various fiscal benefits and policy support (Kearney, 2012; Government of India, 2013). Consequently, both domestic and foreign investors began to invest in India's electricity sector in a big way as 45.21 percent of India’s total installed capacity in 2017-18 was owned by private sector; jumped from just 9.78 percent of installed capacity in 2000-01(Central Electricity Authority, 2018).

An assessment of India’s electricity statistics revealed that its electricity sector has grown significantly and shown many interesting trends. **First**, India’s electricity sector is dominated by fossil fuels (coal, gas, and oil), which have availability problems in the future (Jain, 2004). Rapid economic growth in India exacerbated this situation further. **Second**, India’s electric power sector was earlier developed exclusively under public sector; now the private sector has entered in electricity business in a big way. **Third**, major capacity additions in electricity were made in the thermal, hydro and nuclear powers; however, thermal power grew rapidly, whereas the growth of hydro and nuclear segments remained relatively slow. **Fourth**, within the thermal sector, more coal-based thermal capacities were added; but some gas/oil-based thermal plants were also visible in the post-1990s (Jain,2014; Kaur, 2016). These thermal plants based upon fossil fuels (coal/gas/oil) have environmental concerns, and therefore, put a question mark on its future sustainability (Singh and Gill, 2015). In the light of these observations, this paper examines the surging growth of electricity production/consumption, demand-supply gaps, outdated technology, need for technological up-gradation and its future sustainability in India. The study also identifies the factors behind surging demand of electricity; present modes of production, technology used, and supply constraints, particularly during peak-load hours. For analyzing these critical issues, the paper has been divided into three sections. Section-I deals with growth of India's energy needs, inputs used and emerging policy issues for the future. Section-II examines growth of electricity sector in India wrt installed capacity, inputs used for generation, consumption pattern, supply shortages, losses/wastages, etc. The major findings and strategic policy issues have been set forth in Section-III.

Section-I

1.1 Critical Issues in India’s Energy Sector

India’s surging growth in the post-reforms era has generated enormous demand for scarce energy resources. Further, rising incomes, education levels, uses of machinery, and automation in the production processes, etc. have also raised the demand for energy inputs multiple times. As per one estimate, India will become the second-largest consumer of global energy by 2035; accounting 18 percent share of world energy consumption (Government of India, 2015). Further, India has already become 4th largest energy consumer state (after USA, China and Russia) in the world, although it is not endowed with abundant energy resources (Government of India, 2013; 2015). Moreover, India's rising energy demands cannot be fulfilled by available domestic resources (coal, oil, hydro, uranium and other renewable resources), instead these inputs are to be imported from abroad (Government of India, 2015; 2017; Kaur, 2016). And, this heavy reliance on imported energy inputs will not only raise high costs of final output/s, but also put greater stress on the foreign exchange and, in turn, impinges India’s energy security adversely. Table 1 presents data on supply of India’s commercial energy inputs, measured in terms of million tons of oil equivalents (Mtoe). An analysis of data clearly showed that different energy inputs witnessed rising trends at varying rates. For instance, on the coal front, actual supply of coal was 210.92 Mtoe during 2006-07, and it increased to 286.80 Mtoe during 2011-12. The projected demand of coal also increased to 415.35 Mtoe during 2016-17 and 579.0 Mtoe during 2021-22. Similarly, supply of crude oil/petrol which was 132.2 Mtoe during 2006-07 and rose to 169.09 Mtoe during 2011-12. A projected supply of crude oil is likely to reach at 195.19 Mtoe and 237.0 Mtoe during 2016-17 and 2021-22 respectively. The supply of natural gas rose to 55.35 Mtoe during 2011-12 from 36.16 Mtoe during 2006-07. The projected supply of natural gas was also measured at 101.00 Mtoe during 20116-17 and 134.0 Mtoe during 2021-22. Further, actual supply of hydro power was equivalent to 10.04 Mtoe during 2006-07 and rose to 11.67 Mtoe during 2011-12, 13.42 Mtoe during 2016-17 and 17.6 Mtoe projected for 2021-22. Similarly, supply of nuclear power was 8.43 Mtoe during 2011-12 up from 4.91 Mtoe during 2006-07. Further, projected production of nuclear power was 16.97 Mtoe and 30.0 Mtoe for years 2016-17 and 2021-22 respectively. Further, actual production of renewable energy was just 0.87 Mtoe during 2006-07 and rose to 5.25 Mtoe during 2011-12. Projected production of renewable energy was 10.74 Mtoe and 20.0 Mtoe for years 2016-17 and 2021-22 respectively. In aggregate terms, total energy supply, which was 395.3 Mtoe during 2006-07, rose to 536.59 Mtoe during 2011-12. The projected demand for energy inputs was752.40 Mtoe during 2016-17 and 1017.6 Mtoe for 2021-22. The most worrisome point is India's heavy reliance upon imported energy inputs. For instance, coal imports rose significantly from 24.92 Mtoe (11.81 percent) during 2006-07 to54.00 Mtoe (18.83 percent) during 2011.12. In 2016-17, estimated value of imported coal was 90.0

