Innovative Thought Forum

Ensuring India's Energy Security

Proceedings of a Seminar

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1st Floor, A-7, Safal Profitaire, Corporate Road, Near Prahladnagar Garden, Ahmedabad – 380 015.

Innovative Thought Forum

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PREFACE

Innovative Thought Forum (ITF) has been established by a group of likeminded individuals to deliberate on India Centric Problems in a free and objective manner and exchange ideas that lead to implementable solutions. We have already had brainstorming sessions on subjects like Land and Water, Indian Agriculture and Allied Sectors, Food Security, Nutritional Security and Food Processing. In our opinion, all these topics are interrelated and important to nation's economic growth and well being of our citizens.

Today's subject is Energy, a resource that is required for sustenance, maintenance and growth of all forms of activities. In the report on Integrated Energy Policy prepared in the year 2006, energy security has been defined as the life line that needs to be provided to all irrespective of the cost and irrespective of the capacity to pay or not. An additional requirement stipulated is that energy supply should be provided in an environment friendly manner. When it comes to hierarchy of requirements, energy for cooking finds itself as the top most priority. Environment friendly energy resources therefore need to be found for cooking.

For economic activities, various forms of energy are required for manufacturing, transport, agriculture, commercial and domestic needs. Most of these activities are dependent right now on availability of fossil fuels. China has driven the world energy market expansion in the recent years. However, the International Energy Agency (IEA) and World Economic Outlook (WEO) 2015 project that India will be recording fastest growth in energy demand upto the year 2040 as China effects structural changes in its economy from growth in manufacturing to growth in services. Fossil energy demand therefore in India is expected to grow three times by 2040 from the present levels even after factoring energy efficiency gains. Coal consumption may reach 1,300 million tonnes and oil requirement to 9.8 mb/d (3.2 mb/d presently). We are dependent on crude oil import for most of our demand and have also become a substantial importer of coal due to poor quality of coal reserves. With India's commitment to environment and climate change, it is imperative that we increase use of renewable energy resources manifold and consider them as high priority in our energy policy.

Today, we will have the benefit of views of people who are involved with different aspects of energy for the last 3-4 decades. It is important that our energy policy integrates demand side management with supply side management. Implementation of energy conservation and energy efficiency measures in different sectors of economy are neither consistent nor constant but very patchy. For example, Energy Conservation Building Code (ECBC) that was introduced in the year 2007 on voluntary basis is yet to see any traction largely due to poor implementation and inclination at the ground level.

Mere growth in economy is no more sustainable now. Economics and ecology need to go together where every step towards economic growth is harmonized with ecology. In a lecture by Prof. Vijay Modi of Columbia University at the Pandit Deendayal Petroleum University, Gandhinagar, it was revealed that in an economy of skewed production and skewed energy supply, poor people are compelled to pay enormous cost for energy. People that use batteries are required to pay as much as Rs.500/- per kWh though the quantum of energy used is very small. It is time that decentralized generation and distribution of power is combined with centralized power production and distribution. We have had a policy for distributed and decentralized power but challenges in its acceptance are yet to be overcome to showcase successful models.

The term "circular economy" is slowly becoming a buzzword. This refers to the conversion of waste of any activity into useful products by deployment of suitable process, technology or means and to use it as resource wherever possible. Fly ash considered to be a major waste in thermal plants is now used for making bricks and other value added products in Building & Construction sector. Similarly, conversion of methanogenic waste into biogas and organic fertilizer is becoming a profitable reality changing the current paradigm. Through our deliberations we need to come out with pilotable projects that can be quickly implemented. We thank all the speakers and participants for their presence today in the discussions.

S.B. Dangayach **N.K. Bansal**

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Chapter 1: India's Energy Challenges and Solutions

N.K Bansal

1. Introduction:

India is home to 18% of world's population and uses 6% of world's primary energy. However, since the year 2000, the energy consumption in the country has almost doubled and the trends are that this will continue. India's economy, which is already the world's third largest in terms of PPP, is growing rapidly and policies are in place for country's modernization and an expansion of its manufacturing. Coal is the most important fuel in India's energy mix and its demand may reach 1300 mtce by the year 2040, oil demand may reach 10 mb/d and the natural gas demand may also triple to 175 bcm per year. In the energy market, India has occupied the centre stage with most developed counties have decreasing energy consumptions and China is already entering a regime of low energy economy with more concentration on the service sector (IEA 2015).

India's pledge at the recent Paris climate convention underlines country's commitment to low carbon economy with solar, wind and nuclear at the central stage. Also Indian population is at a transition stage and an additional 315 million people (equivalent to the population of USA) may start living in urban areas in the next 20 years. This transition has a wide range effect on energy use accelerating the switch to modern fuels, rise in the number of appliances and vehicle ownership driving domestic energy use away from solid biomass to oil and electricity. This population shift also requires major overhaul of infrastructural requirements, which should be able to cope with increasing number of vehicles and power demand. India's power system needs to quadruple in size by 2040 to meet growing electricity demand boosted by increasing incomes. "Make in India" approach of the country needs energy to work and requires efficiency to prosper.

In this presentation, we present India's energy availability and demand and bring out the future primary and secondary energy demand along with the challenges faced by the country in limiting greenhouse gas emissions and honouring its commitment towards climate change. The challenges, faced by the country for implementable solutions to meet increasing energy demand and at the same time tackle environmental concerns, are also discussed.

2. Energy Security and Energy Sources

With changing economic scenario, the definition of energy security has changed from providing life line energy irrespective of the cost to "Ensuring uninterrupted energy supply required to support economic and commercial activities necessary for sustained economic growth". This definition of energy security demands identification of various energy sources, their availability and the capability to provide the Indian population with adequate form of energy. The proverb that "Sun is the ultimate sources of Energy", is really true because this incessant flow of radiant energy to the earth's surface is ultimately responsible for nearly all primary energy sources (Fig.1) along with gravitational and geothermal energy sources. This radiant energy is also responsible for maintaining the earth's atmosphere at an average temperature of 14oc.

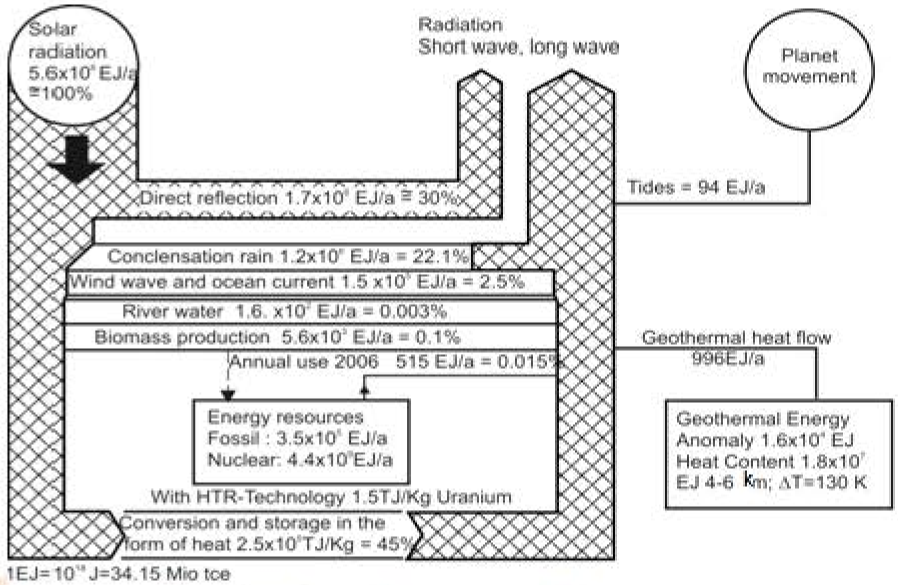


Fig.1: Energy flows into and from earth (Bansal 2014)

All energy sources that are found inside the earth's surface (fossil fuels) or received on the earth's surface are termed as Primary Energy Sources, which through appropriate energy conversion processes are converted into heat, or electricity or steam, known as secondary energy sources (Fig.2).

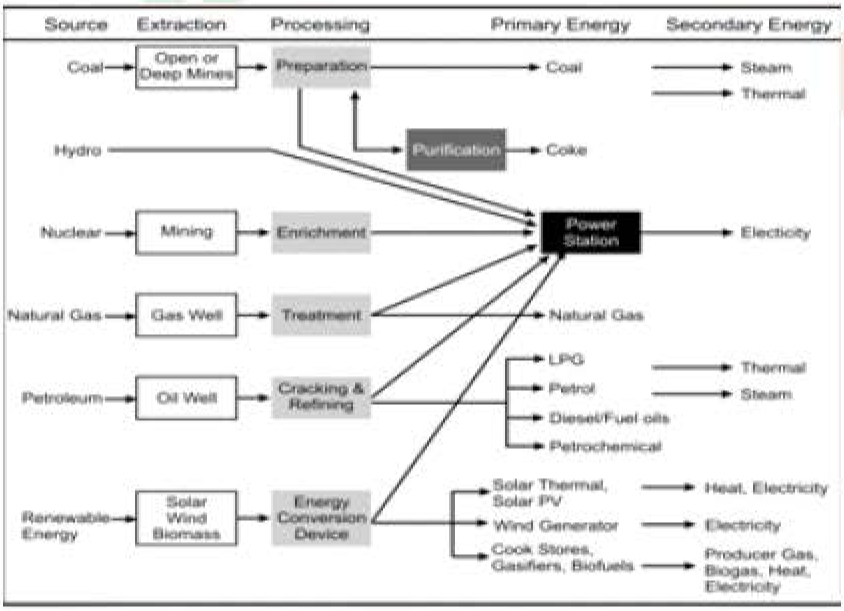


Fig.2: Primary and secondary energy sources (Bansal 2014)

3. Worlds Primary Energy Consumption

A comparison of world's primary energy consumption in the year 1973 (year of world's energy crisis) and in the year 2008 is given in Fig.3. It may be observed that the percentage of crude oil consumption in the world has decreased irrespective of increase in the number of vehicles whereas, the percentage of gas has increased; the trends continued till the year 2013 (Fig. 4); increase in energy consumption, from 2008 to 2013 in the world, has been due to China's increasing energy production, imports and consumption. In all other countries, the energy consumptions have decreasing trends. Even in India, energy consumption has increased only marginally during this period (Table-1.).

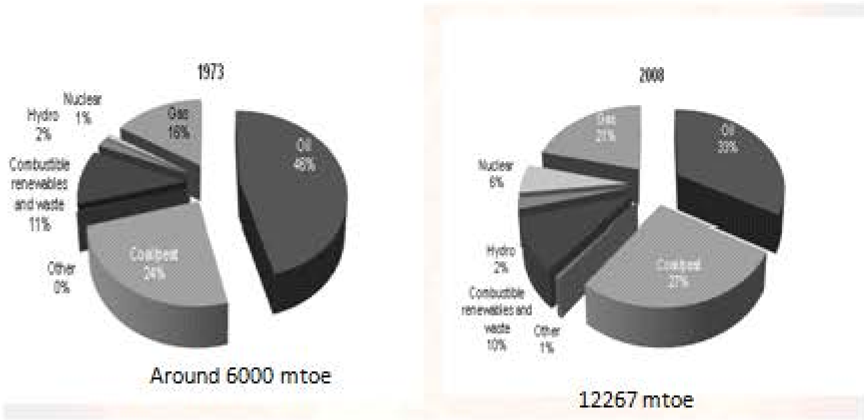


Fig.3: World's primary energy consumption in the year 1973 and 2008

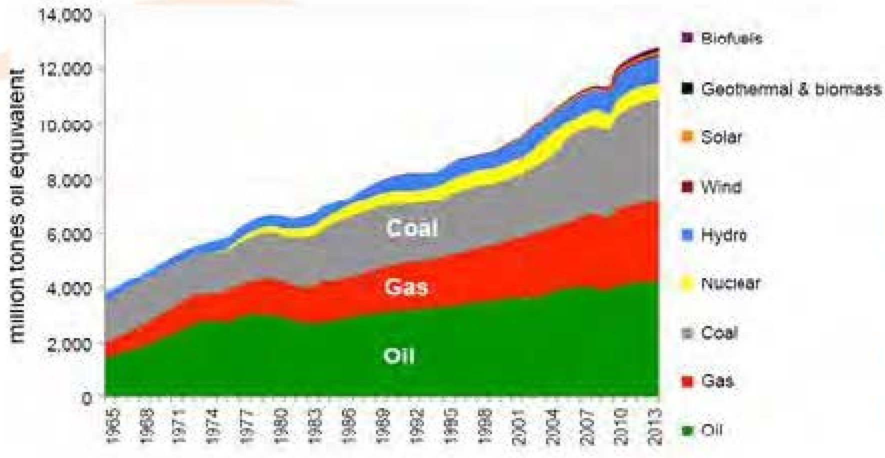


Fig.4: Trends in global primary energy consumption 1965-2013

Country	In Million tonnes oil equivalent Oil	Natural Gas	Coal	Nuclear Energy	Hydro electric	Renewable and waste	Total
USA	884	594	615.7	83.8	28.2	77.3	2283
Canada	157	83	31	9.4	68.6	N.A.	442.4
France	83	45	12.4	43.9	14.8	67.4	266.5
Russian Federation	494	438	153	16.3	35.6	N.A.	1136.9
United Kingdom	76.8	71.2	39.1	20.1	1.3	N.A.	208.5
China*	430	95.1	2500	12.3	55.5	103.1	3206
India*	205.5	47.1	352	4.1	11.4	98.4	718.5
Japan	199	93	71.6	25.8	8.3	98.1	495.8
Others	1807.3	1276.6	114.5	501.4	70.0	524.1	4293.9
TOTAL	4337.6	2746	3889.3	717.1	296.7	968.4	12995.1

4. India's energy availability and consumption

Source wise availability of primary energy in India has been given in Table2., where electricity generated by hydro and nuclear has been clubbed with the renewable energy the last column shows the primary energy consumption in PJ and figures in the brackets show energy losses in percentage occurred in the transport or transmission. It is observed that the primary energy availability in the country has increased almost linearly at a rate of about 4.5% from 2006 to 2014. Source wise consumption of energy is given in Table-3, which shows that electricity consumption has grown at a cumulative growth rate of 9.95%, oil at 6.14%, while coal has increased only about 4% and the percentage contribution of natural gas has been declining because of limited availability of the same.

