A Study of Power Sector of India with Focus on Wind Energy to Meet India's Requirements of Low Cost Renewable Energy

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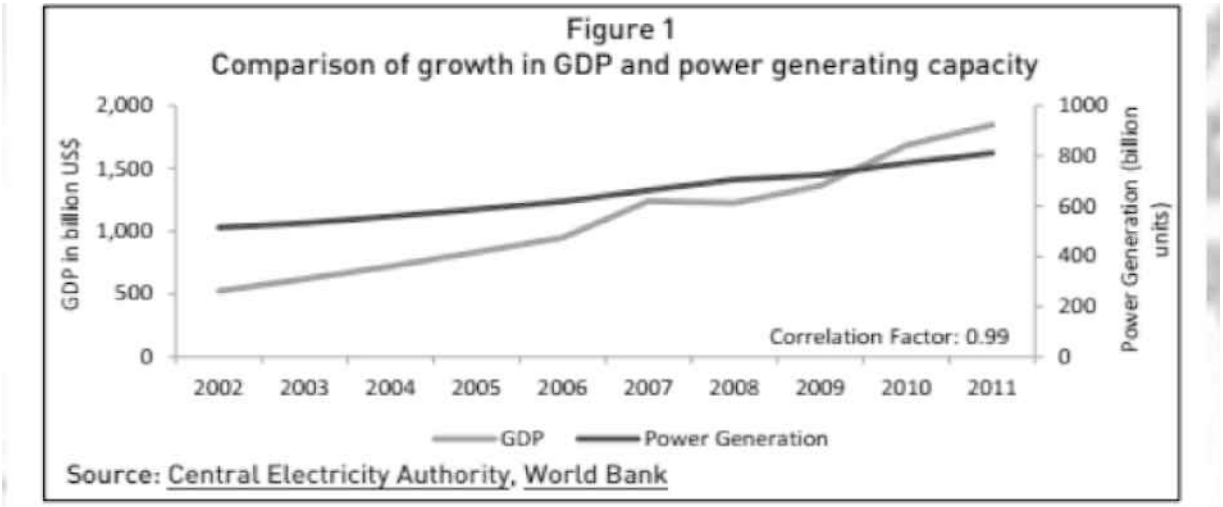
Abstract

This study was carried out in the form a desk research to understand issues relating to Indian power sector. The study highlights some key achievements of Indian power sector after establishing a link between power production and economic performance. While the achievements are noteworthy, the rate of electrification is neither fast enough nor is it reaching the poorest of the poor. India witnessed a percentage increase of households with no lighting in 22 states/Union Territories out of 35 listed during the period from 2001 to 2011. Key problems of the power sector are presented here. Wind energy is presented as an option that permits providing power at a low cost as compared to other renewable energy options. Further, India has great strengths in its use and would not depend upon external expertise or technology in tapping wind energy.

Key Words: Electric power, T & D losses, Renewable energy, Wind energy

Introduction

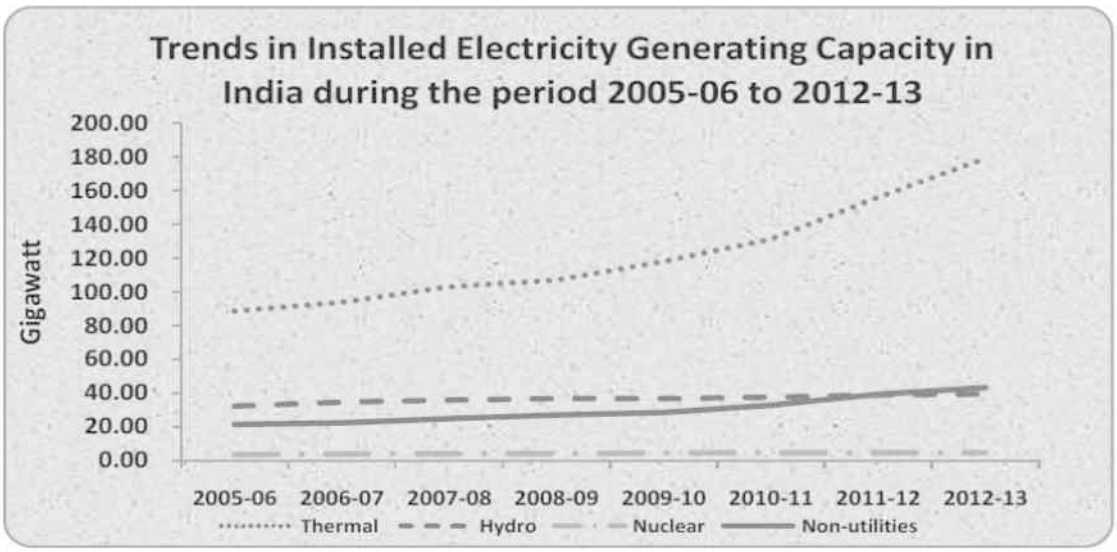
Power generation has a big impact on all societies on account of its role in different human activities. For a country like India, higher power generation causes the GDP to rise, improves our current account deficit by permitting production of exportable goods and employment potential of industry as well as agriculture. Fig. 1 below shows this linkage as regards Indian economy from 2002 to 2011 with a correlation of 0.99.



Source: "Power Sector in India", Paper by IMC – Economic Research & Training Foundation

Power generation has an immediate impact on industry and various factors that impact growth. The Indian Daily, Hindustan Times, reported on 1st of August 2015 that a mere 0.2% annual growth in power generation in June 2015 affected performance in the infrastructure sector, crude oil, natural gas, coal, steel and cement. Over the past decades, power generation in India has shown impressive growth from the time India became independent with the pace improving over time. From 2005-06 onwards the compounded annual growth rate has been 7.84% from 31st March 2006 till 31st March 2013 with actual installed capacity having jumped from 145.755 GW to 266.644 GW in this duration. The breakup of this increase is shown in the figure below with the graph clearly showing that thermal power accounts for most power generated in India (about 67%). The most rapid annual increase of 14.71% was observed for thermal power generation in the period from 2011-12 to 2012-13.

Figure 2: Break-up of installed capacity Addition by mode of power generation



Source: 21st Issue of Energy Statistics (2014), Central Statistics Office, Government of India, pp 12

Such increase in power generation requires big investments. The investment requirement of power sector, estimated by IEA in 2003, is given in the table below.

Table 1: Investment Outlook for the Electricity Sector in Billion USD

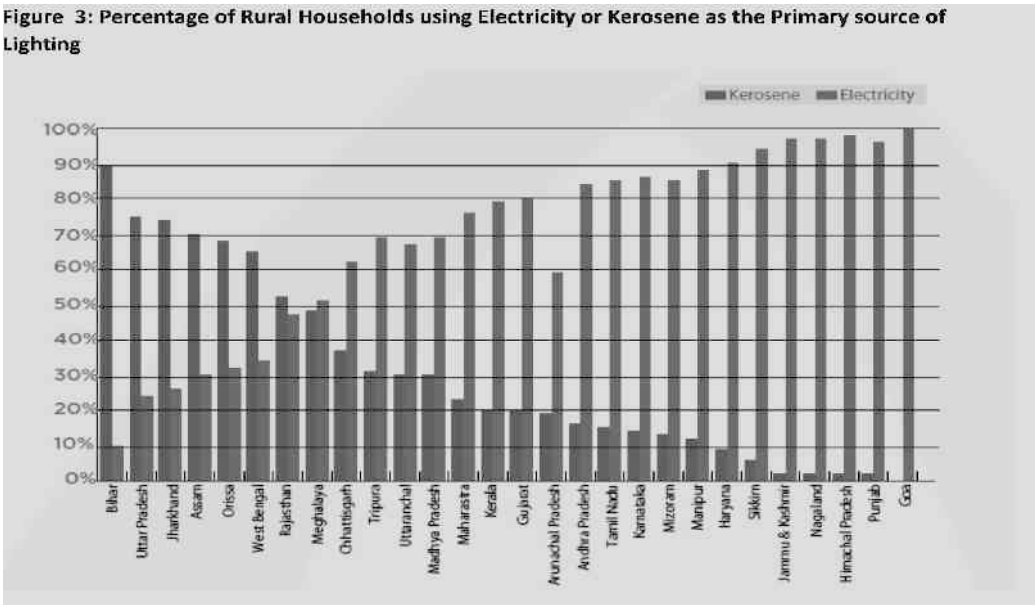
Table 1: Investment Outlook for the Electricity Sector in Billion USD

	2001–10	2011–20	2021–30	2001–30
	World			
Generation	926	1422	1731	4080
Refurbishment	145	152	142	439
Transmission	439	548	581	1568
Distribution	1052	1274	1429	3755
Total	2562	3396	3883	9842
	OECD Countries			
Generation	390	595	734	1719
Refurbishment	98	90	71	260
Transmission	188	209	172	569
Distribution	520	507	461	1488
Total	1196	1401	1438	4036
	Developing Countries			
Generation	501	704	859	2064
Refurbishment	35	46	57	138
Transmission	230	307	382	918
Distribution	452	664	871	1987
Total	1218	1721	2169	5107
	PRC			
Generation	199	285	311	795
Refurbishment	13	17	20	50
Transmission	90	119	136	345
Distribution	175	254	294	723
Total	477	675	761	1913
	India			
Generation	69	83	116	268
Refurbishment	4	5	6	15
Transmission	29	39	51	119
Distribution	44	85	134	262
Total	146	212	307	664

Source: Singh, A. (2007). Policy, Environment and Regulatory Reforms for Private and Foreign Investments in Developing Countries: A Case Study of the Indian Power Sector citing IEA (2003), World Energy Investment Outlook, International Energy Agency, Paris.