Mtoe (21.67 percent), which will jump to 150 Mtoe (25.90 percent) during 2021-22. In the case of total petroleum products, India's imports of oil were pegged at 98.41 Mtoe (74.33 percent) during 2006-07 and 129.44 Mtoe (76.80 percent) during 2011-12. The projected imports of petroleum products were 152.44 Mtoe (78.09 percent) during 2016-17 and

Table 1: Total Supply of India's Commercial Energy by Primary Source (Figures in Mtoe*)

S. No.	Primary Source	Actual Figures				Projected Figures			
		2006-7	%	2011-12	%	2016-17	%	2021-22	%
1	Coal/Lignite	210.92	53.36	286.80	53.45	415.35	55.20	579.0	56.90
	of which Imports	24.92 (11.81%)		54.00 (18.83%)		90.00 (21.67%)		150.00 (25.90%)	
2	Crude Oil/Petroleum Products	132.4	33.49	169.09	31.51	195.19	25.94	237.0	23.29
	of which Imports	98.41 (74.33%)		129.86 (76.80%)		152.44 (78.09%)		194.0 (81.86%)	
3	Natural Gas/LNG	36.16	9.15	55.35	10.32	101.00	13.42	134.0	13.17
	of which Imports	8.45 (23.37%)		12.56 (22.69%)		24.80 (24.55%)		31.0 (23.13%)	
4	Hydro Power	10.04	2.54	11.67	2.17	13.42	1.78	17.6	1.73
	of which Imports	0.26 (2.59%)		0.45 (3.86%)		0.52 (3.87%)		0.60 (3.41%)	
5	Nuclear Power	4.91	1.24	8.43	1.57	16.97	2.26	30.0	2.95
6	Renewable Energy	0.87	0.22	5.25	0.98	10.47	1.39	20.0	1.97
Total Commercial Energy		395.3	100.00	536.59	100.00	752.40	100.00	1017.6	100.00
	of which Imports	132.04 (33.40%)		196.87 (36.69%)		267.76 (35.59%)		375.6 (36.91%)	
Non-Commercial Energy		153.28		174.20		-		-	

*Mtoe: Million Tonnes of Oil Equivalent.
Source: GOI (2013).

194.0 Mtoe (81.86 percent) during 2021-22. Similarly, imported Natural Gas/LNG was 8.45 Mtoe (23.37 percent) during 2006-07 and it stood at 12.56 Mtoe (22.69 percent) during 2011-12; 24.08 Mtoe (24.55 percent) during 2016-17 and 31.0 Mtoe (23.13 percent) during 2021-22. On the whole, net imports of all energy inputs rose from132.04Mtoe (33.04 percent) during 2006-07 to 196.87Mtoe (36.69 percent) in 2011-12, 267.76 Mtoe (35.59 percent) during 2016-17 and projected to 375.0 Mtoe (36.91 percent) during 2021-22. In nutshell, more than one-third of India's energy requirements are/will be fulfilled by the imported energy inputs.

The analysis makes it clear that India's commercial energy inputs faced three broad trends. **First**, coal/lignite remained the most dominant source of primary energy, followed by the crude oil/petroleum products and the natural gas/LNG. **Second**, share of hydro power, nuclear power and other renewable energy sources together did not show any appreciable rise; instead rose marginally from 4.00 percent during 2006-07 to 4.72 percent during 2011-12, 5.43 percent during 2016-17 and 6.65 percent during 2021-22. **Third**, a significant proportion of India's overall energy demand is fulfilled by importing inputs (varied in the range of 33.40 percent and 36.91 percent), much higher in the case of the crude oil/petroleum products. It means that India's rising commercial energy demands in the coming decades will be met (i) by raising imports of coal/lignite, crude oil/petrol, and natural gas; and (ii) by relying upon renewable energy sources (solar energy, wind energy, etc.). For both of these situations, India needs huge investments, technological imports and a clear-cut state specific electric policy (Singh and Gill, 2015).

Section-II

2.1 Growth of Installed Electricity Generating in India by Mode

The data in Table 2 showed a tremendous rise in India's total installed electric power capacity.

For instance, India's overall installed power capacity in India was just 28,448 MW in 1979-80 and reached to 243,029 MW in 2013-14 and 344,002 MW in 2017-18; rose by 12.1 times. Within total installed capacity, hydro power rose from 11,384 MW in 1979-80 to 40,531 MW in 2013-14 and 45293 MW in 2017-18, but its relative share in total installed power capacity decreased from 40.02 percent in 1979-80 to 16.68 percent in 2013-14 and 13.17 percent in