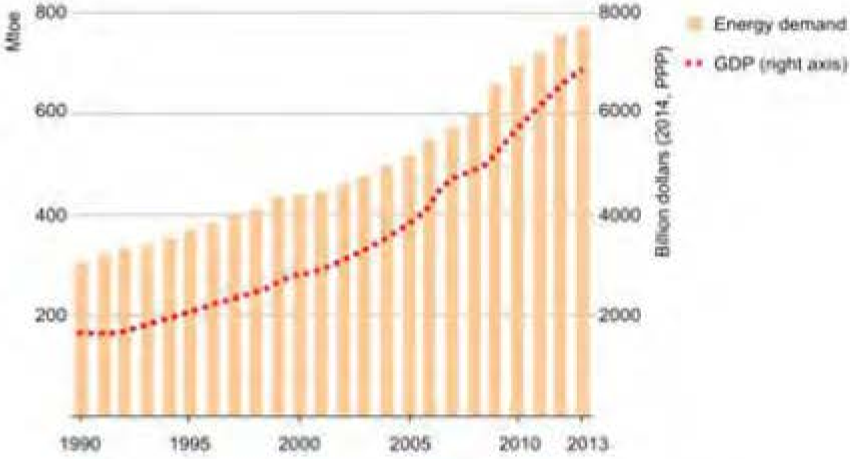
Table2: Primary energy availability in India

Energy source	2006	2007	2008	2009	2010	2011	2012	2013	2014	PE consumption (PJ)
Coal + lignite (MT)	463.5 (7416 PJ)	493.2(7891 PJ)	537.5 (8600)	581.4 (9302)	620 (9920)	628 (10048)	681 (10896)	756 (12096)	784 (12544)	9939 (20%)
Oil(MT)	130.11 (5464 PJ)	147(6174 PJ)	156(6552)	161(6762)	173(7266)	197(8274)	204 (8568)	219 (9198)	223 (9366)	9316 (5.3%)
N.G.(BCM)	31.33(1206 PJ)	30.8 (1186 PJ)	31.5 (1213)	31.8(1225)	46.52(1792)	51.3(1975)	46.5(1790)	39.8 (1532)	34.6 (1332)	1332(0%)
Electricity(hydro+ nuc.+ RE) bkWh	178 (640 PJ)	186.2(670 PJ)	207(745)	214(770)	243(875)	243(875)	243(876)	273 (982)	326(1173)	1045(11%)
Total(PJ)	14726	15921	17110	18059	19853	21172	22130	23808	24415	21464(12 %)

Table 3: Trends in Indian source wise energy consumption

Year	Coal #	Lnite	Crude Oil**	Natural Gas ***	Electricity* (GWh)
	(Million Tons)		(MMT)	(Billion Cubic Metres)	
1	2	3	4	5	6
2005-06	407.04	30.23	130.11	31.33	411,887
2006-07	430.83	31.29	146.55	30.79	455,748
2007-08	457.08	33.98	156.10	31.48	510,899
2008-09	492.76	32.42	160.77	31.75	562,888
2009-10	532.04	34.07	192.77	46.52	620,251
2010-11	532.69	37.73	196.99	51.25	684,324
2011-12	535.88	41.88	204.12	46.48	755,847
2012-13	567.60	46.31	219.21	39.78	912,057
2013-14(p)	571.89	43.90	222.50	34.64	967,150
Growth rate of 2013-14 over 2012-13(%)	**0.76**	**-5.22**	**1.50**	**-12.93**	**6.04**
CAGR 2005-06 to 2013-14(%)	**3.85**	**4.23**	**6.14**	**1.12**	**9.95**

Fig.5 shows the trends of Indian GDP growth and energy demand. From 2005 to 2014, the GDP growth rate is higher than the energy demand showing the energy intensity use has decreased and it is likely to register further fall to a value of less than 0.3 MJ/Rupee of GDP. Diversity of Indian demography and economic parameters still put per capita energy consumption in India, well below world's average, lower than even Africa and with in India itself, various states have wide range of per capita energy consumption. For example per capita electricity consumption in Delhi is much higher than other states where as it is lowest in Bihar. Overall per capita primary energy consumption in India has however remained stagnant in the last five years (2009-2014).

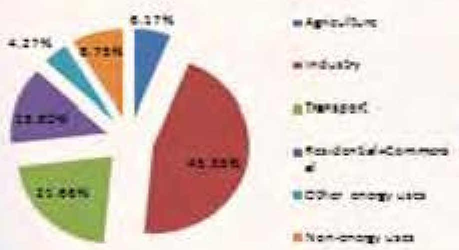


Note: Mtoe= million tonnes of oil equivalent.

Fig.5: Indian GDP and energy demand patterns

4.1 Sector wise Primary Energy Consumption

Sector wise primary energy consumption in various sectors of Indian economy is given in Fig. 6. Industry is the biggest user of energy, whereas agriculture uses only 5.1% of total primary energy. Non energy uses like use of fossil fuels to make fertilizer, naphtha, lubricants, bitumen, plastic products etc also use 7.3% of the primary energy.



Industry	9860 PJ	9860PJ(37.7 %)
Agriculture	1341 PJ	1341PJ (5.1%)
Transport	4709 PJ	4709 PJ (18%)
Residential + Comm	2998 PJ	8750PJ (33.4%)
Other energy uses	928 PJ	928 PJ (3.5%)
Non-energy uses	1902 PJ	1902PJ ((7.3%)

Fig.6: Energy consumption in main sectors of Indian economy

Agriculture sector provides livelihood and employment to about 54% of India's population and constitutes around 14% to the GDP, making it a vital element for inclusive and sustainable growth of the India economy. 265 MT of food grains were produced in the country in the year 2013-14. Fertilizer industry is one of the major consumers of primary energy, which contributes almost 60-70% of the total fertilizer manufacturing costs. Though the total urea consumption in agriculture increased from 59% to 66%, its use per ha has fortunately declined over the same period of 2010 to 2012. Indian agriculture uses 18956350 pump sets and 590672 tractors responsible for 13% of total diesel consumption in the country.

Main energy consuming industries in India are steel, aluminium, textile, paper, cement, glass and fertilizer. The industry has adopted several energy conserving measures and some of the industries like the cement are one the best in the world in terms of energy and material utilization efficiency.

Roads handle 64.5% of freight and 86% of passenger traffic. Since the year 2005, the number of registered vehicles has increased from 81.5 million to 160 million. Port and shipping handles 100 MT and 10.5 GT of freight annually respectively. Crude oil consumption is presently 3.8 mb/d, 40% of which is used in the private sector. 70% of diesel and 99.6% of petrol is consumed by the road sector; 13.5% diesel consumed by private cars and UVs, 8.94% by commercial cars and UVs, 6.39% by three wheelers, 28.25% by trucks, 9.55% by buses and 3.24% by the railways. Petrol consumption in two wheelers is 61.42%, cars 34.33% and three wheelers about 2.34%.

In the domestic sector, 300 million people have no access to electricity and 800 million people still use biomass; 24%, of rural households and 6.1%urban households depend upon biomass; 22.3% of households use kerosene for lighting, its use however is declining fast. Tables 4 and 5, give the household distribution for rural and urban areas for lighting and cooking respectively for 2001 and 2011 census. 84% rural households still use biomass for cooking.

Table 4: Percentage of households using various energy sources for lighting

Energy source	2001 census		2011 census	
	Rural	Urban	Rural	Urban
Electricity	43.6	87.6	55.3	92.7
Kerosene	55.6	11.6	43.2	6.5
Solar energy	0.3	0.2	0.5	0.2
Any other	0.3	0.2	0.5	0.3
No lighting	0.3	0.4	0.5	0.3

Table5: Percentage of households using different energy sources for cooking

Energy source	2001 census		2011 census	
	Rural	Urban	Rural	Urban
Firewood	64.1	22.7	62.5	20.1
Crop residue, dung etc	26.9	8.7	24.0	6.1
Kerosene	1.6	19.2	0.7	7.5
LPG/PNG	5.7	48	11.4	65
Any other	1.4	0.9	1.1	0.8

5.0 Projected Energy Demand; Implications of New Policy.

Integrated Energy Policy of the Government of India in the year 2006, based on providing life line energy to all irrespective of their capacity to pay, and had projected the commercial energy demand to grow to 1334 MTOE from 510 MTOE presently. At that time, the cost of solar electricity was too high to be economically adaptable for centralized use. With the new government "Make in India" approach and greater commitments towards climate change, the policy assumptions have changed considerable such as:

- Priority to energy related missions such as energy efficiency, solar and wind.
- Continued levy on coal to support National Clean Energy Fund.
- Measures to increase fossil fuel supply.
- Greater encouragement for private investments in energy supply.
- Expedite environment clearances.
- Super-critical technology in new coal power plants.
- Strengthening of national power grid and limiting transmission losses to 15%.
- Latest fuel efficiency standards for new cars and light truck wef. 2016.
- Policy support for electric and hybrid cars.
- Increase share of manufacturing industry, "Make in India" program.
- Building efficiency standards to all new building stock.
- Expansion of LPG supply.
- Metered electricity consumption in agriculture.

If the new policies are in place and well implemented, the country could witness 7% GDP growth and the primary energy fuel demand may be 2.5 times of the demand in 2013, in the year 2040; fuel wise demand in the past, now and in future (projected) is given in Table-6.

Table-6 : Past and projected demand of various energy sources(MTOE)

Fuel	2000	2013	2020	2030	2040	Share 2013	Share 2040
Oil	112	176	229	329	458	23%	24%
N.G.	23	45	58	103	149	6%	8%
Coal	146	341	476	690	934	44%	49%
Nuclear	4	9	17	43	70	1%	4%
Renewable	155	204	237	274	297	26%	16%
Hydro	6	12	15	22	29	2%	1.5%
Bio-energy	149	188	209	217	209	24%	11%
Other renewable	0	4	13	35	60	0%	3%
Total	441	775	1018	1440	1908	100%	100%

Against fossil fuel consumption of 70% now, it will be 80% in the year 2040, when coal consumption alone will be 1300 MT, which will be 50% more than the combined OECD countries and second to only China. Main use of coal will be in power generation of 265 GW and the rest in the iron &

steel and cement industries. Renewable energy & nuclear contribution will have to be much more in the year 2040 to meet our primary energy demand. Bio-energy contribution will decline to 11%, though it will remain important energy source for rural families. The expected total primary energy demand and the corresponding GDP along with the growth rates are given in Fig.9.

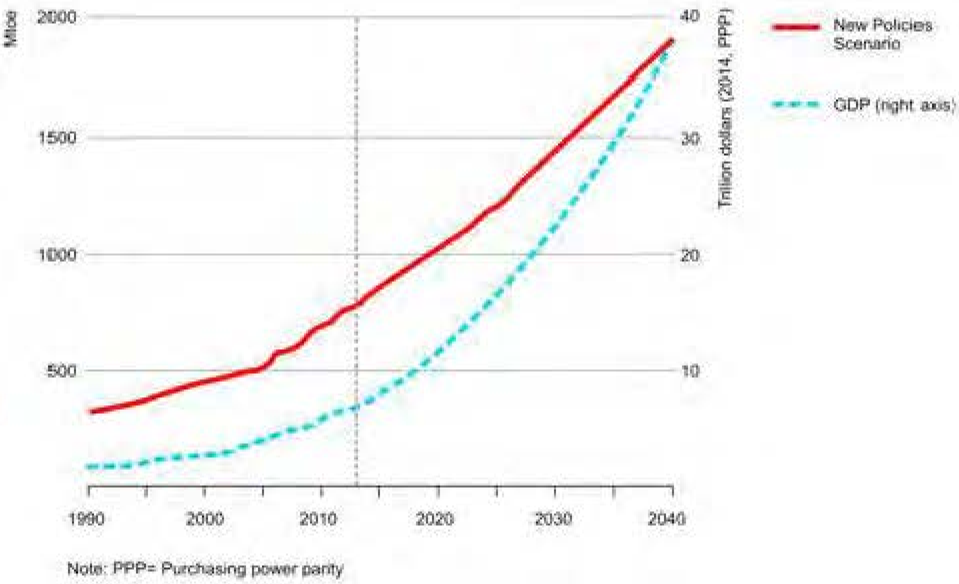


Fig. 9: Primary energy demand and GDP along with the respective growth rates

5.1 Expected Sectoral Primary Energy Consumption

In the new scenario of national development, energy consumption across India's various sectors, namely, buildings, industry, transport and agriculture increase at a rate of 3.3% per year on an average up to 2040, more than doubling to reach 1275 MTOE. This is more than the level of final consumption in the European Union today. It is anticipated that energy consumption will mainly increase in the industry and transport sectors respectively due to Make in India approach and increased number of vehicle ownership in the country. The main fuels contributing to this end user demand are coal (in Industry) and oil (Transport) and electricity (in Buildings Industry and agriculture) Table 7. Biomass energy remains stable in absolute terms; the percentage share however falls to only 11%.

Table 7: Anticipated primary energy consumption across various sectors in India

						Shares		2013-2040	
	2000	2013	2020	2030	2040	2013	2040	Change	CAAGR*
Industry	83	185	263	417	572	35%	45%	388	4.3%
Transport	32	75	108	176	280	14%	22%	205	5.0%
Road	28	68	100	165	264	13%	21%	196	5.1%
Building	158	214	242	274	299	41%	23%	85	1.2%
Agriculture	15	24	31	43	51	5%	4%	27	2.9%
Non-energy use**	27	29	40	58	72	6%	6%	43	3.4%
Total	315	527	686	968	1275	100%	100%	748	3.3%
*Industry, incl. transformation****	111	217	317	507	691	n.a.	n.a.	474	4.4%

5.1.1 Buildings

Energy use in the building sector (both residential and services) is projected to change considerably over coming years due to population growth, trend towards urbanization, growth in access to modern energy and rising income and hence increase in the ownership of appliances. In 2013, 65% of 214 MTOE energy consumed in the building sector consisted of solid biomass; in year 2040 more than 60% of 299 MTOE used in this sector is either electricity (95%) or oil (16%). This change is largely attributed by India's growing number of towns and cities that would accommodate additional 315 million people. Changes in India's energy in the building sector from 2013 to 2040 are shown in Figs. 10 & Fig. 11.