Despite the successes achieved and planned for decades to come, access to power has shown big disparities in favour of urban users. Woolbridge, Sharma and Fuente (2011) present state as well as national-level household fuel expenditure / consumption data based on the National Sample Survey 61st Round (2004-05) to find that despite India's economic growth about 36% of Indian population (more than 400 Million people) lack access to electricity while about 70% of Indian population (more than 725 Million people) continue to rely on biomass cooking fuels like firewood, cow-dung or farm waste. This disparity in energy consumption pattern shows in only about 10% of rural households in Bihar using electricity as the primary lighting source, the comparable figure being 100% in Goa. Figure 2 below gives the breakup of use of electricity and kerosene as the primary lighting fuel in different states in India. The graph shows that in 7 Indian states, over half the lighting comes through use of Kerosene. These states are Bihar, Uttar Pradesh, Jharkhand, Assam, Orissa (Odisha), West Bengal and Rajasthan.

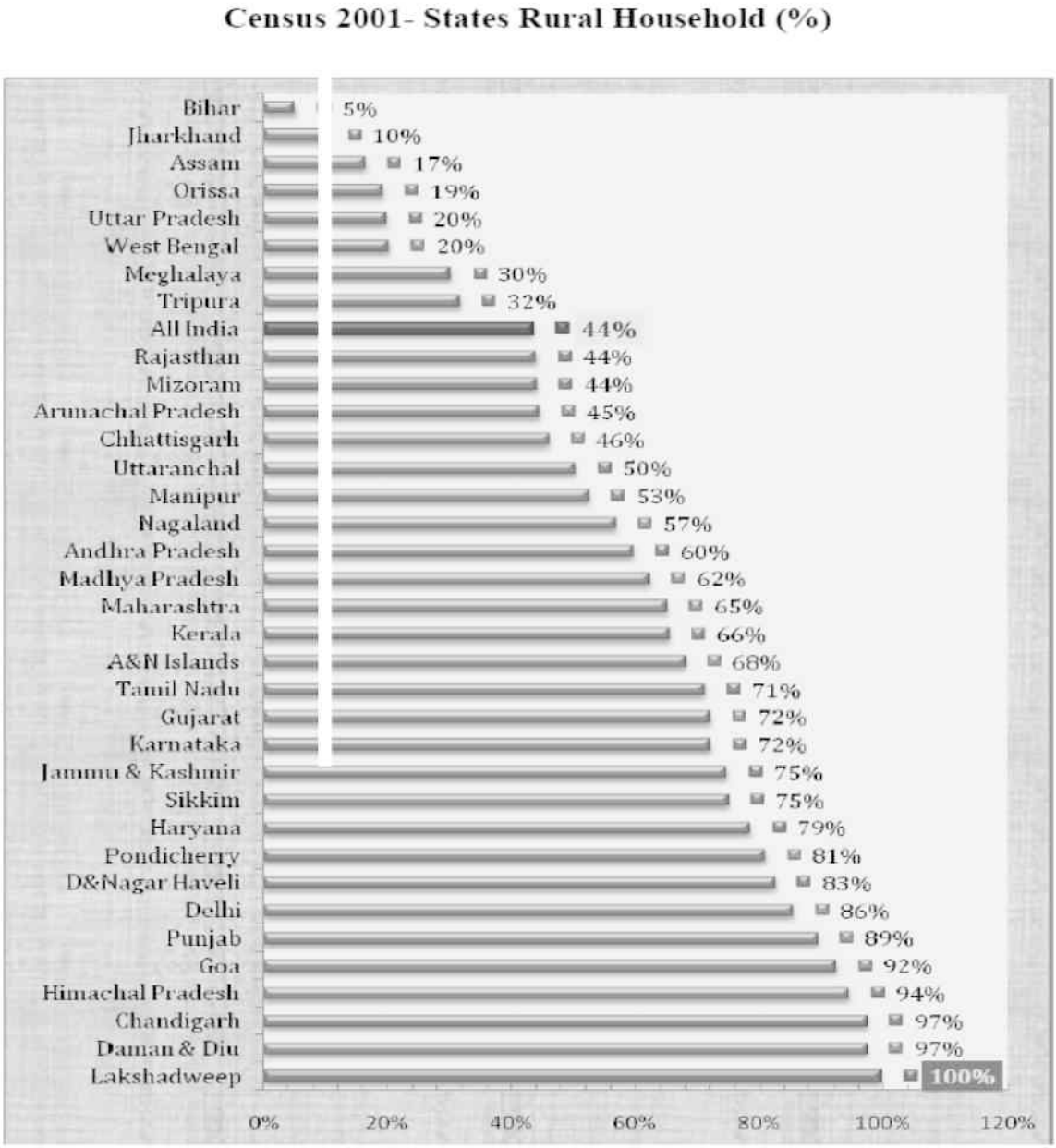
Figure 3: Percentage of Rural Households using Electricity or Kerosene as the Primary source of Lighting



Source: Woolbridge, R., Sharma, M. and Fuente, D. (2011). Atlas of household energy consumption and expenditure in India. pp 2

This scenario was worse ten years back. Figure 3 below presents the scenario on access to electricity among Indian rural households in 2001. The performance has improved in almost all states.

Figure 4: Access to Electricity in Rural India: Statewise data (2001 Census)



Source: Annual Report (2013-14) on The Working of State Power Utilities and E lectricity Department from http://planningcommission.nic.in/reports/genrep/rep_arpower0306.pdf pp 07

The improvement in electricity supply to rural households led to an all India average of 55% rural households being covered through electric power as per 2011 Census data, 11% increase from an all India average of 44% in 2001. However, the benefits did not reach the poorest of the poor. The table below that presents data on rural households having no lighting.

Table 2: Comparing data from 2001 Census & 2011 Census for 'No Lighting' in Rural Households

		2001	2001	Percent	2011	2011	Percent
1	Andaman & Nicobar Islands	49653	386	0.78%	59030	342	0.58%
2	Andhra Pradesh	12676218	35641	0.28%	14246309	67214	0.47%
3	Arunachal Pradesh	164501	17309	10.52%	195723	27321	13.96%
4	Assam	4220173	3579	0.08%	5374553	10221	0.19%
5	Bihar	12660007	3664	0.03%	16926958	10963	0.06%
6	Chandigarh	21302	51	0.24%	6785	7	0.10%
7	Chattisgarh	3359078	13638	0.41%	4384112	13653	0.31%
8	Dadra & Nagar Haveli	32783	343	1.05%	35408	208	0.59%
9	Daman & Diu	22091	81	0.37%	12750	25	0.20%
10	Delhi	169528	1043	0.62%	79115	169	0.21%
11	Goa	140755	533	0.38%	124674	775	0.62%
12	Gujarat	5885961	58224	0.99%	6765403	92293	1.36%
13	Haryana	2454463	8900	0.36%	2966053	15495	0.52%
14	Himachal Pradesh	1097520	2604	0.24%	1310538	1789	0.14%
15	Jammu & Kashmir	1161357	6821	0.59%	1497920	38330	2.56%
16	Jharkhand	3802412	1518	0.04%	4685965	2081	0.04%
17	Karnataka	6675173	22611	0.34%	7864196	40886	0.52%
18	Kerala	4942550	1562	0.03%	4095674	1712	0.04%
19	Lakshadweep	5351	0	0.00%	2523	0	0.00%
20	Madhya Pradesh	8124795	13141	0.16%	11122365	24804	0.22%
21	Maharashtra	10993623	62618	0.57%	13016652	171886	1.32%
22	Manipur	296354	3331	1.12%	335752	2286	0.68%
23	Meghalaya	329678	2499	0.76%	422197	3768	0.89%
24	Mizoram	79362	587	0.74%	104874	500	0.48%
25	Nagaland	265334	8537	3.22%	284911	4231	1.49%
26	Orissa	6782879	25388	0.37%	8144012	85903	1.05%
27	Pondicherry	72199	93	0.13%	95133	484	0.51%
28	Punjab	2775462	30208	1.09%	3315632	30524	0.92%
29	Rajasthan	7156703	38535	0.54%	9490363	91395	0.96%
30	Sikkim	91723	367	0.40%	92370	527	0.57%
31	Tamil Nadu	8274790	29144	0.35%	9563899	55712	0.58%
32	Tripura	539680	1136	0.21%	607779	2147	0.35%
33	Uttar Pradesh	20590074	19254	0.09%	25475071	36079	0.14%
34	Uttaranchal	1196157	3438	0.29%	1404845	4710	0.34%
35	West Bengal	11161870	9589	0.09%	13717186	59320	0.43%
	TOTAL	138271559	426373	0.31%	167826730	897760	0.53%