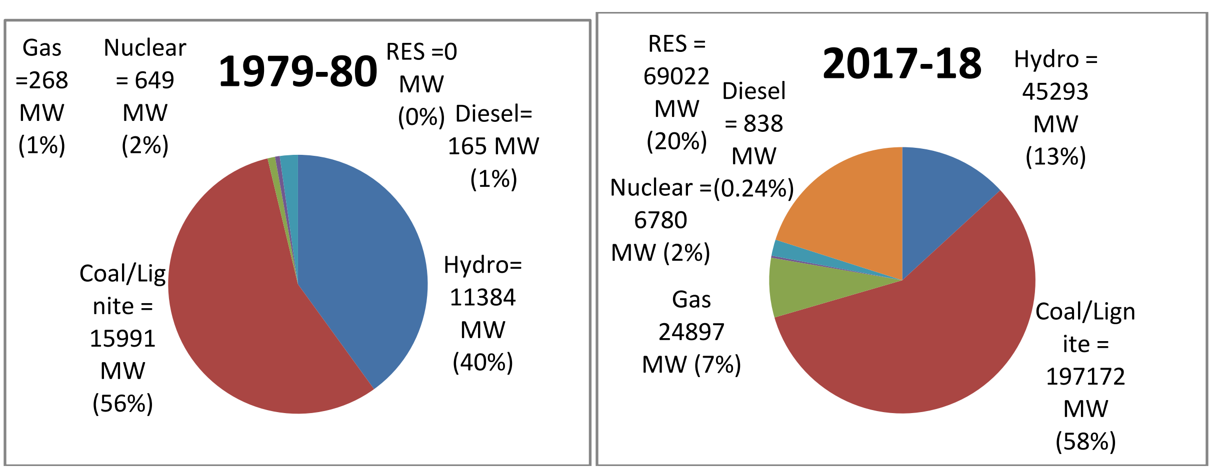
2017-18. Further, thermal power capacity has sharply increased from 16,424 MW (57.73 percent) in 1979-80 to 208,750 MW (85.90 percent) in 2013-14 and 222,907 MW (64.80 percent) in 2017-18. However, nuclear power's share decreased from 2.25 percent (640 MW) in 1979-80 to 1.97 percent (4780 MW) in 2013-14 and 1.97 percent (6780 MW) 2017-18. Interestingly, the share of renewable energy sources (RES), which was 0.00 percent in 1979-80 and 1.05 percent in 1996-97, but rose to 12.12 percent in 2013-14 and 20.00 percent in 2017-18.

Table 2: Growth of Installed Electricity Generating Capacity in India by Mode (Figures in MW)

Year	Hydro	Thermal				Nuclear	RES	Grand Total
		Coal/Lignite	Gas	Diesel	Sub-Total			
1979-80	11384	15991	268	165	16424	640	0	28448
%	40.02	56.21	0.94	0.58	57.73	2.25	0.00	100.00
1989-90	18307	41236	2343	165	43764	1565	0	63636
%	28.77	64.80	3.68	0.26	68.77	2.46	0.00	100.00
1991-92	19194	44791	3095	168	48054	1785	32	69065
%	27.79	64.85	4.48	0.24	69.58	2.58	0.05	100.00
1996-97	21658	54154	6562	294	61010	2225	902	85795
%	25.24	63.12	7.65	0.34	71.11	2.59	1.05	100.00
2001-02	26269	62131	11163	1135	74429	2720	1628	105046
%	25.01	59.15	10.63	1.08	70.85	2.59	1.55	100.00
2006-07	34654	71121	13692	1202	86015	3900	7660	132329
%	26.19	53.75	10.35	0.91	65.00	2.95	5.79	100.00
2011-12	38990	112022	18381	1200	131603	4780	24504	199877
%	19.51	56.05	9.20	0.60	65.84	2.39	12.26	100.00
2012-13	39491	130221	20110	1200	151531	4780	27542	223344
%	17.68	58.31	9.00	0.54	67.85	2.14	12.33	100.00
2013-14	40531	145237	21782	1200	208750	4780	29463	243029
%	16.68	59.76	8.96	0.49	85.90	1.97	12.12	100.00
2016-17	44478	192163	25329	838	218330	6780	57244	326833
%	13.61	58.80	7.75	0.26	66.80	2.07	17.51	100.00
2017-18	45293	197172	24897	838	222907	6780	69022	344002
%	13.17	57.32	7.24	0.24	64.80	1.97	20.06	100.00

Source: Central Electricity Authority, 2018.

Figure 1: India's Installed Electric Capacity - A Comparison (1979-80/2017-18



2.2 Growth of Electricity Generation in India by Mode

Regarding the growth of electricity generation, the data in Table 3 revealed an impressive increase. For instance, overall electricity generation in India increased from 104,627 MUs in 1979-80 to 963,722 MUs in 2012-13 and 13,03,493 MUs in 2017-18. Out of total electricity generation, hydro-electricity rose from 45,478 MUs in 1979-80 to 130,511 MUs in 2011-12, decreased to 113,626 MUs in 2012-13, and rose to 126,123 MUs in 2017-18. However, relative share of hydro-electricity decreased from 43.47 percent in 1979-80 to 11.79 percent in 2012-13 and 9.68 percent in 2017-18. On the other hand, absolute and relative shares of thermal electricity generation increased sharply from 56,273 MUs (53.78 percent) in 1979-80 to 759,776 MUs (78.84 percent) in 2012-13 and 1037,184 MUs (79.57 percent) in 2017-18. Electricity generated by nuclear plants also increased from 2846 MUs in 1979-80 to 32,871 MUs in 2012-13 and 38,346 MUs in 2017-18; its relative shares remained around 3.00 percent (2.75 percent in 1979-80, 3.41 percent in 2012-13 and 2.94 percent in 2017-18). The electricity generated by the RES also rose from 6 MUs in 1989-90 to 57,449 MUs in 2012-13 and 101,839 MUs in 2017-18; and in relative terms, its (RES) share rose from just 0.22 percent in 1996-97 to 5.96 percent in 2012-13 and 7.81 percent in 2017-18.