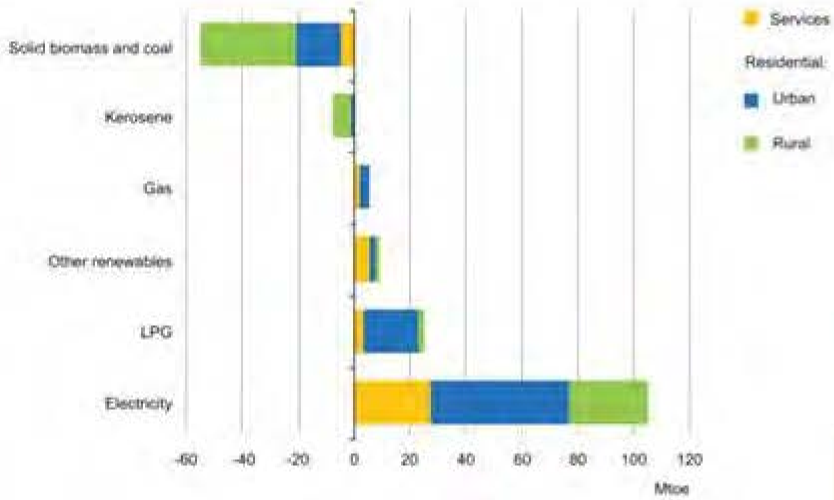


Fig. 10: Change in consumption of energy resources in buildings

India's residential energy outlook is marked by a series of transition, away from solid biomass and kerosene to LPG/PNG and electricity. This shift will happen at different speeds in different parts of the country with varying transition from rural to urban society. Main electricity demand would increase from increasing requirement for space cooling both in the service sector as well as in the residential buildings. In order to de-accelerate electricity consumption in buildings, Bureau of Energy Efficiency (BEE) has set up a programme for energy efficiency in buildings and programme of standards and labelling for appliances.

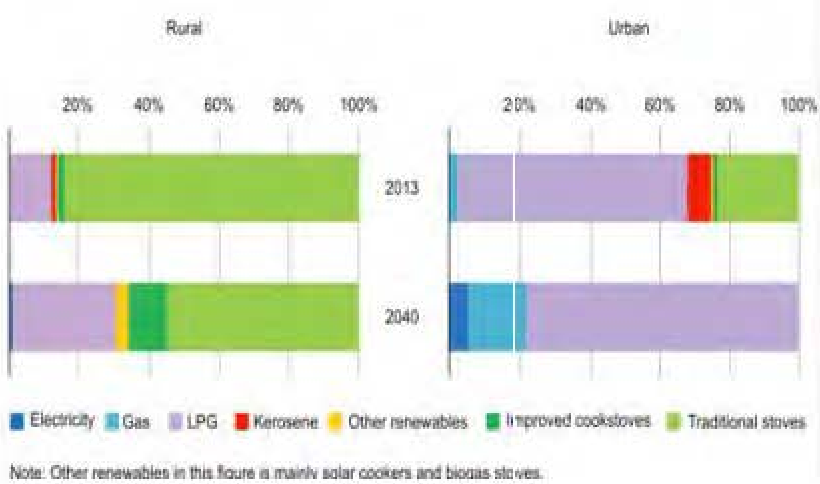


Fig.11: Forecast of primary fuel consumption in Indian households

It is projected that average income of an Indian household will increase to almost four times of its current level reaching almost $ 22000 per annum (2014 dollars), while spending on household energy will increase from $ 200 to $ 900 per year (increasing the share of energy expenses from 3% in 2013 to 4% in 2040). This increase is driven by oil consumption for road transport and increase in electricity consumption

5.1.2 Industry Sector.

It is projected that energy demand in the industry will increase rapidly at a rate of 4.4% annually up to 2040 to account for 50% of the total primary energy (40% in 2013) . Massive infrastructure over the next decades drives massive demand for energy intensive materials like cement, steel and glass; India becoming a manufacturing hub for these materials. Traditional building materials, such as clay, bricks are increasingly being replaced by steel and cement. Fig. 12 shows the change in the energy consumption of various industries. Coal will remain the dominant source of energy for industry accounting for 50% of industrial energy use. However, due to inexpensive coal prices and demand for steel, brick and cement, the coal energy contribution grows to 56% in 2040. Percentage contribution of oil, gas and biomass decrease, though the absolute quantities grow. Gas availability becomes limited due to subdued domestic growth and relatively high import prices.

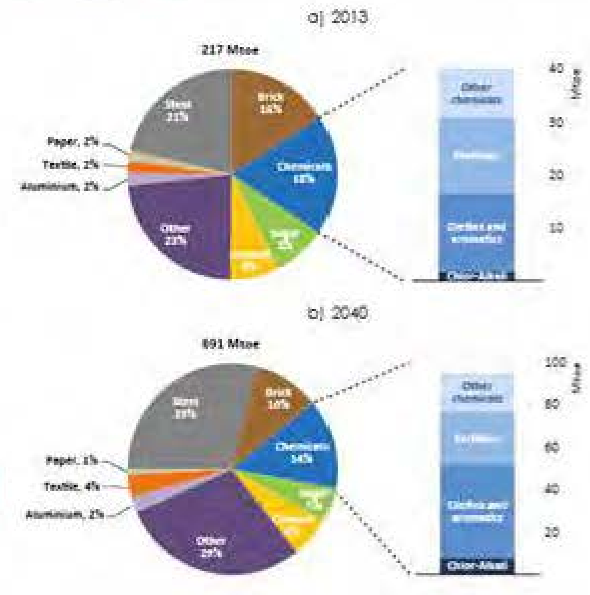


Fig.12 : Present and projected energy demand in various industries

The structure and energy consumption patterns of various industrial branches in the country are very different. Chemical, cement, aluminium and to some extent steel are dominated by large enterprises; whereas brick industry consists of thousands of small and medium enterprises. The brick industry normally has poor energy performance.

Steel is the largest industrial energy user in India and also the largest source of projected industry energy use in 2040. The steel production will grow from 46 MTOE present to 200 MTOE annually overtaking USA and Japan before 2020. Steel industry in India consists of relatively large efficient steel plants and in future it is expected to be less reliant on direct reduced iron (DRI), turning more towards traditional blast furnace route and depending less on electricity.

Brick industry in India is the second largest in the world (after China) and also the second largest energy consumer after steel and iron. Brick production in India is very labour intensive; it is a large consumer of biomass and there are more than 1,00,000 small plants. Approximately 70% of the estimated 250 billion bricks produced per year are made in fixed chimney bull trench kiln, a relatively inefficient production method. There is a large potential of energy efficiency in the Indian brick industry.

Domestic fertilizer industry is a major energy consumer as well as a pillar for India's food security of the three broad categories of nutrients available to India's more than 100 million farmers, most of the potassium and phosphorus based fertilizer are imported whereas three quarters of nitrogen based fertilizer (Urea) are produced at home. Priority is given to the fertilizer industry to access domestically produced natural gas. Imported LNG met almost one third of fertiliser industry requirement in 2013. The energy intensity of urea production has decreased significantly since the year 1990 from 0.84 toe/tonne to 0.65 toe/ tonne in 2013. The energy intensity may decrease further to about 0.55 toe/tonne.

Other large consumer of energy, are the cement, petrochemical, paper and aluminium industries. The cement industry is projected to almost triple its energy demand by 2040. Indian cement industry is already one of the most efficient industries in the world; it uses relatively high share of fly ash and blast furnace sludge as substitute for energy intensive clinker.

India has very low per capita consumption of petrochemical products presently, but demand is increasing from textile, car manufacturing and food packaging subsectors. Production of ethylene, the most basic petrochemical, is expected to increase from 3 MT in 2013 to 13 MT in 2040. As a feed stock India relies heavily on domestic naphtha; it has however, looked in the ethane option from the US also.

Aluminium production presently consumes 4 MTOE; that may increase to 16 MTOE by 2040. Aluminium industry is already very efficient. Indian paper industry, however, remains energy inefficient and its structure is not likely to change significantly in future.

5.1.3 Transport.

Energy use in India's transport sector, at 75 MTOE presently, accounts for only 14% of total energy consumption – a much lower share than in many other countries. With a growth rate of 6.8% since 2000, it has however become the fast growing of all the end use sectors (90% of increase coming from oil use in the road transport.). Though per capita energy in transport and vehicle ownership in India is much less, than other major economies of the world, growth in energy demand in the new policy scenario for India, from transport sector will outplace growth in all other sectors. Transport fuel demand may reach 280 MOTE in 2040 (presently 75 MOTE/a), dominated by the road transport (Fig. 13).

Passenger cars still play a relatively minor role in India's overall transport system, because bulk of travel is undertaken by collective modes of transport (i.e buses) and partly because of high level of use of two and three wheelers. In the new projections, the share of passenger cars increase sharply by 2040, accounting for 54% of road fuel demand for personal transport. The vehicle ownership rises to a number of 175 vehicles per 1000 inhabitants against 20 presently (Fig. 14).

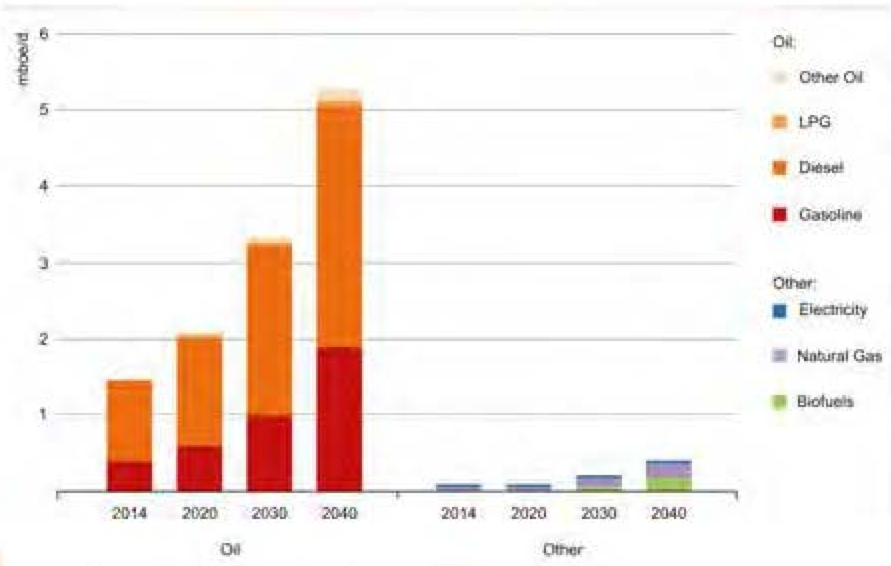


Fig. 15: Present and projected fuel sources consumption in the Indian transport system

5.1.4 Agriculture

Though agriculture contributes only 14% to the GDP, it engages almost 50% of population and also it is an important energy consumer responsible for 15% of diesel and 18% of electricity consumption. Food grain production has increase by 35% since 2000, agriculture faces multiple challenge relevant to energy sector. Inefficient electrical pumps, over-consumption of electricity (due to subsidies) and poor irrigation performance plague the Indian agriculture. In future projections, diesel consumption will reduce to 30% and electricity grows to 68%; the total energy consumption in agriculture increases to 50 MTOE in 2040 against 27 MTOE presently. The projected energy sources for agri-pumps are given in Fig. 16. The majority of new pumps will be operated by grid connected electricity.

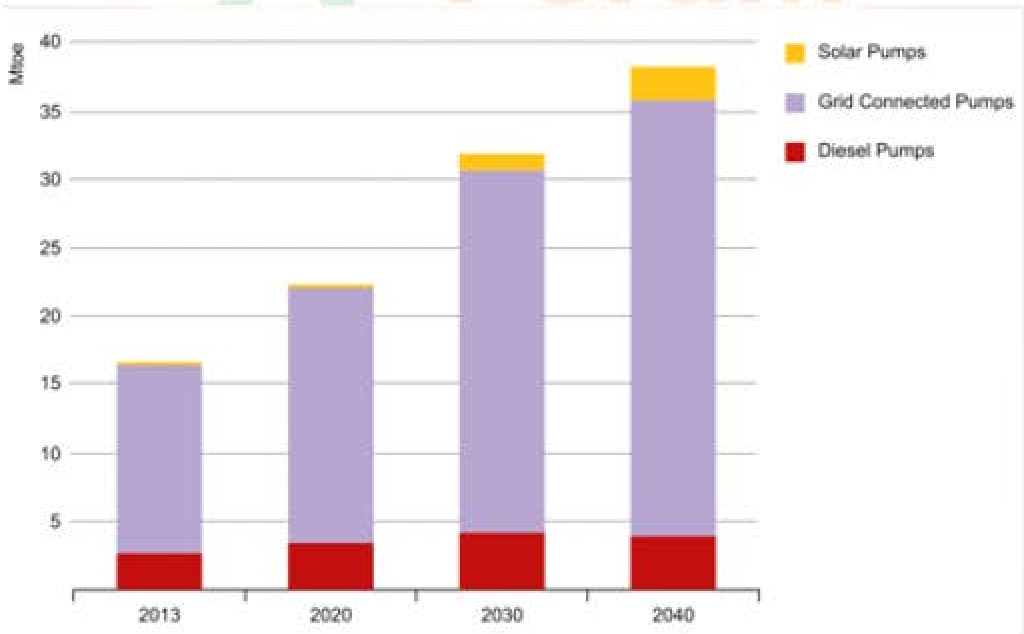


Fig. 16 : Growth of fuel consumption in India's agro-pumps

6.0 India's Electricity Generation Demand

In recent years, there have been marked achievements in the power sector in India, including a rapid expansion of the generation capacity (dominated by private sector), introduction of policies to tap large wind and solar power potential, a sharp rise in improving access to electricity and the strengthening and extension of national power grid. Present installed capacity of electrical power is 300 GW dominated by coal (64%) and renewable increasing its share substantially to 12 % (Fig. 17). After thermal power (Coal + Gas), hydro contributes nearly 11% and the non-utilities including renewable 13%. Nuclear electricity contribution is only 4.8% (Fig. 18). The total annual electricity generation in the country is 1200 bkWh presently.

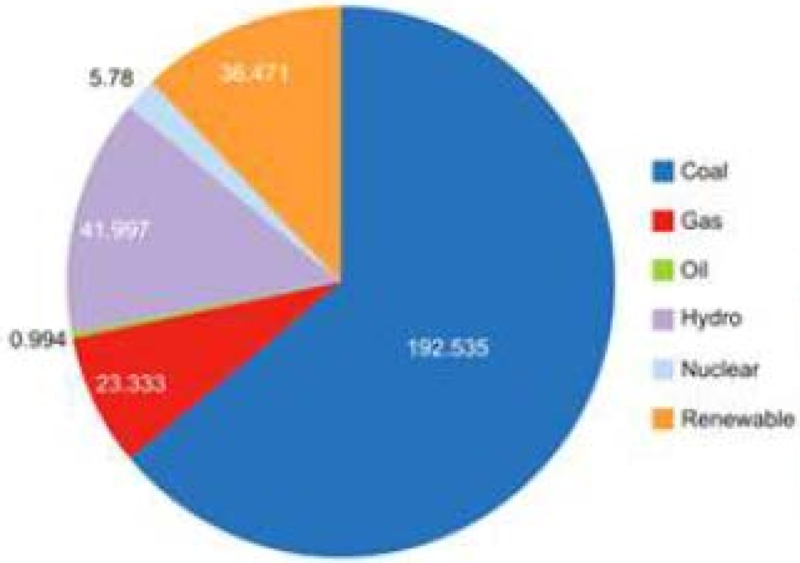


Fig 17: Installed power capacity in India in GW by energy source

Source	Electricity Generation bkWh
Thermal	853
Hydro	134
Nuclear	34
Non-utilities	156

Fig. 18: Present electricity generation by source in India (2015)

6.1 Sectorwise Electricity Consumption

The total consumption of the electricity at the distribution bus bar is 882 bkWh, showing a loss of 26% in the transmission and due to pilferage. The sector wise consumption in the year 2013-14 is given in Fig. 19, showing that industry is the highest consumer with 44% electricity, followed by buildings 31% (domestic & services), agriculture (18%) and others.