Source: **Annual Report (2013-14) on The Working of State Power Utilities and Electricity Department from** http://planningcommission.nic.in/reports/genrep/rep_arpower0306.pdf , Annexure 1.1 and Annexure 1.5

The percentage of households with no lighting increased in 22 states/Union Territories out of 35 listed during the period from 2001 to 2011. The all India percentage of rural households with no lighting increased from 0.31% to 0.53% clearly showing that the benefits of rural electrification programmes are not trickling down to the poorest. Even among the rest, an average all India increase of 11% (from 44% to 55%) over a ten year period, though noteworthy, points to a need for increasing the pace of electrification as this pace would mean 100% rural electrification requiring several decades. A study of the graphs and tables above presents the essential motive and purpose of this study: To study the power sector scenario in India and propose cost effective solution to the problem of power availability in rural India. Several studies have been carried out in power sector in India but the researcher found few that integrate different power generation approaches with the unique strengths and experiences of Indian power sector. This study aims to fill that gap and will add to the body of knowledge available to decision makers for addressing the power crunch in India.

Literature Review

Power generation in India has historically been carried out in a planned manner through the five year plans. These five year plans are further broken down to make the annual plans. The Table below gives the target and actual electricity generation in India from 2009-10 to April 2015-16.

Table 3: Target, Actual generation (BU) and growth in India from 2009-10 to 2015-16 :-

Year	Target (BU)	Achievement (BU)	% of Target	% 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
2015-16*(Upto April 2015)	91.781	86.695	94.46	-0.52

*** Provisional**

Source: Ministry of Power, Govt. of India website http://powermin.nic.in/power-sector-glance-all-india

Achievement has consistently been well above 90% from 2009-10 onwards and exceeded 100% twice during the period from 2009-10 to 20014-15. It is important to establish a linkage between targeted production and actual requirement. Subsequently, it would be useful to establish how Indian households compare with their counter parts in different parts of the world. The Table below gives the power supply position in India from 2009-10 to 2015-16.

Table 4: Power Supply Position in India from 2009-10 to 2015-16

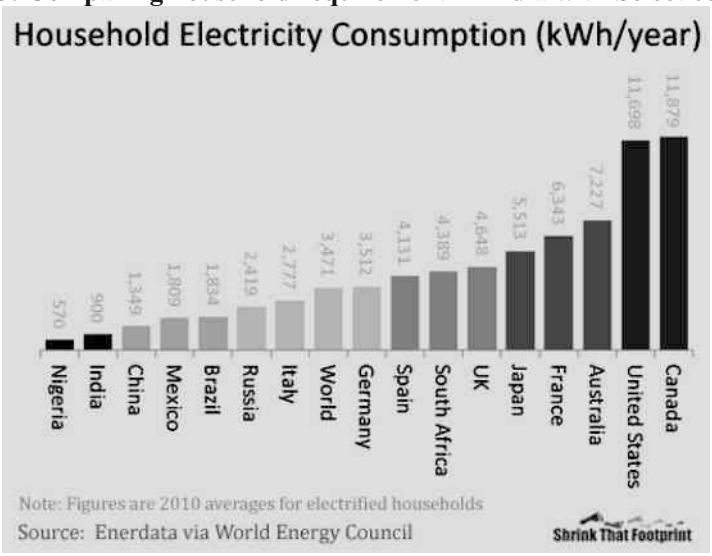
	Energy				Peak			
Year	Requirement	Availability	Surplus(+) / Deficit(-)		Peak Demand	Peak Met	Surplus(+) / Defects(-)	
	(MU)	(MU)	(MU)	(%)	(MW)	(MW)	(MW)	(%)
2009-10	8,30,594	7,46,644	-83,950	-10.1	1,19,166	1,04,009	-15,157	-12.7
2010-11	8,61,591	7,88,355	-73,236	-8.5	1,22,287	1,10,256	-12,031	-9.8
2011-12	9,37,199	8,57,886	-79,313	-8.5	1,30,006	1,16,191	-13,815	-10.6
2012-13	9,95,557	9,08,652	-86,905	-8.7	1,35,453	1,23,294	-12,159	-9.0
2013-14	10,02,257	9,59,829	-42,428	-4.2	1,35,918	1,29,815	-6,103	-4.5
2014-15	10,68,943	10,30,785	-38,138	-3.6	1,48,166	1,41,160	-7,006	-4.7
2015-16*	85,786	83,862	-1924	-2.2	1,40,212	1,36,658	-3554	-2.5

***Provisional Upto April, 2015**

Source: Ministry of Power, Govt. of India website http://powermin.nic.in/power-sector-glance-all-india

One feature that stands out from the two tables above is that the targeted generation has been below requirement suggesting inevitable deficit that is further accentuated by shortfall in achieving the target. The macro position shows improvement over the years with the deficit falling over the years. This is partly due to improved generation levels and also because the average power consumption in India remains much lower than what is observed in developed countries. The figure below gives the average household requirement in India compared to select other countries and shows that an average household in Canada consumes over 13 times as much electricity as one in India.

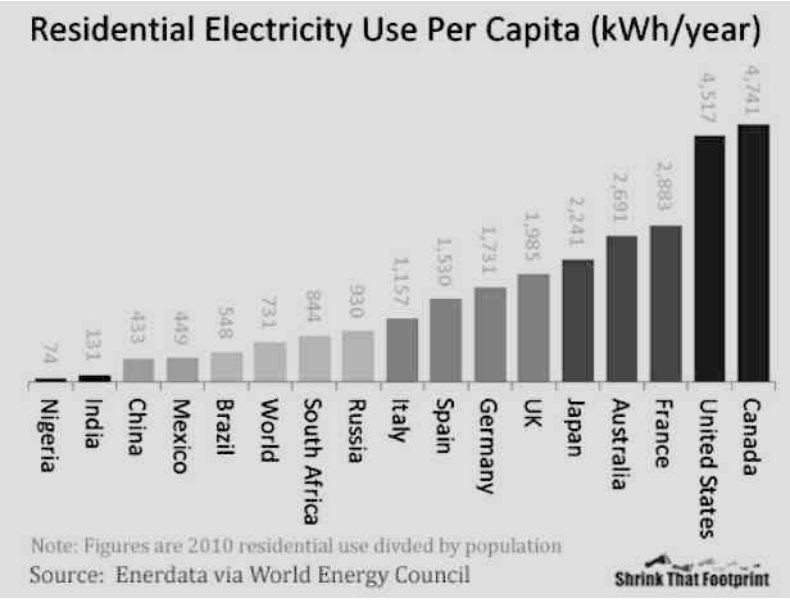
Figure 5: Comparing household requirement in India with Select countries



Source: http://shrinkthatfootprint.com/average-household-electricity-consumption

The difference is even more marked when one takes into account the fact that average Indian households include more individuals than many developed countries leading to a lower per capita consumption of electricity as shown by the figure below. Now the per capita consumption in Canada is over 36 timers what is observed in India.

Figure 6: Comparing per Capita electricity consumption in India with same Select countries



Source: http://shrinkthatfootprint.com/average-household-electricity-consumption

The improvement in electricity access in rural households occurred on account of various government initiatives. Given below is the improvement in access on account of Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) launched in 2005. The Table below gives year wise data on achievement in the 10th and 11th five year plans through implementation of RGGVY that demonstrated an improvement from 16.4% achievement in 2006-07 to an average of over 70% in the 11th Five Year Plan.

Table 5: Year wise Achievement in 10th and 11th Five year plans through implementing RGGVY

Year-wise progress during 10th Plan and 11th Plan period

10th Plan						
Year	Un-electrified Villages (No.)			BPL Households (lakh)		
	Target	Achieved	Achieved %	Target	Achieved	Achieved %
2005–06	10,000	9,819	98.2	3	0.17	5.0
2006–07	40,000	28,706	71.0	40	6.55	16.4
Total	50,000	38,525	77.1	43	6.72	15.6
11th Plan						
2007–08	10,500	9,301	88.6	40	16.21	40.0
2008–09	19,000	12,056	63.5	50	30.85	61.7
2009-10	17,500	18,374	105.0	47	47.18	100.4
2010-11	17,500	18,306	104.6	47	58.84	125.1
2011-12	14,500	7,934	54.7	52	34.45	66.2
Total	79,000	65,971	83.5	236	187.53	79.5
Cumulative (03/2012)	**112,795***	**104,496**	**92.6**	**275***	**194.25**	**70.6**

* Revised coverage including Phase II projects.