Table 3: Growth of Electricity Generation in India by Mode (MU)

Year	Hydro	Thermal				Nuclear	RES	Grand Total
		Coal/ Lignite	Gas	Diesel	Sub-Total			
1979-80	45478	55720	500	53	56273	2846	0	104627
%	43.47	53.26	0.48	0.05	53.78	2.75	0.00	100.00
1989-90	62116	172643	5962	85	178690	4625	6	245438
%	25.31	70.34	2.43	0.03	72.80	1.88	0.00	100.00
1991-92	72757	197163	11450	95	208708	5525	38	287029
%	25.35	68.69	3.99	0.03	72.71	1.92	0.01	100.00
1996-97	68901	289378	26985	679	317042	9071	876	395889
%	17.40	73.10	6.82	0.17	80.08	2.29	0.22	100.00
2001-02	73579	370884	47099	4317	422300	19475	2085	517439
%	14.22	71.68	9.10	0.83	81.61	3.76	0.40	100.00
2006-07	113502	461794	64157	2539	528490	18802	9860	670654
%	16.92	68.86	9.57	0.39	78.80	2.80	1.47	100.00
2011-12	130511	612497	93281	2649	708427	32287	51226	922451
%	14.15	66.40	10.11	0.29	76.80	3.50	5.55	100.00
2011-12	130511	612497	93281	2649	708427	32287	51226	922451
%	14.15	66.40	10.11	0.29	76.80	3.50	5.55	100.00
2012-13	113626	685857	71641	2278	759776	32871	57449	963722
%	11.79	71.17	7.43	0.24	78.84	3.41	5.96	100.00
2016-17	122378	944022	49094	401	993516	37916	81548	1235358
%	9.91	76.42	3.97	0.03	80.42	3.07	6.60	100.00
2017-18	126123	986591	50208	386	1037184	38346	101839	1303493
%	9.68	75.69	3.85	0.03	79.57	2.94	7.81	100.00

Source: Central Electricity Authority, 2018.

2.3 Growing Electricity Consumption in India by Sector (Utilities and Non-Utilities)

Demand for electricity in India is also growing at a faster speed as suggested by the electricity consumption statistics (Table 4). In 1979-80, India's total electricity consumption was 85,334 MUs which rose to 374,670 MUs in 2001-02 and 852,903 MUs in 2012-13 and 1130,244 MUs in 2017-18. If one looks at consumption of electricity by sectors, industrial sector still maintained a dominating position vis-à-vis other sectors of the economy.

Though its share has decreased from 62.35 percent to 45.89 percent in 2006-07, 44.87 percent in 2012-13 and 41.48 percent in 2017-18, yet the industrial sector has an edge in consuming more electric power than other sectors of economy as suggested by theory of structural transformation (Chenery, 1960). In the case of domestic sector, electricity consumption has been found to be increasing as its share increased from 9.85 percent in 1979-80 to 21.12 percent in 2005-06, 21.79 percent in 2012-13 and 24.20 percent in 2017-18. Electricity consumption in the agriculture sector increased from 15.76 percent in 1979-80 to 26.65 percent in 1996-97, and after that its share declined to 18.84 percent in 2006-07, 17.95 percent in 2012-13 and rose marginally to 18.08 percent in 2017-18. On the commercial front, electricity consumption also increased from 5.46 percent in 1979-80 to 7.65 percent in 2006-07, 8.33 percent in

2012-13 and 8.51 percent in 2017-18. The misc. uses of electricity found to be 3.89 percent in 1979-80, 5.75 percent in 2001-02, 5.25 percent in 2012-13 and 6.47 percent in 2017-18. However, electricity consumption in the traction came down from 2.70 percent in 1979-80 to 2.16 percent in 2001-02, 1.81 percent in 2012-13 and 1.27 percent in 2017-18.

Table 4: Growing Electricity Consumption in India (MU), Utilities and Non-Utilities