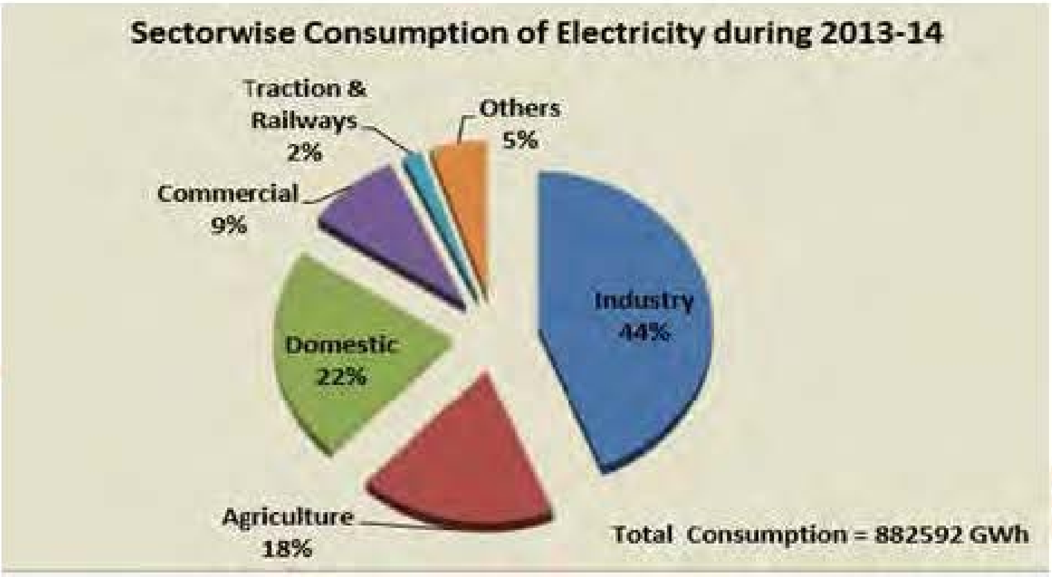


Fig.19: Sector wise electricity consumption in India

The planned target of electricity generation and the achievements, along with the annual growth rates are given in Table 8. The 2014-15 growth has been an impressive figure at 8.43%.

Table 8: Targets, achievements and growth in electricity generation

Year	Target BU	Achievement BU	% Target	% Growth
2009-10	789.5	771.6	97.7	6.6
2010-11	830.8	811.2	97.6	5.6
2011-12	855	877	102.6	8.11
2012-13	930	912	98	4.0
2013-14	975	967	99.2	6.04
2014-15	1023	1049	102.5	8.43

The power and electricity availability and demand from the year 2009 till 2014 have been given in Table 9; it is seen that deficit in the electricity demand and availability has been shrinking to only 3.6%.

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Table 9; Power and electricity demand patterns in India

Year	Requirement BU	Availability BU	Deficit %	Peak Demand GW	Peak Met GW	Deficit %
2009-10	831	747	10	119	104	12.7
2010-11	862	788	8.5	122	110	9.8
2011-12	937	856	8.5	130	116	10.6
2012-13	996	909	8.7	135	123	9.0
2013-14	1007	970	4.7	136	130	4.0
2014	1069	1031	3.6	148	141	4.7

In a business as usual scenario, the electricity demand would have grown to 5000 BU by the year 2045(Fig. 20), however due to various energy efficiency programs exploiting energy saving potential in various sectors (Fig. 21), the demand is restricted to 3300 billion units by the end of 2040.

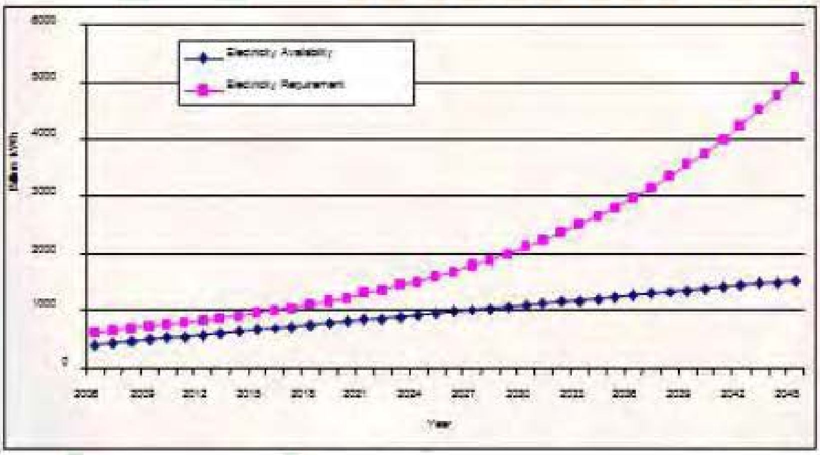

Fig 20; Electricity demand in business as usual scenario

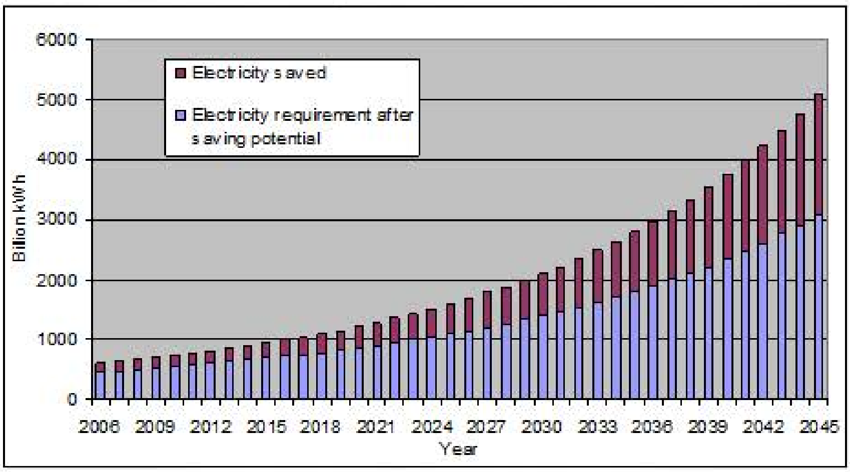

Fig.21 : Electricity saving potential of energy efficiency programmes reducing the future demand to 3300 bkWh in 2045

India accounts for almost 17% of the increase in global electricity demand from 2013 to 2040, an amount roughly equal to today's power consumption of Japan, Middle East and Africa combined. Per capita electricity consumption grows to 2000 kWh (from 710 kWh presently) at an average growth rate of 4%.

The anticipated increase in reliability of power supply, including the peak demand, has widespread implications for the level of power consumption. It would lead to progressively less reliance on backup systems. In the projections, the unmet demand – and estimated amount linked to load shedding in today's power supply diminishes steadily over years and disappears entirely by 2020

Industry remains the largest consumer of electricity in India; its demand more than triples in the projection period though the overall share falls to 39% from 42% (2013). The largest increase comes from the steel and iron and aluminium subsectors responsible for 18% and 9 % rise respectively. In buildings, the demand will increase by 5.8%; in the residential sector it rises rapidly.

Consumption in agriculture also rises, but the overall increase at a rate of 3.5% is tempered towards the end of 2040 because of efficiency and anticipated metering. Electricity demand in the transport sector is relatively small, at less than 1% of the total in 2040.

6.2 Electricity Access

India makes major progress towards full household electrification and achieves universal access by the end of 2040. In the urban area, the universal access is achieved by 2020. In rural areas however about 60 million people still remain without access to electricity in 2030. However by 2040, universal access is an achievable target as shown in Fig. 22.

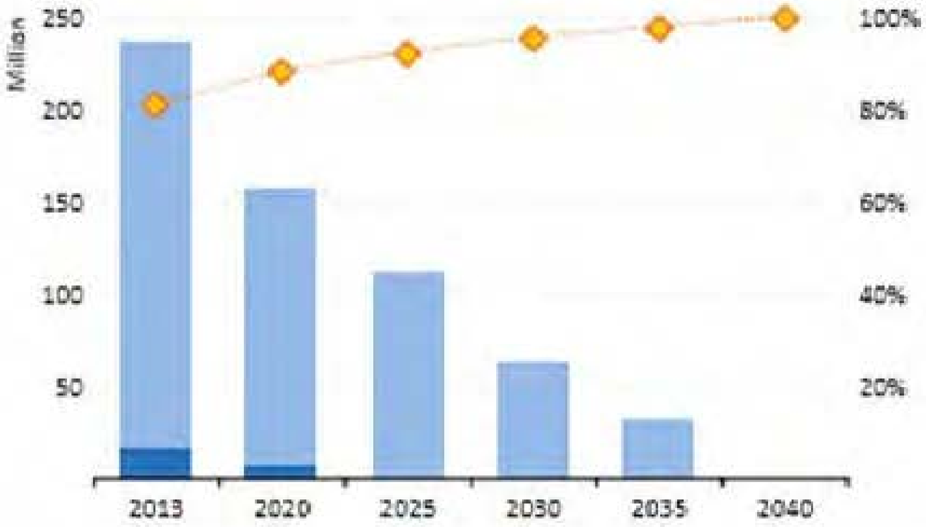

Fig. 22: People with electricity access and rural electrification

6.3 Transmission and distribution

India has five regional networks zones that are connected to each other forming a national grid . About 5% of the network length transports power to large distances from the power plants to demand hubs. The rest consists of distribution lines, which deliver power over the last few kilometres to the consumers. Network losses in India, which are driven by technical and commercial reasons, are highest amongst the world. Ageing and poorly maintained networks are more prone to high technical losses than modern and efficient installations. Theft, unmetered consumption and inadequate revenue collection are other reasons for contribution to power loss in T & D. However, India is taking steps in bringing down T & D losses with share dropping from 20% today to 16% in 2040. Reduction in commercial losses helps re-establish the financial viability of the transmission and distribution companies providing them funds to improve networks.

Other major change in the India network will be to accommodate growing renewable power mainly solar and wind. It will be necessary to integrate the growing share of utility scale solar and wind power plants to improve interconnections with neighbouring power systems and also to reach those settlements and households that don't have access to electricity currently.

6.4 India's Greenhouse Gas Emissions

Greenhouse gas emissions gases, like CO2, CH4 , N2O emitted from anthropogenic activities originate from Energy, Industry, Agriculture, waste and Land use change and forestry. Fig. 23 gives the sector wise GHG emissions of 2007 that peak at 1727.71 million tons of CO2 equivalent of which CO2 emissions were 1221.76 million tons, CH4 emissions were 20.56 million tons and N2O 0.24 million tons. The contribution to CH4 emissions from energy, industry, agriculture and waste sectors contribute 58%, 22%, 17%, and 3% of the net CO2 emissions respectively. Land use, land use change and forestry (LULUCF) was a net sink sequesting 177.03 millions.

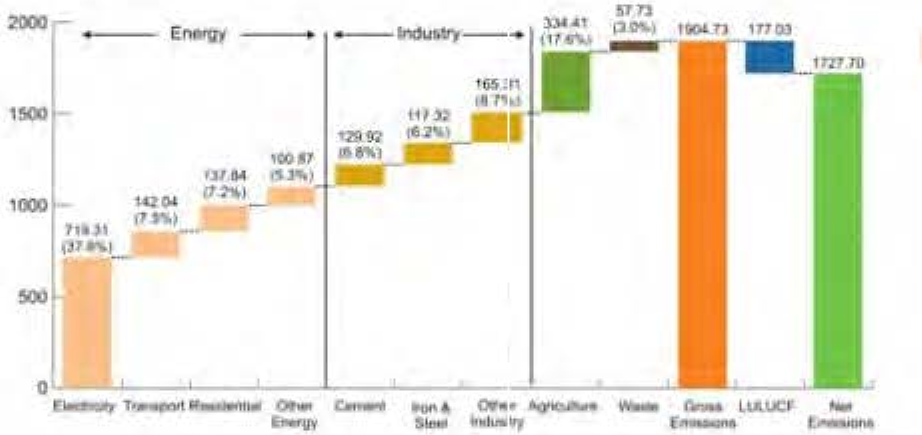

Fig.23: Sector wise green house gas emissions in India

Energy related emissions alone contributed 1100.06 million tons CO2 and the power sector alone contributed 719.31 million tons of CO2; which is 65.4% of the total energy emissions (Fig. 24)

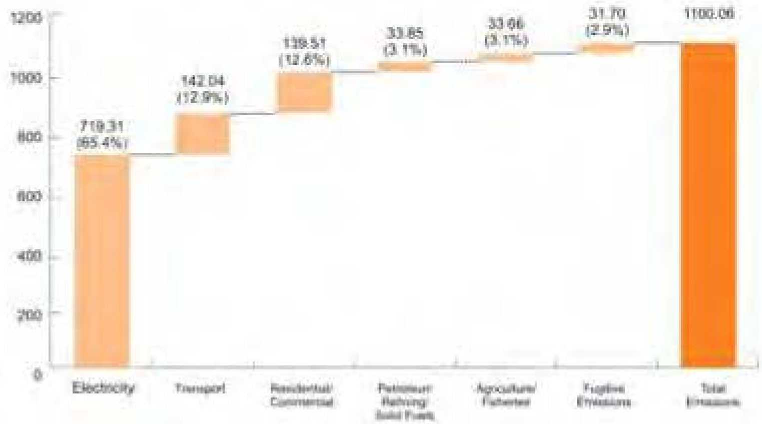

Fig.24: Energy related GHG emissions in India

At the 2009 Copenhagen Climate Summit, India had promised to reduce its emission intensity or emission per unit of GDP by 20-25%. Already a 12%reduction has been achieved by 2010. With aggressive renewable energy input in the power sector (100 GW solar) (70 GW wind), the GHG emissions due to electricity generation start diminishing and India will be able to honour its commitments at the Paris convention 2015 also.