Source: **Annual Report (2013-14) on The Working of State Power Utilities and Electricity Department from** http://planningcommission.nic.in/reports/genrep/rep_arpower0306.pdf, pp 09

The table below presents state wise data as regards rural households based on 2001 census. When compared to 2011 Census data, the average percentage of rural households using kerosene for lighting fell from 56% to 43%, a decrease comparable to those using electricity for lighting purposes. This suggests a shift from kerosene or some other alternate source of lighting to electricity.

Table 6: State wise data as regards rural households (2001 census).

All India - Source of lighting (Census 2001)								
S No.	State / UT	Total	Electricity	Kerosene	Solar Energy	Other oil	Any other	No lighting
1	Andaman & Nicobar Islands	73062	56097	15860	338	201	130	436
2	Andhra Pradesh	16849857	11317766	5414683	37704	19512	10858	49334
3	Arunachal Pradesh	212615	116275	66779	481	1582	9853	17645
4	Assam	4935358	1229126	3685787	10082	2104	3461	4798
5	Bihar	13982590	1433477	12488085	40700	7648	6973	5707
6	Chandigarh	201878	195362	5678	204	61	146	427
7	Chhattisgarh	4148518	2202987	1908190	6804	3705	11004	15828
8	Dadra & Nagar Haveli	43973	37813	5686	63	5	59	347
9	Daman & Diu	34342	33573	610	6	8	31	114
10	Delhi	2554149	2371811	158476	2365	1369	13785	6343
11	Goa	279216	261273	15968	476	97	260	1142
12	Gujarat	9643989	7754307	1745351	23115	14511	24052	82653
13	Haryana	3529642	2926038	571700	6874	5921	5618	13491
14	Himachal Pradesh	1240633	1176338	56671	1423	1405	2076	2720
15	Jammu & Kashmir	1551768	1250738	229493	10309	2086	52005	7137
16	Jharkhand	4862590	1181628	3660073	10333	4961	2695	2900
17	Karnataka	10232133	8037052	2126345	21989	5187	7047	34513
18	Kerala	6595206	4632722	1918660	33291	3965	4358	2210
19	Lakshadweep	9240	9213	18	2	0	6	1
20	Madhya Pradesh	10919653	7641993	3224055	15130	8715	9638	20122
21	Maharashtra	19063149	14772090	4103826	24654	31619	40180	90780
22	Manipur	397656	238733	151219	918	184	3009	3593
23	Meghalaya	420246	179597	234716	1114	991	914	2914
24	Mizoram	160966	112079	46141	849	154	1020	723
25	Nagaland	332050	211194	105066	648	511	5485	9146
26	Orissa	7870127	2118195	5674090	27208	4680	9976	35978
27	Pondicherry	208655	183217	24663	338	44	99	294
28	Punjab	4265156	3920301	287174	5643	4667	9410	37961
29	Rajasthan	9342294	5109018	4122172	31584	19443	12720	47357
30	Sikkim	104738	81444	22610	149	55	111	369
31	Tamil Nadu	14173626	11081424	2987630	34614	5161	10523	54274
32	Tripura	662023	277015	380747	1268	248	1366	1379
33	Uttar Pradesh	25760601	8216439	17370591	93047	23745	22996	33783
34	Uttaranchal	1586321	956995	591090	29726	1049	2709	4752
35	West Bengal	15715915	5885724	9727836	49112	8830	20735	23678
	India	191,963,935	107,209,054	83,127,739	522,561	184,424	305,308	614,849
			56%	*43%*	*0.27%*	*0.10%*	*0.16%*	*0.32%*

Source: Census of India 2001

Note: India figures exclude Mao Marom, Paomata and Purul sub-divisions of Senapati district of Manipur.

Source: **Annual Report (2013-14) on The Working of State Power Utilities and Ele ctricity Department from** http://planningcommission.nic.in/reports/genrep/rep_arpower0306.pdf , Annexure 1.1

This data can be compared to the 2011 Census data to demonstrate significant and tangible improvement in electrification data in rural India.

Table 7: State wise data as regards rural households (2011 census)

Rural Households - Census 2011-Source of lighting

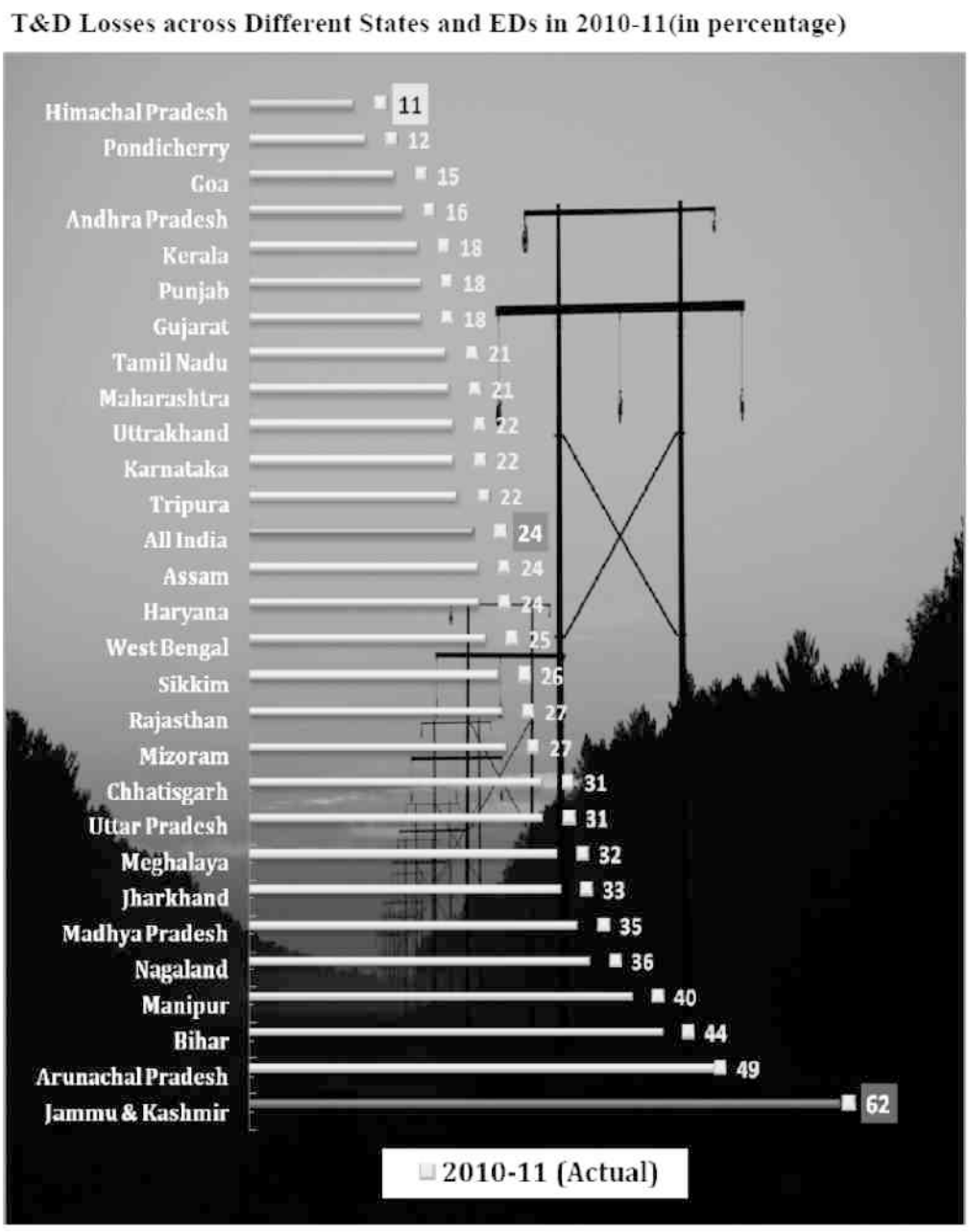
S No.	State / UT	Total	Electricity	Kerosene	Solar Energy	Other oil	Any other	No lighting
1	Andaman & Nicobar Islands	59030	46852	11393	132	243	68	342
2	Andhra Pradesh	14246309	12782453	1312644	33391	36983	13624	67214
3	Arunachal Pradesh	195723	108550	46175	7553	767	5357	27321
4	Assam	5374553	1524221	3782653	46529	7465	3464	10221
5	Bihar	16926958	1754673	14963756	104118	50421	43027	10963
6	Chandigarh	6785	6603	162	1	6	6	7
7	Chhattisgarh	4384112	3070879	1235592	48935	8554	6499	13653
8	Dadra & Nagar Haveli	35408	32452	2697	19	8	24	208
9	Daman & Diu	12750	12532	185	4	1	3	25
10	Delhi	79115	77366	1136	65	133	246	169
11	Goa	124674	119208	4287	269	80	55	775
12	Gujarat	6765403	5749271	869255	13874	20963	19747	92293
13	Haryana	2966053	2585338	335860	5632	9137	14591	15495
14	Himachal Pradesh	1310538	1265897	38895	1762	1037	1158	1789
15	Jammu & Kashmir	1497920	1208527	189124	20260	3969	37710	38330
16	Jharkhand	4685965	1514050	3113279	41723	11258	3574	2081
17	Karnataka	7864196	6819812	965641	19187	13426	5244	40886
18	Kerala	4095674	3772137	304225	10997	4156	2447	1712
19	Lakshadweep	2523	2517	5	0	0	1	0
20	Madhya Pradesh	11122365	6479144	4546696	36275	24901	10545	24804
21	Maharashtra	13016652	9605299	3107049	48506	32422	51490	171886
22	Manipur	335752	205444	108164	9031	1531	9296	2286
23	Meghalaya	422197	217739	193949	4224	1401	1116	3768
24	Mizoram	104874	72138	28159	2872	644	561	500
25	Nagaland	284911	214319	60106	1163	783	4309	4231
26	Orissa	8144012	2895252	5113827	31870	8464	8696	85903
27	Pondicherry	95133	91105	3387	22	113	22	484
28	Punjab	3315632	3166394	96149	4431	6832	11302	30524
29	Rajasthan	9490363	5528360	3729431	75583	36127	29467	91395
30	Sikkim	92370	83277	8075	293	116	82	527
31	Tamil Nadu	9563899	8683426	791493	8720	19254	5294	55712
32	Tripura	607779	361573	228953	13368	1470	268	2147
33	Uttar Pradesh	25475071	6054978	19111021	141108	72589	59296	36079
34	Uttaranchal	1404845	1166756	204149	23789	2691	2750	4710
35	West Bengal	13717186	5529496	7927731	160497	29974	10168	59320
	All India	167,826,730	92,808,038	72,435,303	916,203	407,919	361,507	897,760
			55%	*43%*	*0.55%*	*0.24%*	*0.22%*	*0.53%*