Year	Domestic	Commercial	Industrial	Agriculture	Traction	Misc.	Total
1979-80	8402	4657	53206	13452	2301	3316	85334
%	9.85	5.46	62.35	15.76	2.70	3.89	100.00
1989-90	29577	9548	100373	44056	4070	7474	195098
%	15.16	4.89	51.45	22.58	2.09	3.83	100.00
1991-92	35854	12032	110844	58557	4520	9394	231201
%	15.51	5.20	47.94	25.33	1.96	4.06	100.00
1996-97	55267	17519	139253	84019	6594	12642	315294
%	17.53	5.56	44.17	26.65	2.09	4.01	100.01
2001-02	79694	24139	159507	81673	8106	21551	374670
%	21.27	6.44	42.57	21.8	2.16	5.75	99.99
2006-07	11102	40220	241216	99023	10800	23411	525672
%	21.12	7.65	45.89	18.84	2.05	4.45	100.00
2011-12	171104	65381	352291	140960	14206	41252	785194
%	21.79	8.33	44.87	17.95	1.81	5.25	100.00
2012-13	185858	71019	382670	153116	15431	44809	852903
%	21.79	8.33	44.87	17.95	1.81	5.25	100.00
2016-17	255826	89825	440206	191151	15683	68493	1061183
%	24.11	8.46	41.48	18.01	1.48	6.45	100.00
2017-18	273550	96141	468825	204293	14356	73079	1130244
%	24.20	8.51	41.48	18.08	1.27	6.47	100.00

Source: Central Electricity Authority, 2018.

The analysis makes it clear that electricity consumption, in absolute terms, jumped up in each sector of Indian economy, but their shares showed some short of wide variations. Further, the demand for electricity will likely to be increased as Indian economy is growing at faster rate and electricity access to the rural areas will expand also in the future. There is ample evidence to show 'unmet demand' of electricity inputs in the rural India as during 2009-10, just 67.3 percent rural households enjoyed access to electricity and their per capita consumption was 8 kw per month (Government of India, 2013). India's Twelfth Five Year Plan (2012-17) put more emphasis on the faster growth in electricity supply seems to be logical to meet this unmet/suppressed demand (Government of India, 2013). In nutshell, one can state that future demands of electricity in India will mostly be come from the domestic, industrial and commercial sectors as these sectors has the tremendous potentials to grow (Government of India, 2017)) as well as faced supply constraints in the past (The Energy and Resources Institute, 2017).

2.4Growing Villages' Electrification and Transmission and Distribution (T&D) Lines

Undoubtedly, growing number of villages in India across a wide geographical spread got an access to electricity in India; so is the length of T&D lines. For instance, in 1979-80, 2.50 lakh Indian villages were electrified; this figure rose to 4.99 lakh villages in 1996-97, 5.12 lakh villages in 2001-02, 5.94 lakh villages in 2012-13and 5.97 lakh villages in 2017-18. However, a large number of these villages are not able to get round-the-clock (24 hours) supply for different uses, particularly for the lighting and domestic appliances.

Further, length of T&D lines for supply electric power also increased from 2351,609 CKT km in 1979-80 to 4407,501 CKT km to in 1989-90, 8970,112 CKT km in 2012-13 and 11031,059 km in 2017-18. In India, per capita electricity consumption rose tremendously. It increases from a base of 172.4 kw in 1979-80 to 329.2 kw in 1989-90, 559.2 kw in 2001-02, 917.2 km in 2012-13 and 1149.0 kw in 2017-18.

Table 5: Growth of Electricity Sector in India by Installed Capacity, Villages Electrified, Length of T& D Lines (Ckt. km) and Per Capita Consumption (KW)

Year	Installed Capacity(MW)	No. of Villages Electrified	Length of T&D Lines (Ckt. kms)#	Per Capita Consumption$ (KW)
March 31, 1979	26,680	232,770	2145,919	171.6
1979-80	28,448	249,799	2351,609	172.4
1984-85	42,858	370,332	3211,956	228.7
1989-90	63,636	470,838	4407,501	329.2
1991-92	69,065	487,170	4574,200	347.5
1996-97	85,795	498,836	5141,413	464.6
2001-02	105,046	512,153	6030,148	559.2
2006-07	132,329	482,864	6939,894	671.9
2011-12	199,877	556,633	8726,092	883.6
2012-13	223,344	593,732	8970,112	917.2
2016-17	326,833	592,972	10678,489	1122.0
2017-18	344,002	597,121	11031,059	1149.0

#It includes 400 Volts Distribution lines also.
$Per Capita Consumption = Gross electricity available/Mid-Year Population.
Source: Central Electricity Authority, 2018.

No doubt, India's per capita electricity consumption zoomed nearly seven-times (6.67 times) by 2017-18 when compared to the base year of 1979-80. However, per capita consumption of electricity in India was much below the world average of 2600 kwh, and 6200 kwh of European Union. Further, there existed a mismatch between the demand for and supply of electricity in India and majority of Indian states experienced acute power deficit and peak load tripping/restrictions/shortages (Central Electricity Authority, 2018). Further, more than 5.97 lakh villages were electrified in India by March 31, 2018 - up from 4.71 lakh electrified villages by March 31, 1990. Despite these achievements, just 52.5 percent of rural households have access to the electricity. Contrary to this, 97 percent of total urban households in India enjoyed electricity connection in 2011 (Central Electricity Authority, 2018). Further, 280 million people (nearly one-fifth of India's population) did not have access to electric power; though Mr. Piyusg Goyal, Union Minister for Power, Coal and Renewable Energy Resources claimed that the country had surplus electricity generation capacity (HT, 2015). These facts indicated 'unmet demand' of electricity on one side and 'surplus capacity' syndrome on the other side in India.