7.0 Conclusions

India is home to 18% of world population and uses 6% of world's primary energy supply. Since the year 2000, the primary energy consumption has doubled and the growth will continue. India's economy, already the world's third largest in terms of PDP, grows rapidly and policies are in pace to press ahead modernization and expansion of manufacturing.

India has occupied the centre stage in the world's energy market with an expected coal demand of 1300 MT, oil demand like to reach 10mb/d and natural gas to ripple at 175bcm. The use of solid biomass in terms of percentage will decrease substantially. Indian people are in the transition phase and additional 315 million people (about the population of USA) will start living in the cities with wide implication on energy demand and switch to modern fuels with increasing ownership of appliance and vehicles. India's need for infrastructure underlies strong demand for energy intensive materials like steel, iron and cement. In order to maintain the targeted 7% GDP the primary energy demand will have to be more than doubled up by 2040 and along with this India has to realise universal access to electricity. This requires mobilisation of all energy resources, switch to energy efficiency regime and growing contribution of renewable energy especially solar and wind. With all these measures in place, in spite of 2-3 times growth in fossil energy by 2040, India should be able to honour its commitment at the Paris convention 2015, to rescue carbon emission per unit GDP by 25 to 30%.

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Chapter 2: Solar Energy for India's Energy Security

Ashvini Kumar.

1. Introduction:

At the outset, I am very happy to be here amongst a gathering of people, with whom I have been associated for a very long time. In my presentation I intend to provide a landscape of India's solar programme, of which Solar Energy Corporation of India (SECI) is an important component. SECI, a Government of Indian Enterprises was set up as a corporate public sector unit (CPSU) under the administrative control of MNRE as an institutional mechanism for implementation of National Solar Mission. On 20th September 2011, SECI was incorporated as a Not for Profit Organization under section 25 of the companies act 1956. The authorised capital of the company is Rs. 2000 corers, subscribed capital of Rs. 600 crores and paid up capital of Rs. 202 crores. Considering the performance of SECI, it was converted to a commercial company under section 3 of the companies' act 2013 on 5th November 2015. The scope of SECI now covers the entire gamut of renewable energy.

Renewable energy has been witnessing a remarkable change since the initiation of Nation Solar Mission with almost 40 GW renewable power installations that is led by wind 27 GW followed by 6.7 GW of solar. These have been major achievements considering the fact that at the start of the mission we only had 2 MW of solar power till the end of 2009. At present RE accounts for 13.7 % of India's total power generation capacity and it is aimed to reach a capacity of 175 GW by renewable in the next six years that is by 2022. If achieved, this will be a huge success promoted by big and positive policy push by the Government at the highest level. Out of this 175 GW, 100 GW is planned by solar, 60GW by wind, 10GW through small hydro and 5 GW through biomass based power projects. The huge target of 100GW by solar (presently only 6.7GW) by 2022, needs concrete planning, requiring land, investments, infrastructure and power evacuation facilities. It is planned to install 40GW utility scale solar plants and 20 GW through ultra-mega solar parks. If these targets are realized by 2022, then the renewable electricity (solar, wind, small hydro) will account for 10% of the total electricity mix in the country.

2. Major Benefits

Installation of 100 GW of solar, besides environmental considerations, is expected to bring other major benefits to the country's economy. Thousands of acres of uncultivable lands can be utilized. This also brings about 100 billion dollars of investment opportunities because 1 MW plant needs about 1 million US $ investment (Rs.6 crores per MW). During construction and installation, 1 MW solar power plant provides employment for 10 people and permanent employment for two people for the plant life. It is easy to assess the huge employment opportunities for the planned 100,000 MW by the year 2016. 100 GW solar power plants will be able to generate 167 billion units of clean electricity annually without using any other fuel and requiring minimum maintenance. Water requirements for operating and maintain solar will be minimal and will also lead to 1.5 million metric tons abatement of CO_2, which is equivalent to replacement of 500000 cars on the road.

3. Regional Targets

Renewable energy like solar, wind, hydro and biomass energy sources are location specific depending on weather conditions. India can broadly be classified as consisting of an Eastern, Western, Northern and Southern region. These region wise renewable power targets along with the states are given in Fig. 1. It can be seen that the eastern region has essentially solar power potential, whereas western and southern regions, solar and wind have almost equal potential. In the northern region, only Rajasthan has been identified as having the wind as well as solar energy potentials.

Fig. 1: Mission 2022: Region wise targets

4. National Solar Achievements

By the end of January 2016, solar cumulative capacity addition is 5284 MW and 1504 MW additional capacity has already been added by the end of February 2016 making total solar power installations as 6878 MW. These targets have been achieved in various states and under different schemes like at Federal Level (MNRE), State level, Renewable Power Obligation (RPO), Rural Electrification Scheme (REC), Private initiative and the Corporate Public Sector Unit (CPSU). State wise cumulative as well as scheme wise solar installations are depicted in Fig. 2.

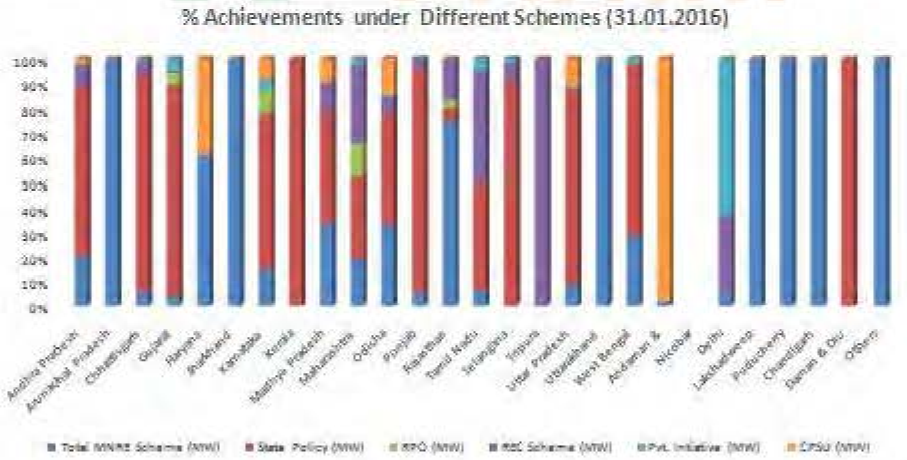


Fig. 2: Mission 2022: Percentage achievements in solar power installations by various states under different schemes

5. Scaling up Solar Power Capacity.

In order to achieve, 100 GW solar target capacity by 2022, one requires a clear cut strategy and provide investment opportunists. Four pillars responsible for Solar Power Plants scaling up are:

- Availability of area

- Production capacity.
- Power Purchase Agreement (PPA)
- Financing

And of course one requires a sound Transmission and Evacuation Network. The first apprehension about a Solar Power Plant is the land availability, which according to us is only a mind set. Land availability in solar mission has been ensured through

- Roof tops
- Ground surface (un-cultivable land)

If one calculates the available roof top and ground areas, then many more GW solar power is possible. Many of you might have attended the solar conference Renewable Energy – Invest. Simply on an offer of green certificate to the industry, the MNRE received a commitment of 270 GW and that provided the GOI confidence to revise National Solar Mission targets from 20 GW to 100 GW.

According to 2011 census of India, the country has

- 330 million houses
- 166 million electrified houses
- 76 million houses use kerosene
- 1.08 million houses use solar for lighting.
- 140 million houses have proper roof (metal or asbestos and concrete roofs).
- 130 million houses have more than 2 rooms.

It is estimated that an average house's roof top can accommodate 1-3 kWp of solar PV systems. Of course large commercial roofs can accommodate large capacities. As a conservative estimate, about 40 GW capacity can be accommodated on roof of buildings, having 2 rooms or more and we consider only 30% of roof tops with 1 kWp capacity each.

Fig. 3, shows the total waste land area in each state. The total area comes out to be 47-23 million ha, considering only 5% of waste land for solar power and allocating 2 ha for each MW, the total solar installation capacity comes out to be 1180 GW.

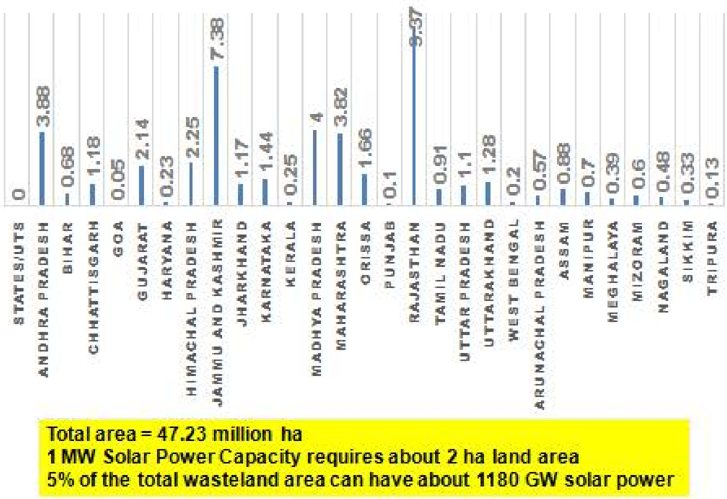


Fig.3: Available waste land and potential for solar power plants

6. Government of India Schemes

During the phase I of the National Solar Mission, based on competitive bid, 1000 MW solar power was installed on the concept of bundling it with thermal power and the state discoms were given the responsibility of signing the PPA through NVVN. In this concept, un-allocated quota of thermal power will be allocated to solar and 1 unit of solar will be bundled with 4 units of thermal power and the price for each unit then will be determined in the same ratio. During the phase-II, NTPC has taken the responsibility of bundling 1.5 GW solar power with the thermal power. The other modes of grid connected solar PV plants are

(1) Viability Gap Funding (VGP)

(2) Solar Park Schemes.

(3) Canal top and canal bank schemes

(4) Defence / Para military forces

(5) Grid connected projects for Central Public Sector Units.

Under the VGF schemes, the following targets are fixed for different options:

(i) 750 MW (2014-15) – Achieved.(Grid connected)

(ii) 2000 MW (2015-16) – Achieved (Grid connected)

(iii) 5000 MW (2016-19)

(iv) 200 MW Grid connected roof top systems.

(v) Indo-Pak Border solarisation schemes.

In all these options, SECI's role is to manage the bid process, disbursal of CFA, project monitoring and power trading (in VGF schemes).

In the following other schemes, SECI's role is in disbursal of CFA and project monitoring:

(i) 20000 MW solar parks

(ii) 100 MW canal top and canal bank schemes

(iii) 300 MW defence / para-military forces

(iv) 1000 MW grid connected systems for Central Public Sector Units.

7. Progress of phase-II

In the 750 MW VGF scheme for batch-1 (Phase-ii), 375 MW solar power has to have domestic component and in the rest 375 MW there are no restrictions. Already 650 MW capacities have been commissioned, out of which 400 MW is being traded on inter-state basis. The government is providing Rs. 1230 crores as support for VGF. Fig. 4 provides the location details with capacity for projects under 750 MW scheme along with the country wise sourcing of modules and inverters.

In the grid connected roof top systems, 45 MW capacity has been sanctioned out of the total allocation of 76.6 MW. 30 MW capacities already stand commissioned. A total of 40 MWp (>100 projects) are operational and Rs.33.9 crores have been released as subsidy through this scheme under four phases. A positive outcome of the policy is the reduction of in the prices that has come down from Rs.130/WP in 2011 Rs.80/WP in the year 2015.

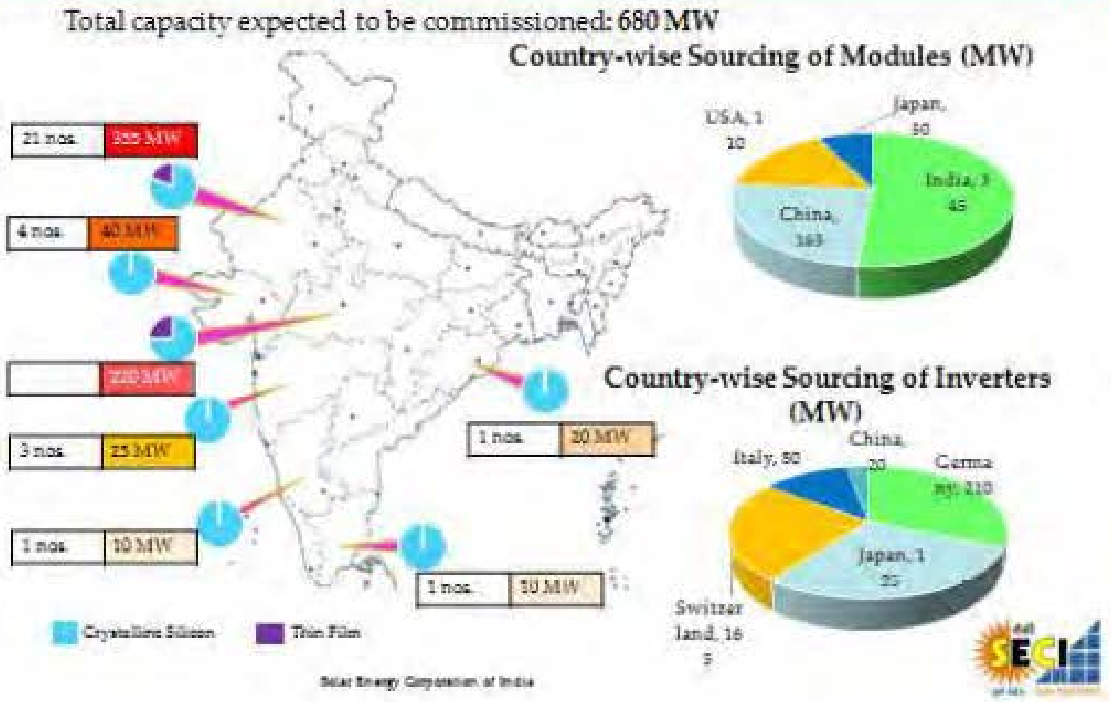


Fig. 4: Projects under 750 MW plants

Fig. 5 shows the presence of Pan-India in the grid connected roof top systems under four different phases along with their respective capacities.