Source: Census of India 2011

Source: **Annual Report (2013-14) on The Working of State Power Utilities and Electricity Department from** http://planningcommission.nic.in/reports/genrep/rep_arpower0306.pdf , Annexure 1.5

One of the biggest losses Indian Power Sector faces is the T & D Losses. These losses have not shown a reduction despite extensive focus on T & D (increased from 22% in 1995-96 to 23.7% in 2010-11). The figure below presents these losses in 2010-11.

Figure 7: Transmission and Distribution Losses across Indian States



Source: **Annual Report (2013-14) on The Working of State Power Utilities and Electricity Department from** http://planningcommission.nic.in/reports/genrep/rep_arpower0306.pdf, Figure 3.11

Thus the challenges of Power Sector include:

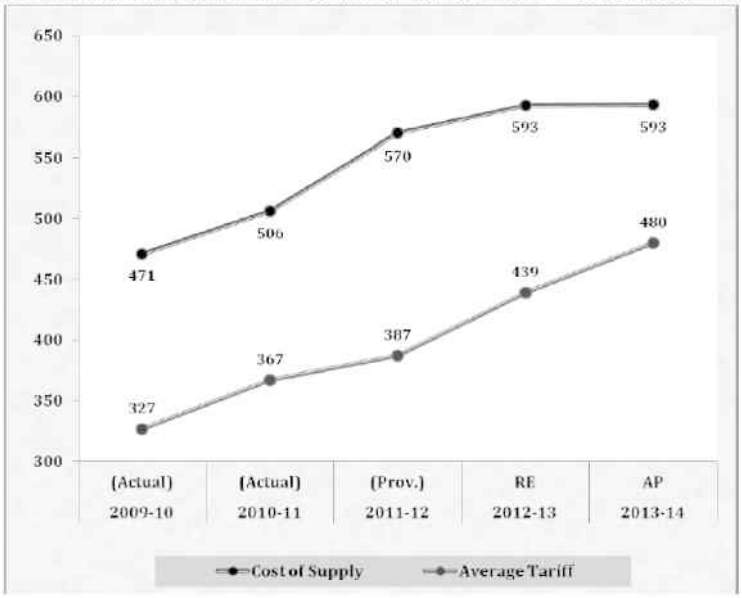
(i) Increasing capacity at a suitable price to address needs of rural and poor India;

(ii) Reducing T&D Losses; and

(iii) Improving tariff realization.

Data on tariff realization is summarized in the figure below for the period from 2009-10 to 2013-14. Again, there can be no denying of the improvement observed and also the need to continue the trend.

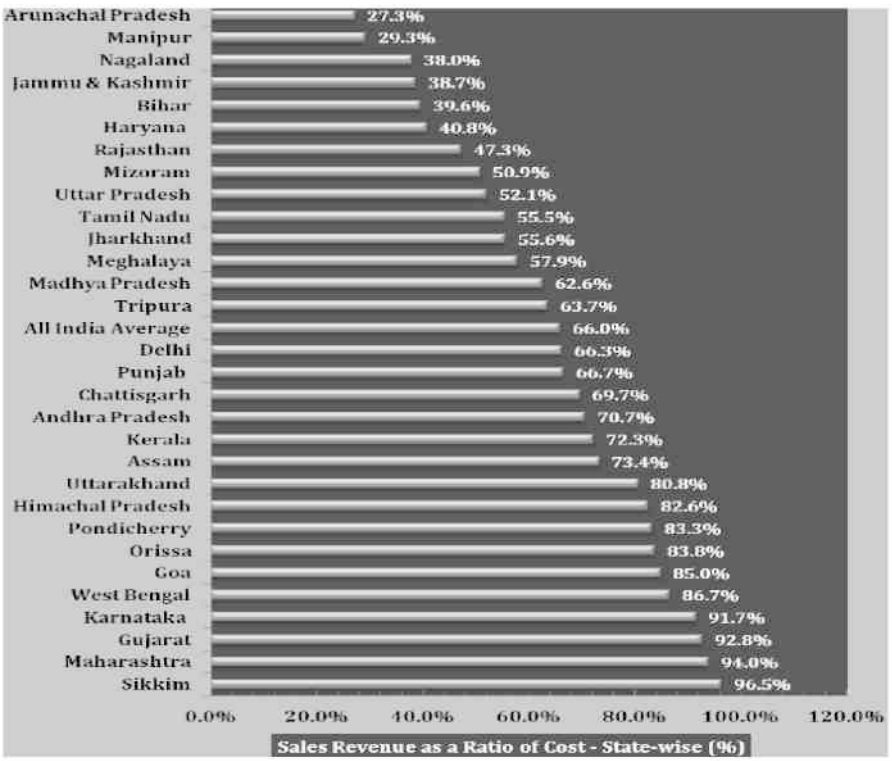
Figure 8: Cost of Power Supply and Average Tariff Realized from 2009-10 to 2013-14 (paise/KWh)



Source: Annual Report (2013-14) on The Working of State Power Utilities and Electricity Department from http://planningcommission.nic.in/reports/genrep/rep_arpower0306.pdf, Figure 4.15

The recovery of cost varies enormously from state to state as shown in the figure below. Thus recovery is over 90% in states like Karnataka, Maharashtra, Gujarat and Sikkim and less than 40% in states like Arunachal Pradesh, Manipur, Nagaland, Jammu & Kashmir and Bihar. These five state, naturally, report the highest T&D losses suggesting a need for improving and improvising appropriate collection mechanism and reducing power theft. An all India average of 66% indicates over 1/3rd of amount was not recovered in 2010-11.