2.5 Low Per Capita Electricity Consumption and High T&D Losses

Although surging electricity production and consumption has become a reality in India, yet its per capita consumption remained a very low as compared to developed countries such as Canada, USA, Australia, Korea, Japan, France, Germany, etc. For instance, per capita electricity consumption of India was 1010 kwh in 2014 and 1075 kwh in 2015, whereas these figures were 15,544 kwh in 2014 and 15,188kwhin 2015 for Canada; and corresponding figures for USA were 12,962 kwh in 2014 and 12,833 kwh in 2015. Further, India's per capita electricity consumption was the lowest compared to the countries listed in the Table 6. More surprising fact of India's electricity supply is related to huge T&D losses. The data showed that out of the total electricity production, 22.77 percent in 2014 and 21.81 percent in 2015 was lost in the T&D against the world average of T&D loss measured at just 9.03 percent in 2014 and 8.95 percent in 2015.India's T&D losses were four/five times higher than that of Korea, Japan, and Germany.

These high T&D losses were largely due to two factors: First, India's transmission and distribution lines constructed a long ago and were based upon outdated technologies; and second, a wide spread nexus of vested interests consisting of politicians, bureaucracy, officials, etc. allowed the thefts and pilferage of electricity at wider scale in India (Government of India, 2013, 2015, 2017; Central Electricity Authority, 2014; 2018).

Table 6: Per Capita Electricity Consumption and T&D Losses across Selected Countries

Name of Country	Per Capita Consumption(KWH)		Name of country	T&D Losses (%)	
	2014	2015		2014	2015
Canada	15544	15188	Korea	3.62	3.59
USA	12962	12833	Germany	4.56	4.30
Australia	10002	9892	Japan	4.50	4.74
Japan	7829	7865	China	6.46	6.42
France	6955	7043	Italy	5.40	6.33
Germany	7035	7015	USA	9.56	9.11
Korea	10564	10558	UK	7.85	7.81
UK	5131	5082	Australia	6.17	5.77
Russia	6603	6588	France	6.31	6.33
Italy	5002	5099	Canada	10.63	11.72
South Africa	4240	4148	South Africa	8.45	8.77
Brazil	2578	2516	Russia	12.62	12.79
China	3927	4047	Brazil	15.69	15.92
India*	**1010**	**1075**	India	**22.77**	**21.81**
World	3030	3052	World	9.03	8.95

*Per Capita Consumption=Gross Electrical Energy Available/Mid-Year Population.
Source: Central Electricity Authority, 2018.

2.6 Base and Peak Load Shortages in India's Electricity Supply

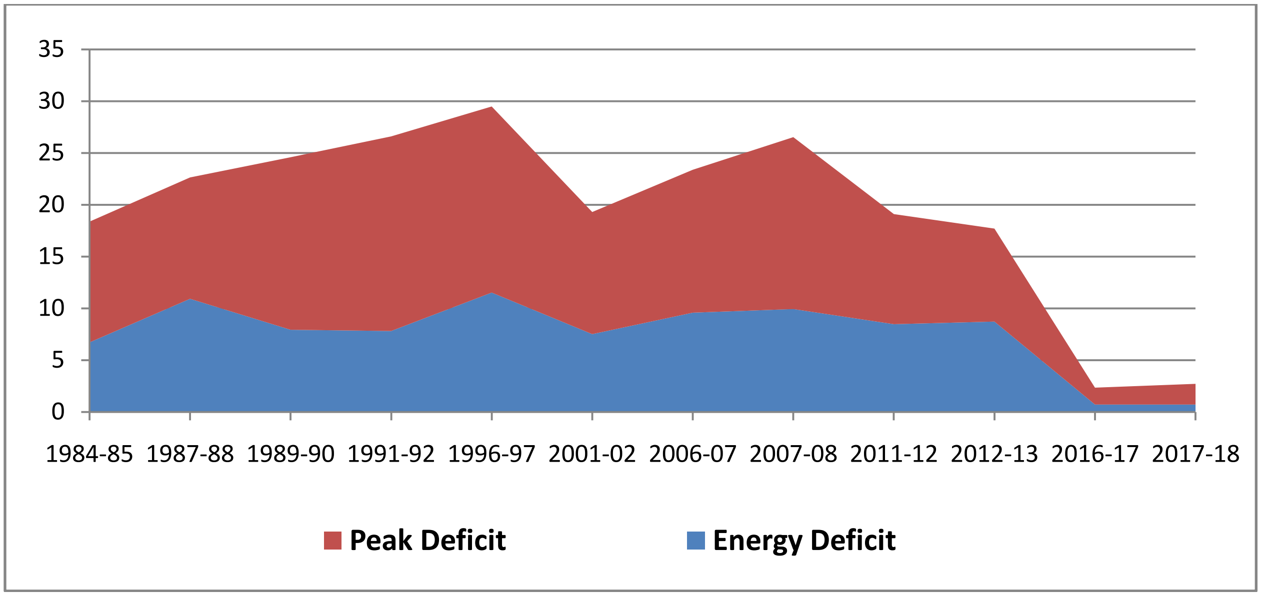
Another major bottleneck in India's electricity sector is related to the base and peak load shortages/restrictions. The data released by Central Electricity Authority showed (Table 7 and Figure 2) that the electricity demand in India far exceeded country's total generation capacity both in terms of its base load and peak availability. For instance, In the case of base load factor, electricity shortage was 6.70 percent in 1984-85 which increased to 11.07 percent in 2008-09, again fell to 8.71 percent in 2012-13 and 0.70 percent in 2017-18. In the case of peak load, electricity deficit was 11.66 percent in 1984-85 which rose to 16.60 percent in 2007-08, declined to 8.9 percent in 2012-13 and 2.00 percent in 2017-18. Between 1984-85 and 2012-13, India faced huge electricity deficits in the range of 6.70 percent–11.51 percent in the case of energy requirements and 8.98 percent–18.79 percent in the case of peak load demands.