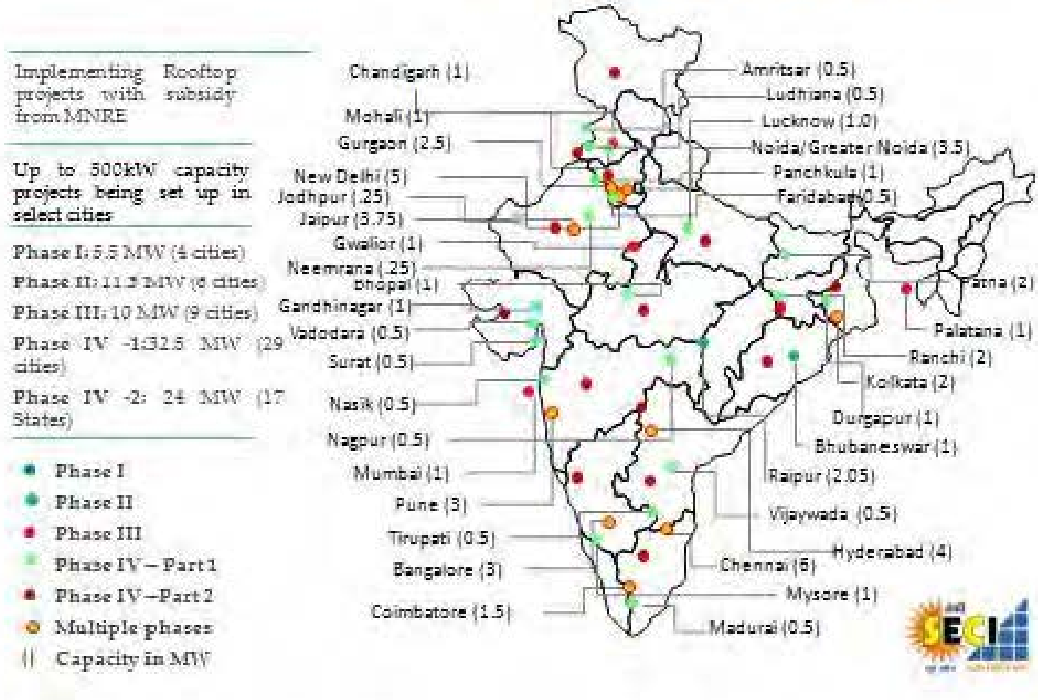


Fig. 5: Pan India Presence for grid connected Roof Top projects

8. Sector wise break up and price trend

The effects of the SECI have resulted in rapid expansion of solar technologies across various sectors; the distribution given in Fig.6. Also the prices have been declining slightly, though the US dollar has appreciated considerably against Indian rupee since 2012 (Fig.7).

Fig 6: Sector wise break up and price trend

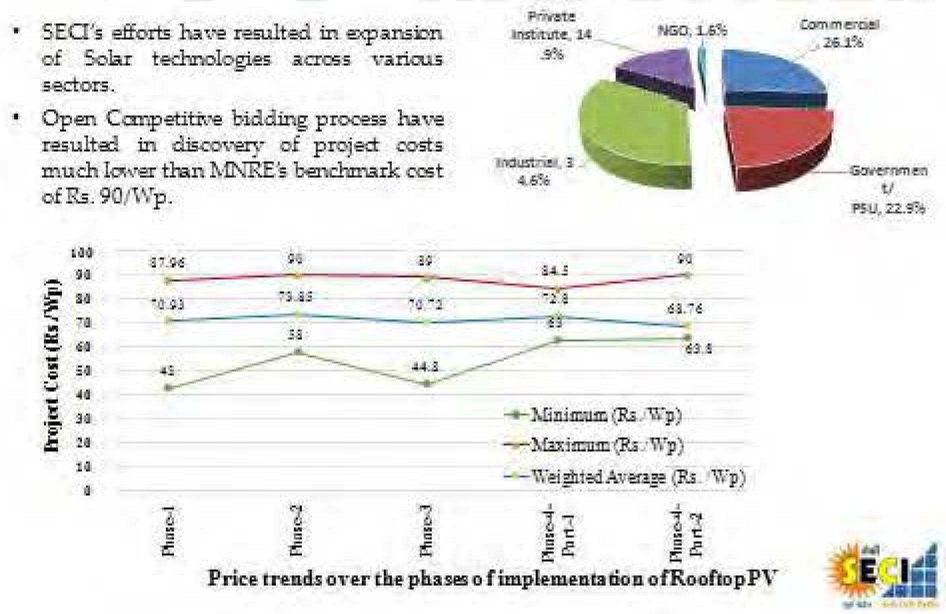


Fig.7: Sector wise break up and price trends

9. Solar Parks

Solar parks are concentrated zones for solar power development; the concept coming from the state of Gujarat, who was the first state to develop Charanka Solar Park of about 1000 MW on a 2000 hectare site in the district of Patan. Such solar parks have dedicated land provided by the respective states and help to provide common infrastructure to multiple projects such as:

- Developed land.
- Roads.
- Water and drainage
- Communication.

- Warehouse.
- Power evacuation infrastructure

It is envisage to develop 25 solar pars in various states with a capacity 7500 MW or more each with total target of 20 GW installed capacity. The budgetary support from the GOI (through SECI) will be Rs. 20 lakhs per MW, for either state government scheme or the central scheme. The duration of each project will be 5 years starting from the year 2014-15. Each state is required to designate an agency for the development of solar parks, that are to be developed in the following four modes:

Mode 1: The state designated nodal agency.

Mode 2: 50-50 JVC between state nodal agency & SECI.

Mode 3: Only SECI.

Mode 4: Private entrepreneurs with or without participation from SECI/state governments or its agencies.

A schematic representation of solar park is given in Fig.8

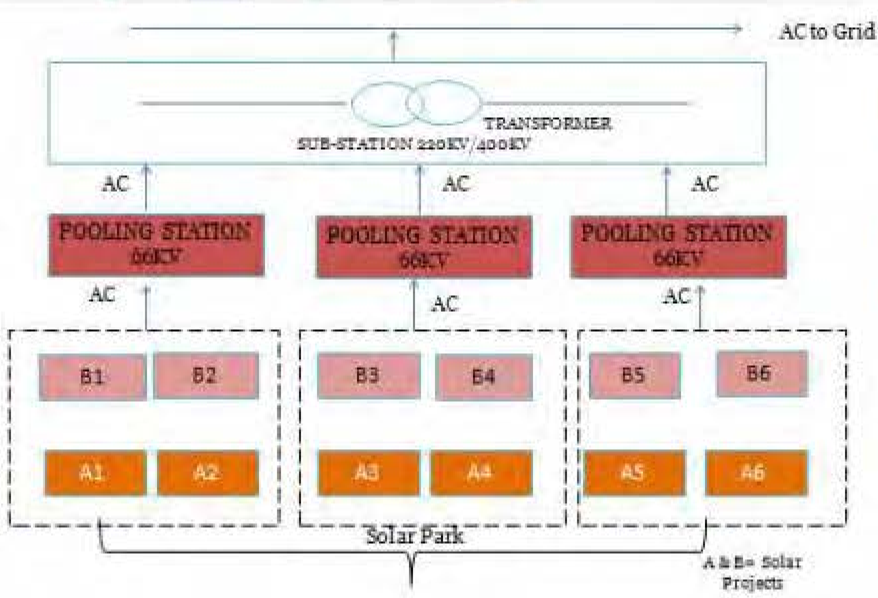


Fig. 8: Schematic representation of a solar park

There are already 33 solar parks approved in 21 states (Fig.9) with an aggregate capacity of 19,900 MW and centralised financial assistance of Rs.374 crores has already been released to the SECI.

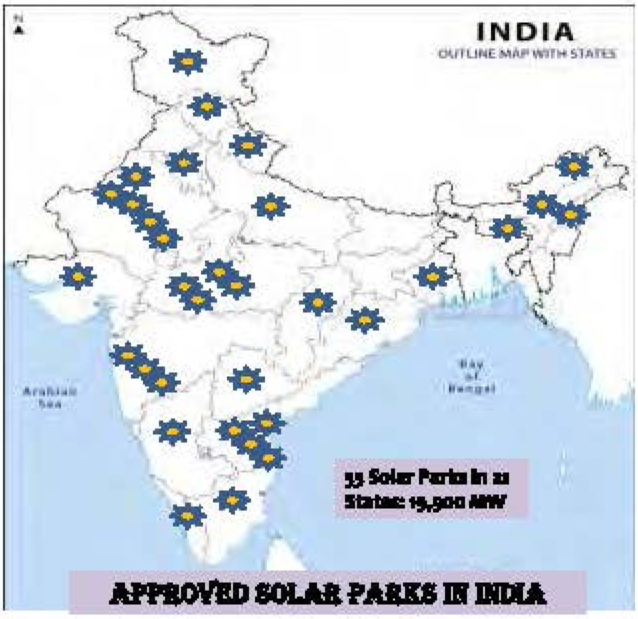


Fig. 9: Sites for approved solar parks in the country.

Table 1 provides the state wise solar park capacities.

Table 1: State wise approved solar park capacities

S.No.	State	No. of Parks	Capacity (MW)
1.	Andhra Pradesh	4	4000
2.	Rajasthan	5	3251
3.	Madhya Pradesh	4	2750
4.	Karnataka	1	2000
5.	Maharashtra	3	1500
6.	Himachal Pradesh	1	1000
7.	Odisha	1	1000
8.	Gujarat	1	700
9.	Uttar Pradesh	1	600
10.	Chhattisgarh	1	500
11.	Tamil Nadu	1	500
12.	Telangana	1	500
13.	West Bengal	1	500
14.	Haryana	1	500
15.	Kerala	1	200
16.	Arunachal Pradesh	1	100
17.	Jammu & Kashmir	1	100
18.	Assam	1	69
19.	Nagaland	1	60
20.	Uttrakhand	1	50
21.	Meghalaya	1	20
		33 Solar Parks	19,900 MW

10. New Initiatives & conclusions

India, being already at the centre stage of solar power market, has been provided further policy push by the cabinet. The first is the power tariff policy that includes:

- 80% electricity consumption excluding hydropower shall be from renewable energy by March 2022.
- Renewable Generation Obligation (RGO) under which new coal / lignite based thermal plants need to establish / procure or purchase renewable capacity after a specified date.

- Affordable renewable power through bundling of renewable power with power from plants whose PPAs have expired or plants that have completed their useful life.
- No interstate transmission charges and losses to be levied for solar and wind power.
- Power to be provided to remote un-connected villages through micro-grids with provision for purchase of power into the grid as and when grid reaches there.

Another major initiative of the government has been to form an International Solar Alliance comprising of 121 countries lying between the tropics of Cancer & Capricorn.

As a part of its commitment to clean energy, India has declared to have 40% non-fossil electricity by 2030. The electricity consumption of 1100 billion units presently is estimated to reach 2500 billion units by 2030 and the requirement of solar power could be 300 GW or above by the period.

Solar is the future source of electric power in India.

Chapter 3: Sustainable Energy Supply Options for India

Amit Kumar.

1. Introduction

My presentation contains an overview of Indian electricity scenario, the challenges that India faces in supplying universal access of electricity and what are the sustainable solutions. Many of the points have already been covered by the previous speakers. India's installed electrical power capacity stands at 290 GW today (CEA January 2016), where thermal contributes nearly 69%, where major energy source is coal, which contributes87% to the thermal power. In spite of major capacity additions, India has to still suffer power shortages. The industry has to restore to captive power generation, which is over 40 GW using only fossil fuels. The electricity fuel mix in the country (Dec. 2015) is given in Fig. 1.

Note: Captive Generation is not included in the total

Fig. 1: Energy fuel mix fir electricity generation in India

2. India's Challenges to Universal Energy Access.

Census of India 2011 estimated that there are 74 million households and 289 million people without access to electricity. Even in most electrified villages, electricity is unreliable characterized by long blackouts and load shedding. Fig. 2 clearly shows the un-served power demand across the entire landscape of India.

Fig. 2: Regions in India with un-served demand of electricity

This un-served demand is further demonstrated in Fig. 3, which shows a split between off-grid and under-electrified household for all states (based on the national average).

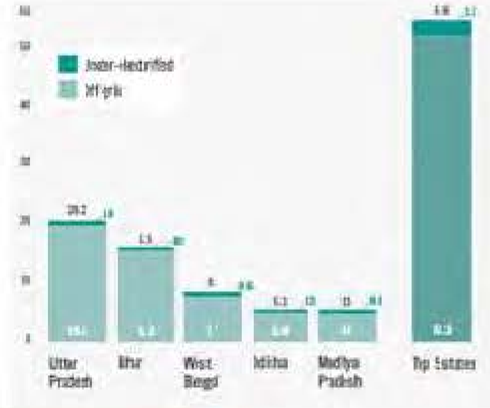
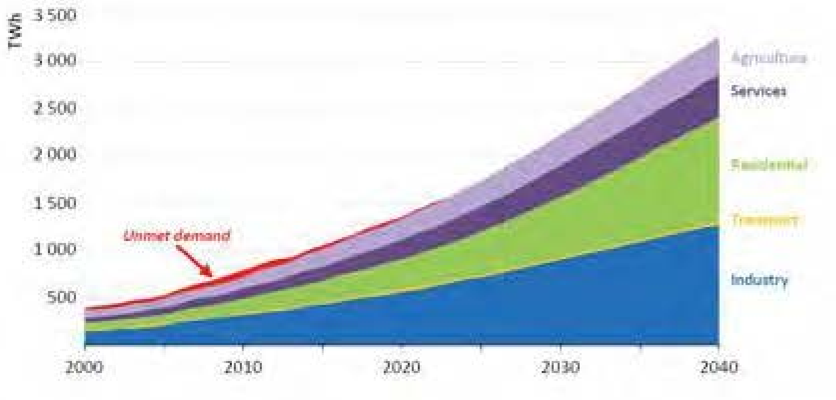


Fig. 3: The un-served demand

3. Sectorwise Electricity Demand, Challenges and Solutions.

International Energy Agency (2015) in a study, devoted to India, projected a total demand of 3300 bkwh by the year 2040, a figure much lower than projected by the Integrated Energy Policy (2006) or TERI study projections up to 2031. The reasons for the discrepancy are the inadequate weight age to energy efficiency measures and decreasing energy intensity in the country. Fig. 4, provides the trends of increasing sector wise electricity demand projected by IEA. One may note consumption of electricity keeps growing across all the sectors, but the industry and residential energy demand will grow much more than any other sector.



Challenges and Solutions.

India's electricity challenges have been essentially in ensuring 24x7 of supply at the national level as well as at the village level. Coal is the main fossil energy source in India that suffers from problems like demand – supply mismatch. Also most coal reserves being in the forest land there are environmental issues for clearances and of course, Indian coal suffers from quality and has to be blended with better quality imported coal.