Figure 9: Comparison of Recovery data across States in 2010-11



Source: Annual Report (2013-14) on The Working of State Power Utilities and Electricity Department from http://planningcommission.nic.in/reports/genrep/rep_arpower0306.pdf, Figure 4.17

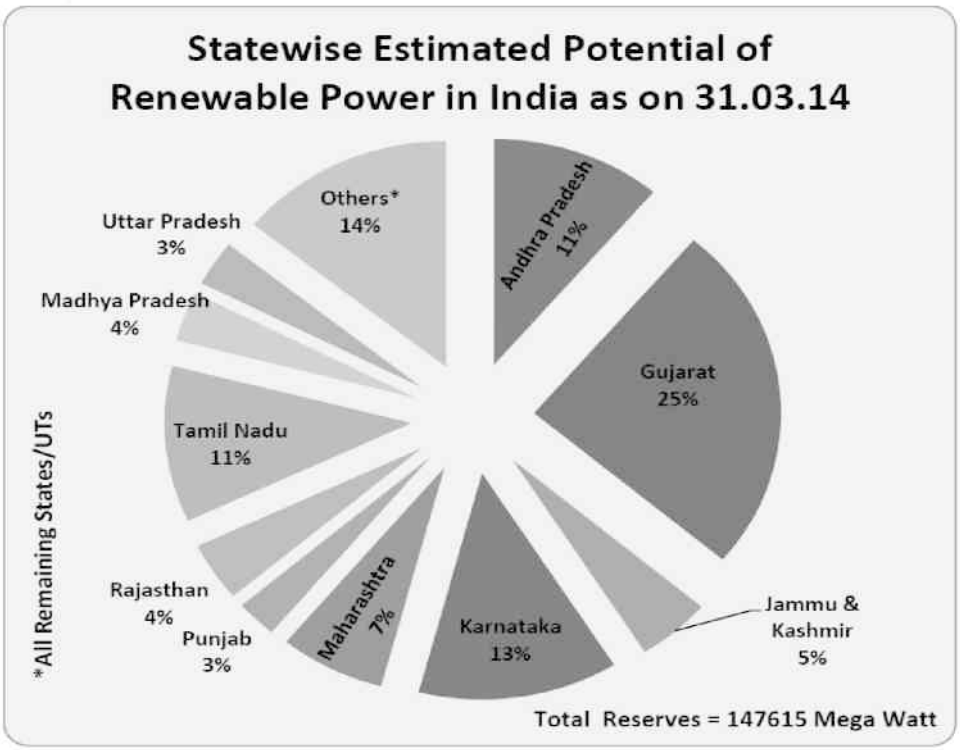
Antmann (2009) discusses Technical as well as non-technical losses (commercial, non-payment and administrative losses) in power distribution. The study cites Handbook by PA Consulting Group for USAID in November 2004 to list critical conditions of success in sustainable reduction of electricity distribution losses. These include (i) Accountability of those responsible for actions; (ii) Ownership through participation with the government and utility desiring change in status; (iii) Holistic approach with all involved institutions working towards the same goal; and (iv) Communicating social benefits of loss reduction to society at large. Implementation plans must include: (i) Focusing on consumers who account for large losses even if they themselves be big customers; (ii) Publicize cases of electricity theft; (iii) Working with reliable MIS on theft and re-engineering operations, as required, to minimize losses; (iv) Ensuring that the mighty and powerful in society are not allowed to get away with electricity theft.

From among the triad of challenges listed above, namely, (i) Increasing capacity at a suitable price to address needs of rural and poor India; (ii) Reducing T&D Losses; and (iii) Improving tariff realization, this study focuses upon the first challenge. Various known options are studied with the purpose of identifying the least cost option.

Renewable Energy to Supply Power at Low Cost

As per Ministry of New and Renewable Energy, Government of India, the nation's installed capacity of renewable energy as on 31st March 2015 was of the order of 35.78 GW with wind power contributing about 65.5% of this capacity (23.44 GW). The total potential capacity for renewable energy in India is estimated by the Technical Assistance Program of PACE-D in 2013 at 3000 GW suggesting that just about 1.2% of the potential capacity has been installed so far. This 3000 GW comprises of primarily Wind and Solar power with Biomass and Small-hydro power contributive very small fraction to the total capacity. The figure of 3000 MW, however, appears to be on the higher side if one goes by governmental statistics. As per Indian government estimates, the total potential capacity of renewable power in India was about 147.615 GW on 31st March 2014. Of this, wind power is at the top with about 70% (102.272 GW) being its potential followed by about 13% (19.749 GW) in the case of small-hydro power potential, about 12% (17.538 GW) through bio mass and a little over 3% (5 GW) through bagasse based co-generation. The state-wise break up of this potential is given in the figure below.

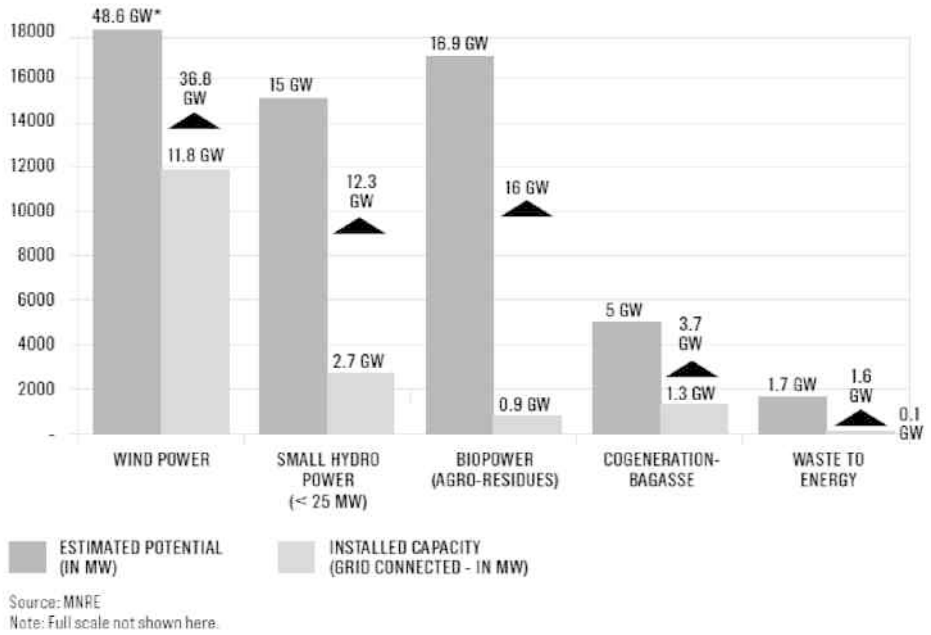
Figure 10: Renewable Power Potential Capacity of Select Indian States.



Source: 22nd Issue of Energy Statistics (2015), Central Statistics Office, Government of India, pp 05

The total estimated capacity is not consistent across estimates. Given below is another estimated for the year 2011 that differs significantly from the one above.

Figure 11: Renewable Energy Potential in India

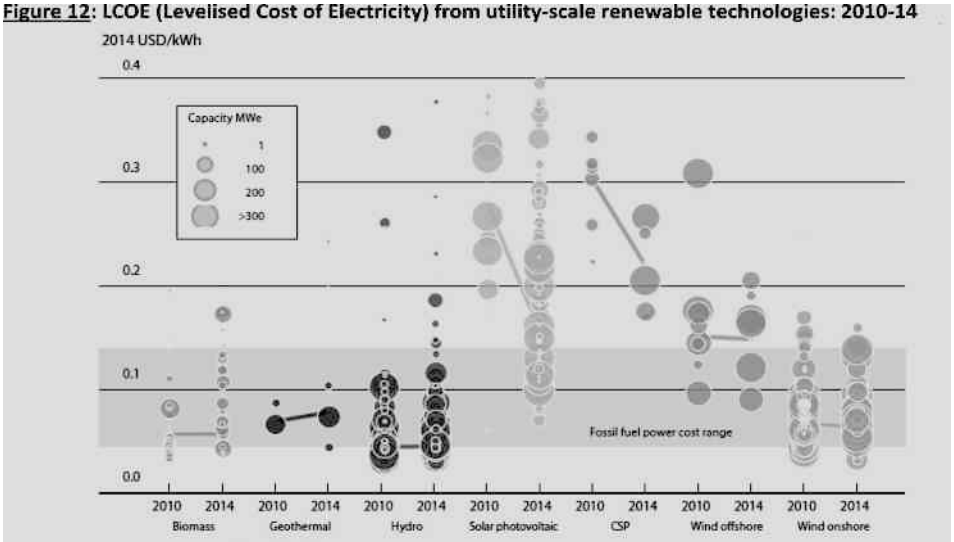


Source: MNRE
Note: Full scale not shown here.

Source: The Climate Group's (2011) 'India's Clean Revolution', pp 6 from http://www.theclimategroup.org/_assets/files/tcgindiareport.pdf

The question confronting any researcher looking at low cost energy is whether renewable energy costs are comparable or less than that from other sources and whether there is scope to increase energy efficiency in a given country (India). The Figure below presents such a comparison with respect to fossil fuel power cost range. IRENA (2015) demonstrates that the cost competitiveness of renewable power generation techniques has improved over the years with wind power, hydro-electric power, power from biomass and geothermal being capable of producing electricity at prices comparable to fossil fuels. The most impressive has been the case of solar photo voltaic cells where the levelised cost of electricity halved from 2010 to 2014 making it increasingly competitive at the utility scale too.