Table 7: Electricity Supply Position in India: Base and Peak Load Shortage

Years	Energy Requirement				Peak Demand			
	Requirement (GWH)	Availability (GWH)	Deficit (GWH)	Deficit %	Demand (MW)	Availability (MW)	Deficit (MW)	Deficit %
1984-85	155,432	145,013	10,419	6.70	25,810	22,800	3,010	11.66
1987-88	210,993	187,976	23,017	10.91	31,990	28,242	3,748	11.72
1989-90	247,762	228,151	19,611	7.92	40,385	33,658	6,727	16.66
1991-92	288,974	266,432	22,542	7.80	48,055	39,027	9,028	18.79
1996-97	413,490	365,900	47,590	11.51	63,853	52,376	11,147	17.97
2001-02	522,537	483,350	39,187	7.50	78,441	69,189	9,945	11.79
2006-07	690,587	624,495	66,092	9.57	106,715	86,818	13,897	13.80
2007-08	739,343	666,007	73,336	9.92	108,866	90,793	18,073	16.60
2011-12	937,199	857,886	79,313	8.46	130,006	116,191	13,815	10.63
2012-13	998,114	911,209	86,905	8.71	135,453	123,294	12,159	8.98
2016-17	1142,928	1135,332	7,596	0.70	159,542	156,934	2,608	1.63
2017-18	1213,326	1204,697	8,629	0.70	164,066	160,752	3,314	2.00

Source: Central Electricity Authority, 2018.

Figure 2: India's Electricity Supply position - Base and Peak Load Deficits (1984-85 to 2017-18)



2.7Coal Shortage and Outdated Technology

India's thermal electricity sector faced shortages in the coal supply, low stocks of coal at power stations and sudden rise in imported coal prices on one hand and outdated technology across majority of thermal plants (Sukhatme, 2014). The coal shortages resulted in either a forced shutdown or low capacity utilization across many thermal power plants (including many NTPC power stations). Further, quality of coal (calorific value) used by these plants was often very low or unsuitable for use; resulting in the low electricity generation. Plant load factor of thermal power stations in India reduced to nearly 60 percent during 2016-17 and 2017-18 compared to more than 72 percent during 2002-03 to 2011-12 (Central Electricity Authority, 2018). Further, application of outdated technology and heavy emission of harmful gases (GHG and CO2) by thermal plants are going-on unabated and polluting India's environment severely. On this count, India's thermal electricity sector has gained notoriety. For instance, nearly 7 percent of global CO_2 was contributed by India's thermal power and these emissions have been risen @ 7.7 percent annually (Government of India, 2013). It meant India's thermal power plants are highly inefficient (Remme, Trudeau, Graczyk, and Taylor, 2011) and are an important source of air pollution, whereas an ultra-modern technology offers a significant scope for reducing emission of harmful gases. Moreover, electricity prices have become another important rather a politically sensitivity issue, which will pose a serious challenge in the coming years. In the business-as-usual approach, India is (would be) heavily dependent on the coal and LPG to meet surging demand for the electricity across alternative uses (Government of India, 2015; 2017). However, using fossil fuels to produce more electricity poses a serious threat to India's fragile environmental and natural resource base because such a power sector has been viewed the highest contributor (38 percent) to India's GHG emissions (Government of India, 2013). All these issues pose severe challenges to the existing thermal power technology, and also offer them an opportunity to respond to the long-run sustainability issues while developing a new electric power infrastructure in India. In India, a raging debate is going-on as to whether the latter could be developed in the decentralized or centralized manner (Künneke, 2003). Another issue is whether global practice of establishing large capacity power plants in India with capital intensive technology and new transmission infrastructure can be better done with low cost decentralized solutions.

2.8 Possible and Doable Solutions

There are several initiatives which can improve efficiency, reduce air pollution and carbon footprints from India's thermal power sector. New mega thermal plants offer a significant scope for application of new technology and innovations in reducing emission of harmful gases through a better technology. One possible solution lies in utilizing clean coal technology and refurbishing of old thermal plants by using ultra-super critical technology. In this context, India has already opted for more efficient and less polluting thermal plants (Box 1).