The issue of coal utilization and green house gases mitigation is being studied and discussed to implement carbon capture and storage (CCS) technologies. TERI conducted this study that integration of CCS technology results in two types of penalties. One, the levelized cost of electricity (LCOE) increased by 41% for imported coal and 42% for Indian coal (Table 1);

Table 1:Life cycle cost of electricity with and without CCS

Item	Imported coal	Indian coal
LCOE without capture (Rs/kWh)	3.97	3.50
LCOE with capture (Rs/kWh)	5.52	4.90
LCOE with CCS (Rs/kWh)	5.58	4.95
LCOE with CCS and monitoring (Rs/kWh)	5.61	4.99
Increase in LCOE due to CCS and monitoring	41%	42%

The second penalty being that the auxiliary power consumption for operation of the coal power plant increase to 18-20% against 8-9% for normal plant. Also, the new coal power plants are envisaged to be of the sizes of 4 GW or 5 GW and nowhere in the world, a single scientific study has been made for the sizing, technology and economics of such size of CCS systems. The problems of carbon storage and its disposal without escape to the atmosphere remains a challenging problem.

The other solutions for our electrical supply system that are being discussed are the use of gas, large hydro and nuclear. In the case of natural gas, there are indigenous production constraints and we are very short of this energy source. The technology of shale gas is being talked about. However most shale gas resources in the country are in water starved region and tracking not only requires water but also lead to enormous environmental problems. Large hydro needs long gestation periods, environmental concerns and rehabilitation issues. In the country, average PLF of large hydro-plants is only 30%, the nuclear resource depends upon fuel imports, public acceptance and geo-political concerns.

From the point of climate change perspectives and India's commitment at Paris and Copenhagen, to reduce emission intensity of its GDP by 33-35% by 2030 from 2005 levels and to install 40%cumulative electric power installed capacity by 2030 on non-fossil power, requires aggressive implementation of clean renewable energy sources.

4. Renewable Energy in India

India is endowed with good renewable energy resources like solar, wind, small hydro and biomass and these resources have the advantage of working equally well on utility scale power generation or as decentralized distribution energy generation. Renewable energy also fits well with country's development agenda in a sustainable manner, complementary energy supply and with social and environmental benefits.

Besides the advantage of short gestation period many renewable energy based technologies are already cheaper than power generation from fossil fuels. New wind projects, at the point of generation, are cheaper than the cost of power from imported coal based projects. Solar photovoltaic costs are cheaper that cost of natural gas based generation. Roof top solar photovoltaic systems provide electricity cheaper that the cost of existing tariffs for large and industrial consumers and even high end use residential consumers in many states. Of course, PV electricity is significantly lower than the cost of diesel backup generators and battery inverter systems.

5. Sustainable Supply Options

In the utility scale power plants, solar PV, CSP, offshore & onshore wind power are all being installed all over the world. Amongst distributed embedded solutions solar PV, biomass and mini- or micro-hydro power systems are more appropriate. Levelized cost of utility scale RE electricity has been coming down from 2010-2014, as shown in Fig. 5.

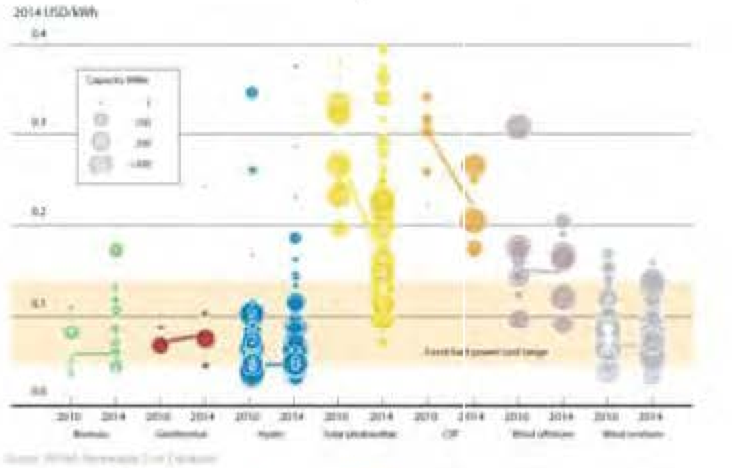


Fig. 5 : levelized cost of utility scale RE electricity

5.1 Solar Photovoltaic

Solar photovoltaic installed capacity installed in the world till the end of 2014 stands at 177 GW. It has grown rapidly since 2004 as shown in Fig. 6 and the top 10 countries where the capacity additions are rapid are illustrated in Fig.(7). In India, there has been rapid expansion of utility PV power by 5.0 GW in 2015 alone.

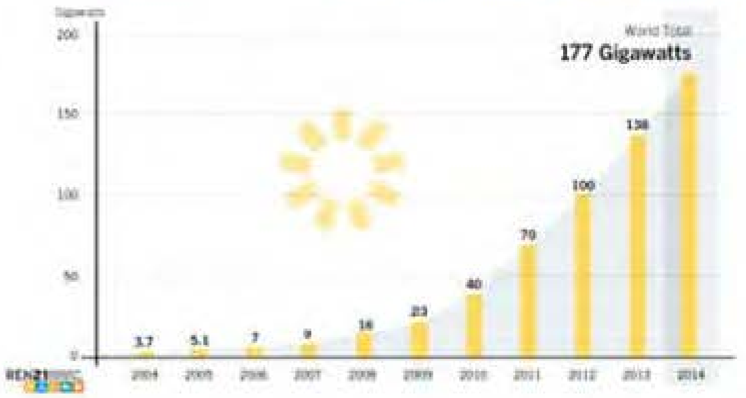


Fig. 6 : Progress of PV based installed power in the world

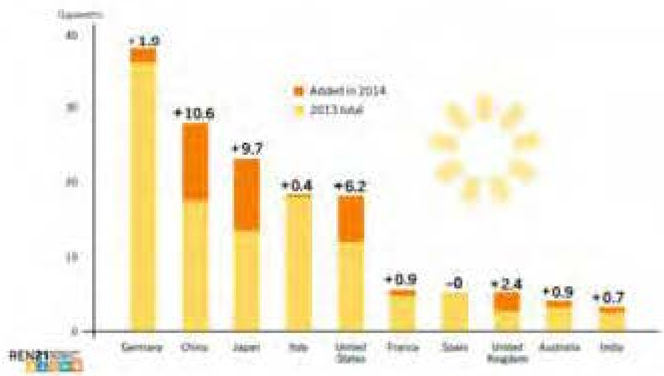


Fig.7: Leading top ten countries in the world for solar PV installations

Various PV cell technologies that may be termed as first generation, second generation and futuristic technologies are given in Table 2.

Table 2: PV cell technologies

Generation	Materials Used	Level of Maturity
First-generation	Use the wafer-based crystalline silicon (c-Si) technology, either single crystalline (sc-Si) or multi-crystalline (mc-Si)	Fully commercial
Second-generation	Based on thin-film PV technologies and include • Amorphous (a-Si) and micromorph silicon (a-Si/μc-Si) • Cadmium-Telluride (CdTe) • Copper-Indium-Selenide (CIS) and Copper-Indium-Gallium-Diselenide (CIGS)	Early market deployment
Third-generation PV systems	Includes technologies • Concentrating PV (CPV) • Organic PV cells	Under demonstration

Corresponding module efficiencies are provided in Table3

Table 3 : PV technologies and corresponding efficiencies

		1st Generation PV		2nd Generation PV	
Technology	Units	Single Crystalline silicon	Poly Crystalline silicon	Amorphous silicon	Copper Indium Gallium Di selenide (CIGS)
Commercial PV module efficiency	%	15-19	13-15	5-8	7-11
Maximum PV module output power	W	320		300	120
PV module size	m²	2	1.4-2.5	1.4	0.6-1.0
State of commercialization		Mature with large scale production	Mature with large scale production	Early deployment phase, medium scale production	Early deployment phase, medium scale production

It is also observed that there are trends of increasing module efficiencies that are already more that 20% and available in the market (Fig. 8).

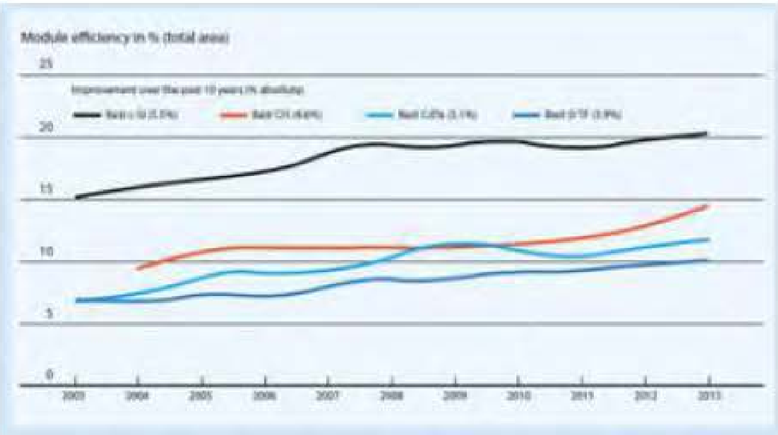


Fig. 8: Module efficiency trends

PV installations have an exponential growth reaching 233 GW by the end of 2015 and the projected growth is up to 600 GW by the end of 2019 (Fig.9).

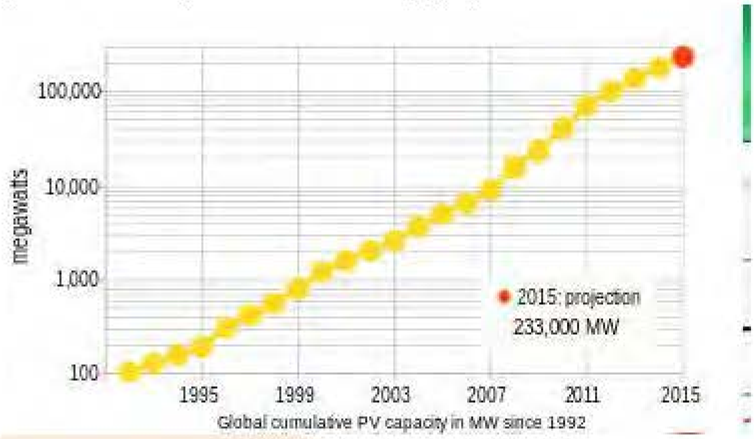


Fig. 9 : Cumulative PV growth since 1992

Dominant technology has of course been multi or mono-crystalline silicon cells. The prices per Wp have been well below a US dollar. The system costs have also been coming down as shown in Fig. 10

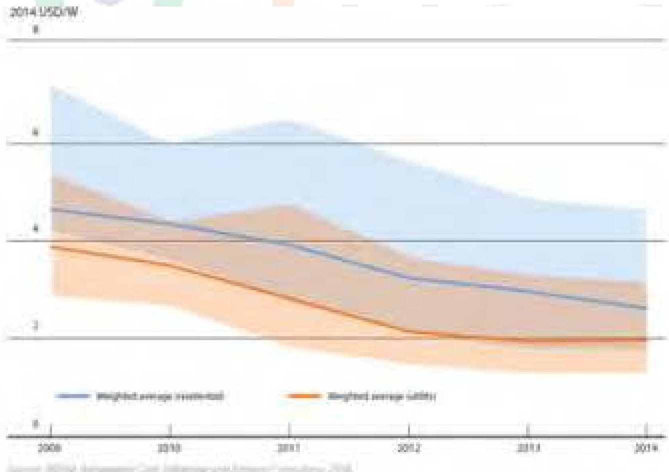


Fig. 10: Trends in installed PV costs

Fig. 11 shows this trend in the Balance of Systems price (BOS) and further cost reduction is essentially driven by the EPC nowadays.

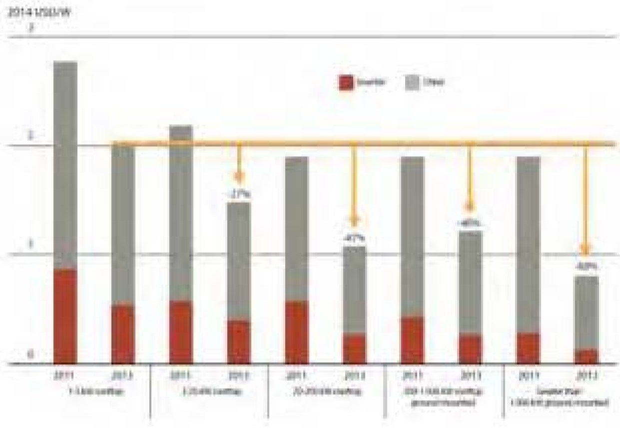


Fig.11: Balance of system price trends

5.2 Concentrated Solar Thermal Power (CSP)

Because of massive price reduction in solar PV modules, the progress in the CSP installations has taken a rather back seat. However, between 2008 and 32014, large CSP capacity was installed dominated by installations in Spain and the US reaching a total capacity of 4.4 GW (Fig. 12).

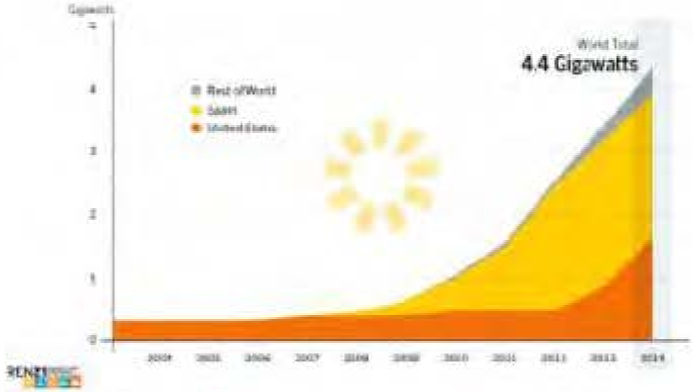


Fig. 12: CSP global capacity and by region

Various CSP technologies namely parabolic trough, solar tower, linear Fresnel and Dish-Stirling have reached different maturity status (Table 4);

Table 4: Maturity status of various CSP technologies

	Parabolic trough	Solar tower	Linear Fresnel	Dish-Stirling
Maturity of technology	Commercially proven	Commercially proven	Early commercial projects	Demonstration projects
Operating temperature (°C)	350-400	250-565	250-350	550-750
Collector concentration	70-80 suns	> 1 000 suns	> 60 suns (depends on secondary reflector)	up to 10 000 suns
Receiver/absorber	Absorber attached to collector, moves with collector	External surface or cavity receiver, fixed	Fixed absorber, no evacuation secondary reflector	Absorber attached to collector moves with collector
Application type	On-grid	On-grid	On-grid	On-grid/Off-grid
Suitability for air cooling	Low to good	Good	Low	Best
Storage with molten salt	Commercially available	Commercially available	Possible, but not proven	Probably, but not proven

However, most successful installations have been based on parabolic trough technologies only. This technology has also as proven to be the most efficient of all the technologies so far. (Table 5)

Table 5: Efficiency of CSP technologies

Technology	Peak solar to electricity conversion efficiency	Annual solar-to-electricity efficiency	Water consumption, for wet/dry cooling (m^3/MWh)	Land use (m^2/MWh/a)
Parabolic troughs	23-27%	15-16%	3-4 / 0.2	6-8
Linear Fresnel systems	18-22%	8-10%	3-4 / 0.2	4-6
Towers (central receiver systems)	20-27%	15-17%	3-4 / 0.2	8-12

Installed cost and capacity factors of CSP plants with and without thermal storage are given in Fig. 13.