Figure 12: LCOE (Levelised Cost of Electricity) from utility-scale renewable technologies: 2010-14

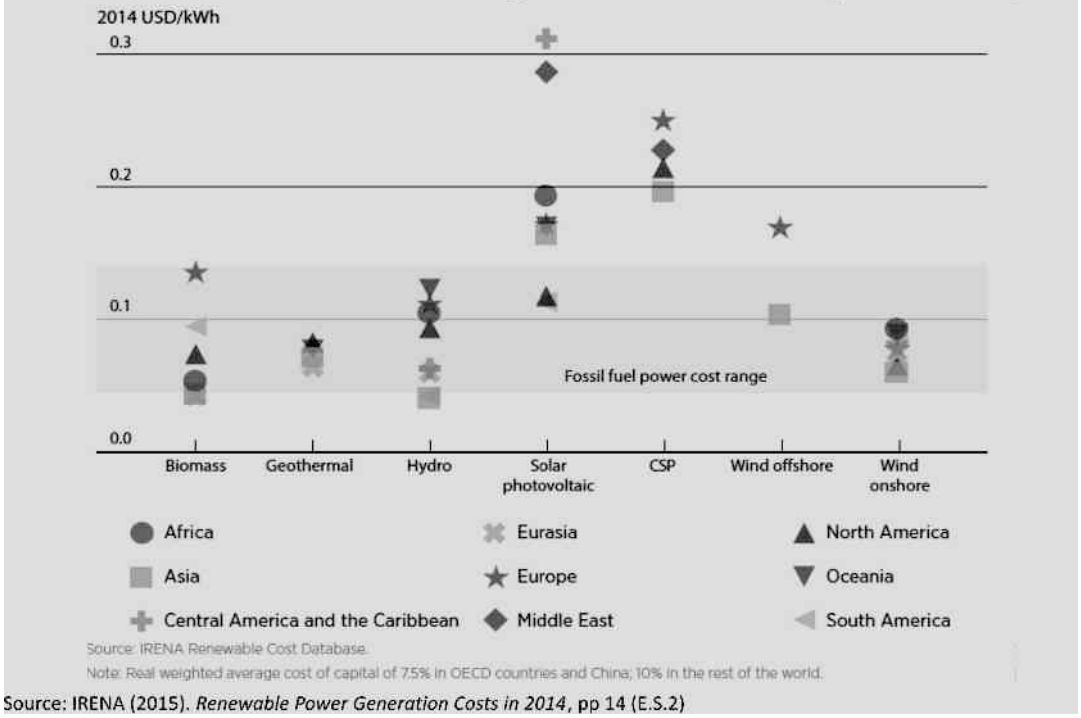


Source: IRENA Renewable Cost Database.
Note: Size of the diameter of the circle represents the size of the project. The centre of each circle is the value for the cost of each project on the Y axis. Real weighted average cost of capital is 7.5% in OECD countries and China; 10% in the rest of the world.

Source: IRENA (2015). *Renewable Power Generation Costs in 2014*, pp 12 (E.S.1)

The prevailing costs and the cost advantages are not the same all over the world. The Figure below gives this comparison in terms of weighted average cost expressed in US Dollars/kWh for utility scale fossil fuel power and renewable technologies in 2013-14 for different regions of the globe.

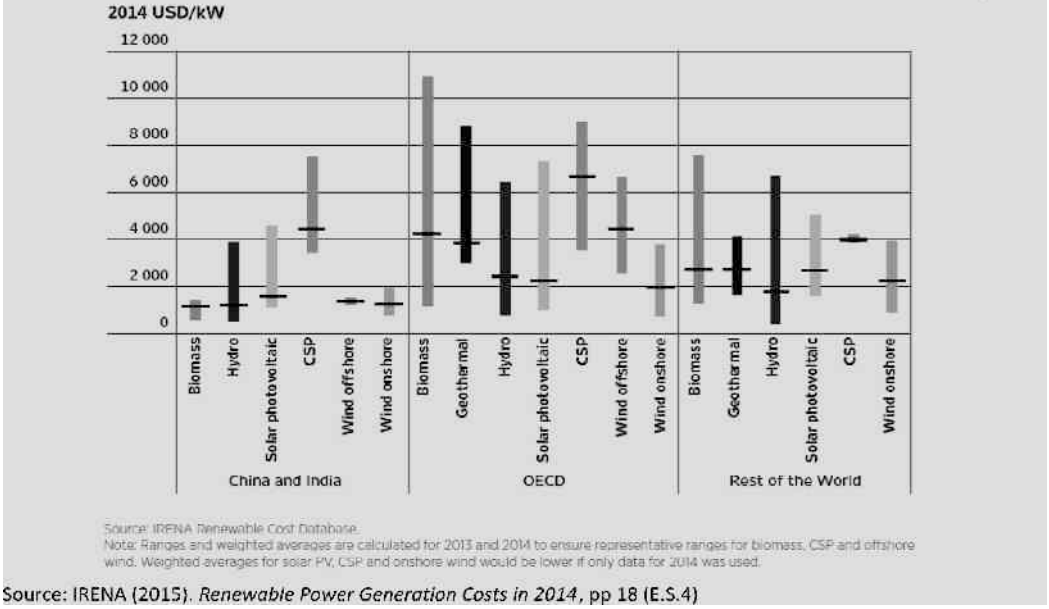
Figure 13: Weighted average cost (in US Dollars/kWh) for utility scale fossil fuel power and renewable technologies in 2013-14 for different regions



Source: IRENA (2015). *Renewable Power Generation Costs in 2014*, pp 14 (E.S.2)

India being an Asian country is likely to see lowest costs in the case of energy from Bio-mass, hydro power and wind power with the costs of power from solar photovoltaics being higher as compared to fossil fuel power costs. This is further substantiated when one examines data relating to China and India. Once again power from biomass and wind energy (on shore) are seen to be the most competitive among all renewable technologies with hydroelectric power also being equally competitive in the China and India region.

Figure 14: Range and Weighted Average Cost of Utility-scale power generation: 2013-14



Source: IRENA (2015). *Renewable Power Generation Costs in 2014*, pp 18 (E.S.4)

The data compiled suggests that Indian could consider Electricity from Biomass, Hydroelectric power and Wind energy (onshore) as equally competitive sources of low cost electricity in the near future. This is also supported by the fact that India proven experience in renewable energy.

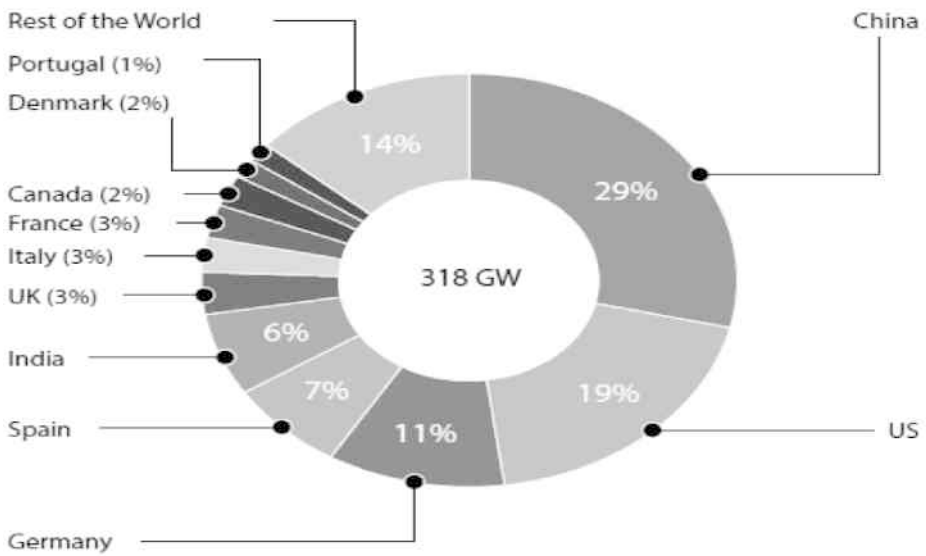
Table 8: Cumulative Installed Renewable Power Generation Capacity (Top 5 Countries) in 2013

Biomass for power		Geothermal		Hydropower		Offshore Wind	
United States of America	12.7	United States of America	3.4	China	258.5	United Kingdom	3.7
Brazil	11.5	Philippines	1.9	Brazil	86.0	Denmark	1.3
China	8.5	Indonesia	1.3	United States of America	82.8	Germany	0.9
Germany	8.2	New Zealand	0.9	Canada	75.5	Belgium	0.6
India	4.7	Mexico	0.8	Russian Federation	49.0	China	0.4
Onshore Wind		**Solar Photovoltaic**		**Solar CSP**		**Tide, Wave & Ocean**	
China	91.0	Germany	36.3	Spain	2.3	Republic of Korea	0.3
United States of America	60.2	China	18.6	United States of America	0.9	France	0.2
Germany	33.8	Italy	17.9	United Arab Emirates	0.1	Canada	0.0
Spain	23.0	Japan	13.6	India	0.1	United Kingdom	0.0
India	20.2	United States of America	12.1	Algeria	0.0	China	0.0

Source: IRENA (2015). *Renewable Power Generation Costs in 2014*, pp 49 (Table 3.1)

With China making big investments in renewable energy, India can consider the proposition of investing in low cost options of renewable energy as an option for addressing the needs of the poor in India. As far as wind power is concerned, China is the world leader while India is at the 5th place in terms of cumul;ative installed capacity as shown in the figure below.