Box 1

Importance of Clean Coal Technology and Superiority of Ultra-Super Critical (USC) Power Plants

A coal-based USC power plant has an efficiency of 46 percent compared with 34 percent for a sub-critical plant and 40 percent for a super critical (SC) plant. Thus, with a USC or SC plant, total savings in coal consumption and reduction in the CO2 emission can be substantial. A 10,000 MW power plant will generate 60 billion units of electricity per year at around 70 per cent plant load factor. It has a specific heat of 1,870 kcal/kwh compared to 2,530 kcal/kwh for a sub-critical plant. So, every electricity unit generated with USC will save 0.165 kg [(2,530-1,870)/4,000] coal of 4,000 kcal/kg; and 60 billion units will save 9.9 million tonne of coal per year.

*Similarly, when we substitute a sub-critical coal plant with solar plants, for every kwh generated we save 0.63 kg of coal (2,530/4,000). Thus, 15.6 billion units (1,000*9.9/0.63) will have to be generated by solar plants to save the equivalent 9.9 million tonne of coal. Since a solar plant generates 1,500 units per kw of installed capacity, the matching installed capacity needed will be nearly 100,000 MW (15.6*1,000/15,000). To put it in simple terms, faster adoption of USC and SC technology can save as much coal as would be saved by installation of ten times the solar power capacity. So, while from a long term perspective, we need the solar option; and from a medium term perspective, development of USC and SC technology based plants should be pursued vigorously.*

Source: Government of India, 2013.

Moreover, as a long term perspective, India must emphasize upon renewable energy sources such as hydro, nuclear, solar and wind power (Sukhatme, 2014). Energy conservation and use of LED lights must be adhering to along with the new energy consumption norms, performance standards, establishing green buildings, etc. Further, new ICT based power grids and transmission networks, which are the backbones of any electricity distribution system, must be established in the country. These grids physically reconnect electricity producers and consumers and contribute to promote vital transmission services such as load management, technical dispatch, handling of emergencies, metering supply, control over energy and capacity building according to specified technical standards.

These new electricity networks developed over more than 100 years' research from the primitive local grids to complex international networks that interconnect numerous countries over great distances have numerous advantages. In these systems, electricity generation has been concentrated in the large-scale production units with a one-directional delivery to the final customer (Künneke, 2003).

Section-III

3.1 Major Findings and Strategic Public Policy Issues

The foregoing analysis and discussion suggest that rising energy needs of growing Indian economy cannot be met by public sector owned utilities alone; although the public utilities must have a dominant and commanding role. Involvement of private players in the generation and distribution of electricity is need of the hour. Undoubtedly, India's electricity sector is still subject to the regulatory controls over production, prices and allocation of fuels. These issues are not only distorting the market and business environment, but also dissuading the private players from making significant investments. For this, there is need to rethink and reformulate new electricity policy by involving all stakeholders (producers, consumers, distributors, etc.).

The study clearly stated that India's rising energy needs could not be fulfilled by domestic resources (coal, oil, hydro, uranium, etc.). Instead, India has to import these inputs along with the latest and critical technologies related to nuclear, solar, wind and clean coal technology. And, these costly imports will not only raise costs of electricity production, but also put greater stress upon scarce foreign exchange, which, in turn, adversely impinges on India's energy security in the future. In the long-run, India must have to augment and rely upon domestic sources of energy. India's Nuclear Energy Vision envisages to create 63,000 MW of installed nuclear power capacity by the year 2032 should loudly be propagated (Chaturvedi, 2014). In the situation of surplus electricity, India must ensure electricity trading (imports) with neighboring countries; particularly with Bangladesh, Myanmar, Pakistan, etc. in lieu of importing natural gas as these countries have enough storage of natural gas with them.

The study, by visualizing over-dependence on thermal power that caused pollution, builds a strong case for (i) technological up-gradation of India's thermal plants; (ii) application of clean coal technology; (iii) greater investments in renewable energy resources; and (iv) radical reforms in electricity sector - generation, transmission and distribution. Further, entry of private sector in electricity sector although is a welcome step on many counts (raising supply, competition, efficiency, etc.), but it has created a number of unresolved and unfavourable public policy issues for the public sector units. The new mega thermal plants, that utilize better technology and reduce emission of harmful gases significantly, must be encouraged. Steps should be taken to implement Energy Conservation Act 2001 in India.

This act, in fact, provides for institutionalizing and strengthening delivery mechanism for energy efficiency programmers in the country and provides much-needed framework for coordination amongst the various government entities. It also provides a legal and regulatory mechanism at the central and state government levels. Further, Bureau of Energy Efficiency (BEE) must be strengthened and its recommendations be made mandatory and legally enforceable. Incentives should be given to those customers who produce their own electricity (say solar power at rooftops) or conserve energy by using energy efficient equipments (LED lighting, five star rated appliances, etc). The study also favors' to install micro-intelligent networks by developing inherent capabilities within secure technological margins while maintaining a maximum transmission capacity. Under these conditions, no centralized electricity system is necessary. Instead, these networks can be operationalized through small semi-independent units that are inter-connected to the main system. There is need to establish new high voltage grid sub-stations and upgrade the old ones along with augmentation of 11 KV and LT lines so that the last-end consumers should not suffer from low voltage fluctuations.

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