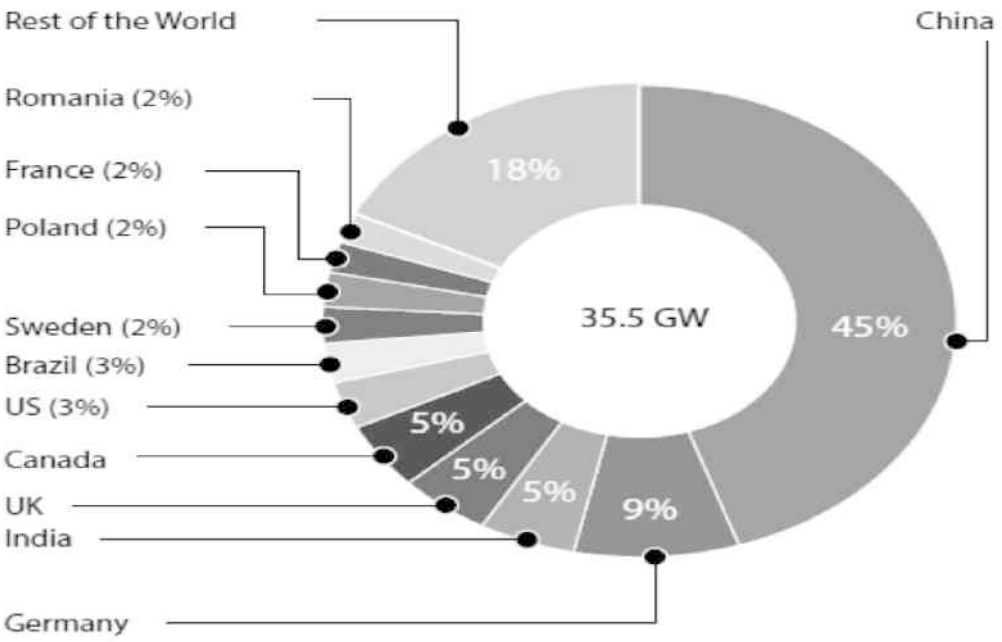
Figure 15: Country-wise comparison of Cumulative Installed Capacity (2013)



Source: IRENA (2015). *Renewable Power Generation Costs in 2014*, pp 56 (Table 4.1)

China remains at the top even in terms of net capacity addition to wind power in 2013 as shown below:

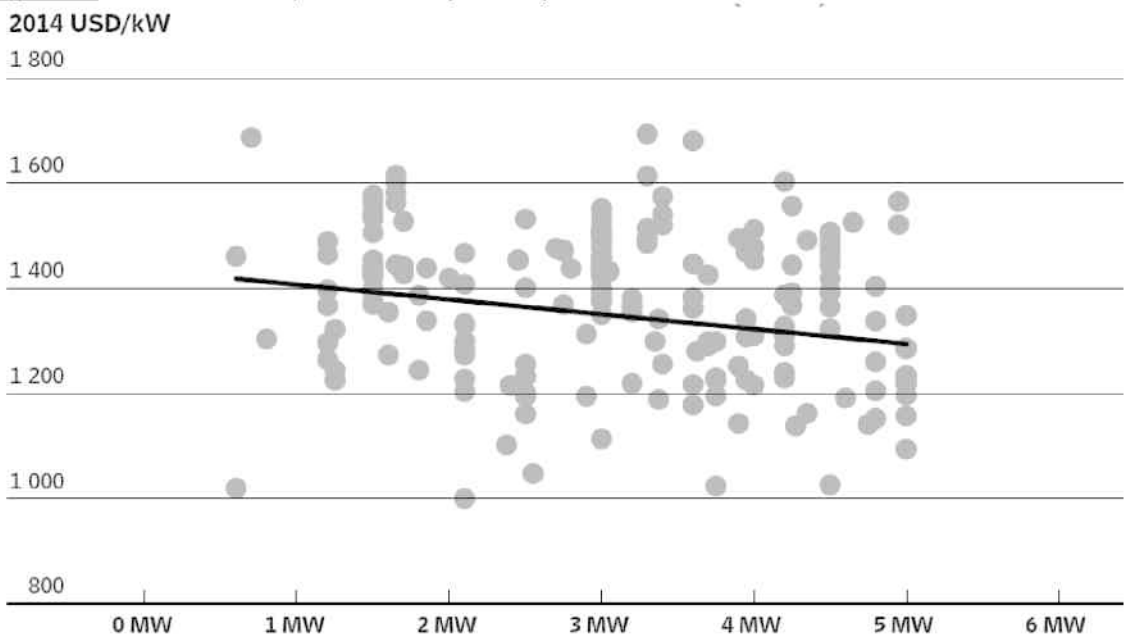
Figure 16: Country-wise comparison of addition to Installed Capacity (2013)



Source: IRENA (2015). *Renewable Power Generation Costs in 2014*, pp 56 (Table 4.1)

IRENA (2015) cites Blanco (2009), Estimates on Climate and Renewables (2013) and UNFCC, CDM database to show that the biggest cost for on shore wind power, turbine cost, can be 64-74% of installation costs. Further, wind power does provide a very wide range in terms of installed capacity with the cost going down as the installed capacity increases. Given below is the variation in installation costs observed in India for wind farms producing less than 5 MW power.

Figure 17: Installation Cost/kW of Small (< 5 MW) Wind Farms in India: 2000-2013



Source: IRENA (2015). *Renewable Power Generation Costs in 2014*, pp 62 (Table 4.5)

Besides the cost benefits India enjoys in better utilizing wind power, Indian industry also needs to improved power efficiency as should by the Figure below:

Figure 18: Country wise Comparison of Specific Energy Consumption of select industries (KWH/Ton)

COUNTY	STEEL	CEMENT	PULP & PAPER	FERTILIZER
INDIA	9.5	2.0	11.1	12.2
UK	6.1	1.3	7.6	11.2
US	6.1	0.9	9.7	11.3
JAPAN	4.2	1.2	-	-
SWEDEN	5.0	1.4	7.6	-

Source: The Climate Group's (2011) 'India's Clean Revolution', pp 18 from http://www.theclimategroup.org/_assets/files/tcgindiareport.pdf

In all the four industries, Indian's performance is below that of the other countries listed. Quite clearly, this is another area Indian industry needs to focus on if power scenario in the country has to improve.

Conclusions and Proposed Solution

Despite great strides made by the Indian power sector, the following emerge as areas for improvement:

1. Per capita power consumption in India is far below that of developed countries. However the costs involved in raising per capita power consumption in India are very high;
2. Improved power generation doesn't appear to have benefitted the poorest of the poor Indians;
3. Transmission and Distribution (T&D) losses remain very high in several Indian states;
4. States with high T & D losses report poor cost recovery suggesting occurrence of power thefts;
5. The need is for low cost energy where India has a clear advantage of technology and experience;
6. India has great strengths in the area of wind energy, bio-mass energy, hydro-electric power as well as solar power with wind energy emerging as one of the best options because of high potential, acceptable costs and learning from experience in India. These strengths need to be nurtured so that wind energy can be tapped for uplifting the poorest of the poor in rural India. However, wind power is not a panacea for all situations. Ryan (2009) presents several disadvantages of wind power that include:

a. Lack of consistency in power generated by wind turbines as they are driven by wind that does not provide the same force at all times leading to situations where ;

b. While there is much flexibility in use of wind energy with the range stretching from small homes to large communities, large wind farms are needed for supplying power to the large communities. For eg. Considering that large wind turbines can supply power to 475 homes when running at full capacity, over 2000 such turbines would be required for a town of 0.1 Million homes.

Limitations of the Study and Areas for Further Research

The following emerge as limitations of this study and areas for further research:

1. There is a need for data comparing trends from different renewable energy sources over the years so as to benefit from faster reducing costs among the different renewable energy sources;
2. There is a need for a detailed analysis of wind power costs at different levels of performance since wind velocity determines the effectiveness of wind turbines.

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