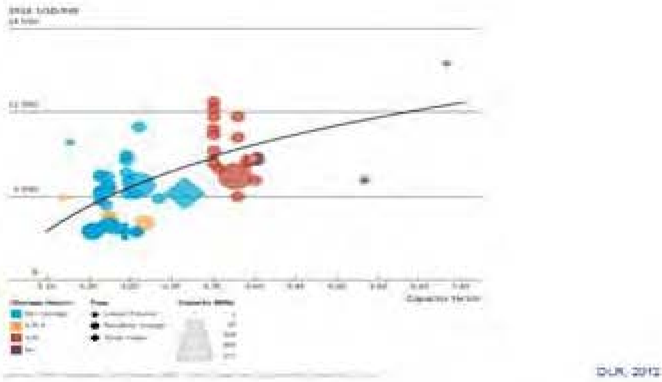


Fig. 13: Installed costs and capacity factors of CSP technologies

Fig. 14: Status of CSP technologies in the world

It is observed that 95% of the installed CSP plants use parabolic trough technology and central tower technology is being used in 18% of the plants under construction. In India, only two plants, out of seven sanctioned, have been commissioned so far, namely, 50 MW parabolic trough based system and 100MW linear Fresnel based systems, both in Rajasthan close to Pokhran. The levelized cost of electricity by CSP between 2008 and 2014 has been given in Fig.15.

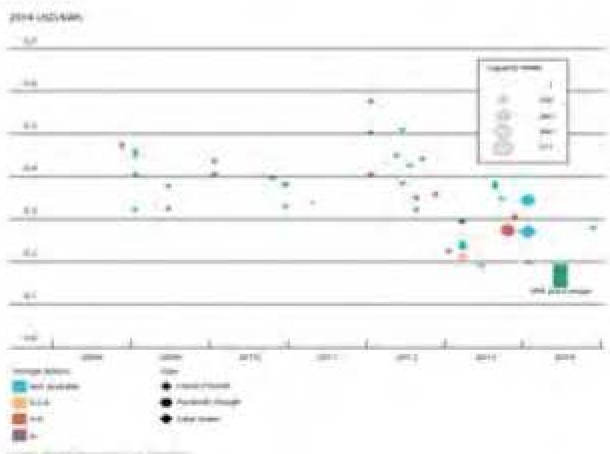


Fig. 15: Levelized costs of electricity for CSP technologies (2014)

Innovative Thought Forum

5.3 Wind Energy

Wind power is one of the fastest growing sectors amongst the power technologies. By the end of the year, 370 GW wind power installations were set up all over the world (Fig.16).

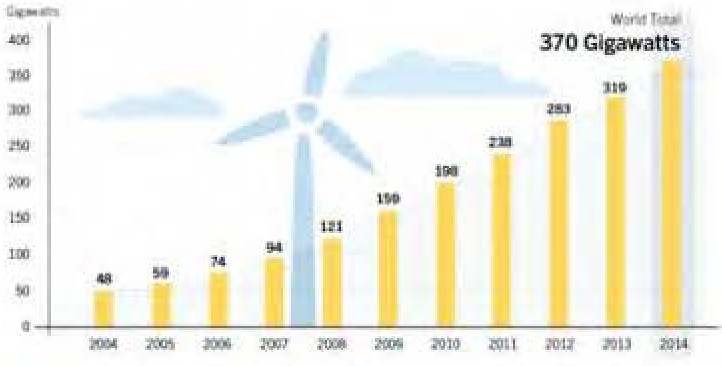


Fig. 16: Global wind power capacity (2004-2014)

China is the world leader followed by the US and Germany; India occupying the fifth position at 2.3 GW (Fig.17)

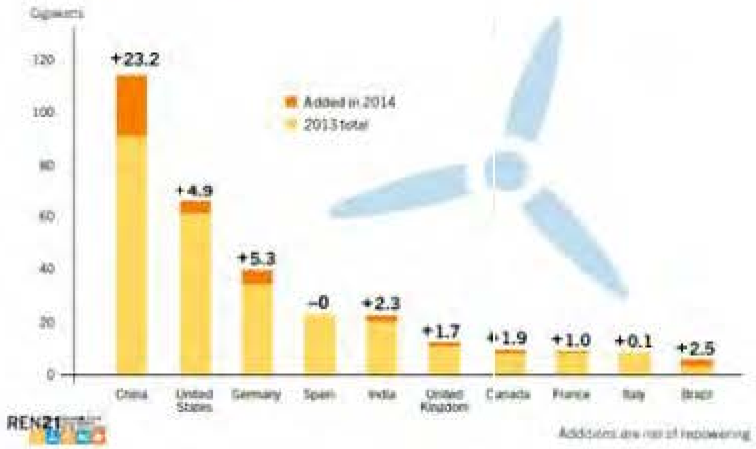


Fig. 17: Top ten countries of the world with wind power installations

Early wind installations were small power machines; however it was found technically superior and also economically beneficial to develop MW wind turbines. Since the year 2010, 5 MW machines have been developed and the future wind power system may reach 20 MW single turbines exploiting higher wind speed at higher altitudes (Fig.18).

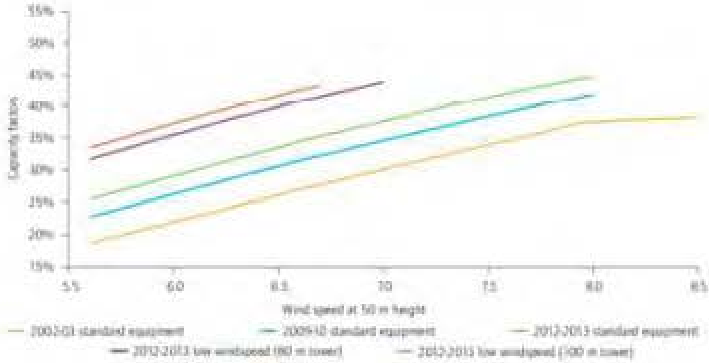


Fig. 18: Technology trends in wind power

There have been major advances in the wind blade design and the controls have been greatly improved resisting in higher yield of power. Gearless machines, like from Enercon, or direct drive turbines increased their share from 12 to 20%. The cost of power generation has been coming down to 0.80 Euro per W, the share of wind turbine being the maximum at 74% (Fig.19)

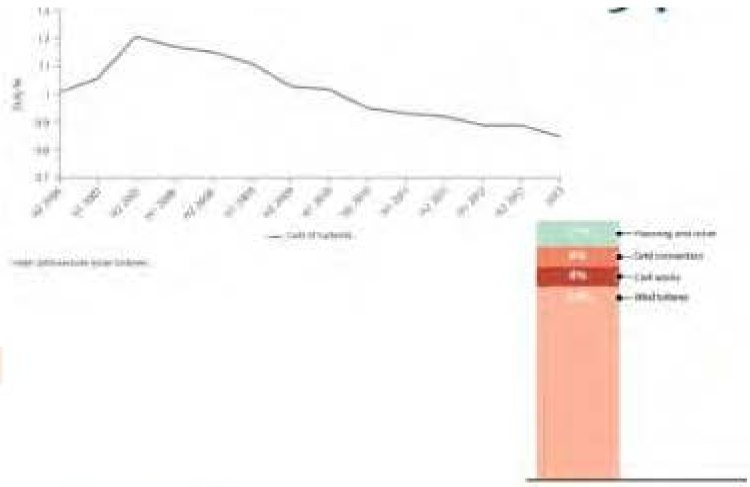


Fig. 19 : Cost trends of on-shore wind power plants in the world

In Europe, there are trends of off shore wind power in installations, in India however this technology is at the feasibility stage.

5.4 Biomass

A TERI study suggested that 500-600 MT biomass is available for bio-energy conversion or for thermo chemical conversion into procures gas. It is also well established that biomass energy systems are more suitable for decentralised and distributed energy systems. As an example of bio energy conversion using organic waste and anaerobic digestion; in 2014-15 about 20,700 lakh cubic meters of biogas was produced in the country which is equivalent 5% of the total LPG consumption. The government is also extending substantial subsidy for setting up new biogas plants.

Thermo chemical partial combustion based biomass gasifier power plants in India are providing a great solution for off-grid decentralised power that are lighting homes in several Indian states. Biomass based gasifier produces a mixture of hydrogen and carbon-monoxide, known as producer gas. Unusually the gas contains tar; if it is used in the IC engine for electrical power generation then it corrodes the engine. Separation of tar using scrubbing requires large amount water. TERI in collaboration with Denmark, has developed two-stage gasifier(Fig.20), that produces tar free producer gas.

Fig. 20: Two stage gasifier developed at TERI

Four plants are being set up as pilot demonstration in the field and the performance requires to be studied in detail.

6. Conclusions

Renewable energy, as an option for sustainable power has been growing rapidly. In the year 2014 alone renewable made up an estimated 58.5% of net additions to global power capacity and already it comprised an estimated 27.7% of the world's power generating capacity. Renewables are supplying an estimated 22.8% of global electricity, hydropower providing about 16.6% of the total Renewable Energy. A glimph of renewable energy progress with each technology is given in Table 6.

Table 6: Renewable energy indicators 2014

		START 2004	2013	2014
INVESTMENT				
New investment (annual) in renewable power and fuels	billion USD	45	232	**270**
POWER				
Renewable power capacity (total, not including hydro)	GW	85	560	**657**
Renewable power capacity (total, including hydro)	GW	800	1,578	**1,712**
Hydropower capacity (total)	GW	715	1,018	**1,055**
Bio-power capacity	GW	<36	88	**93**
Bio-power generation	TWh	227	396	**433**
Geothermal power capacity	GW	8.9	12.1	**12.8**
Solar PV capacity (total)	GW	2.6	139	**177**
Concentrating solar thermal power (total)	GW	0.4	3.4	**4.4**
Wind power capacity (total)	GW	48	319	**370**

The respective life cycle costs are given in Fig. 21, in terms of 2014 US dollar. A comparison of coal, gas, nuclear and wind power life cycle energy cost is provided in Fig.22.

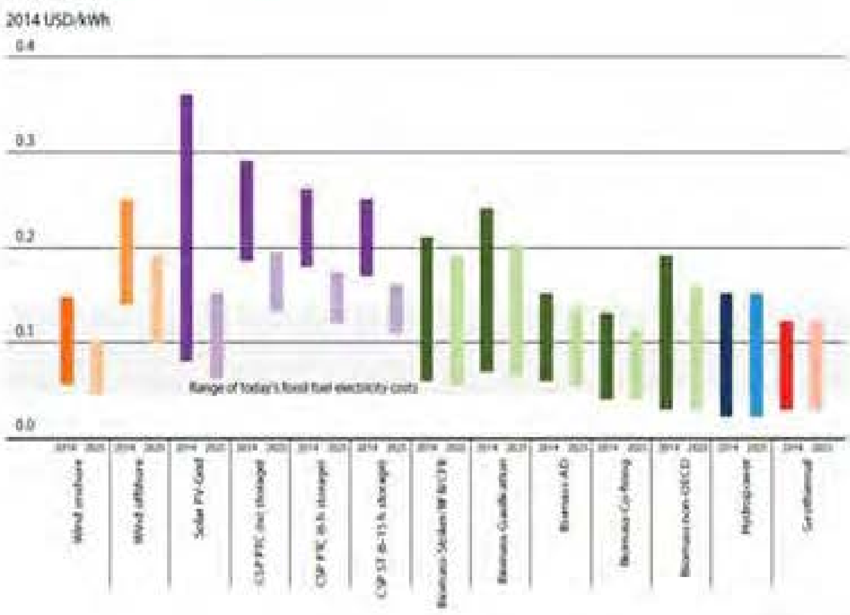


Fig.21: LCOE ranges for renewable electricity 2014-2025

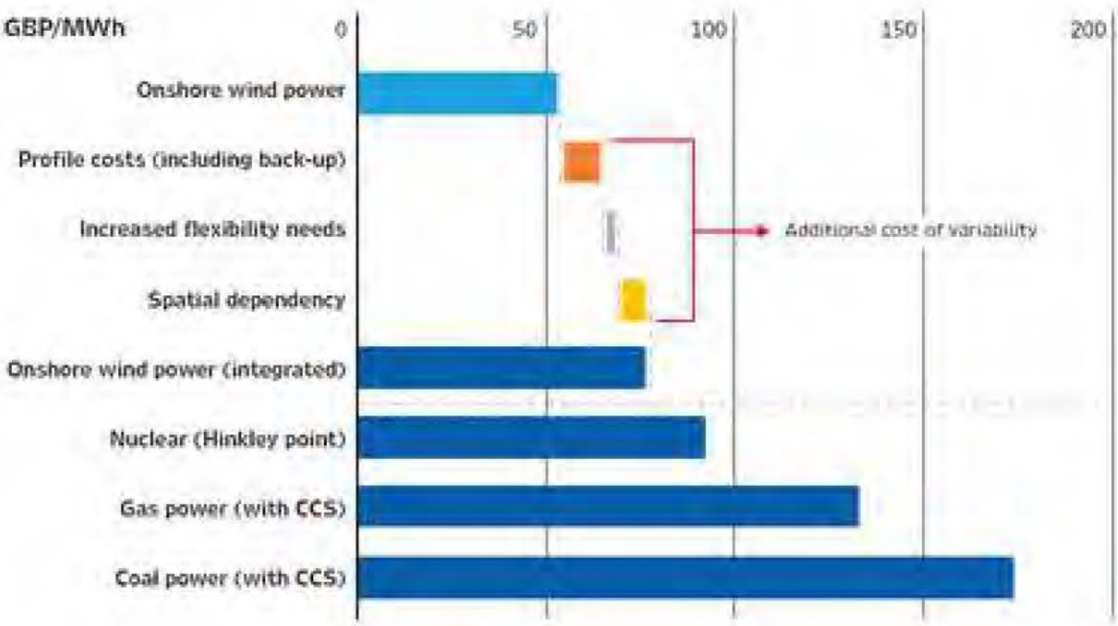


Fig. 22: LCOE of integrated on-shore wind, coal and gas with CCS and nuclear electricity

A projection of levelised RE electricity cost and average power generation cost by the year 2040 has been given in Fig. 23, indicating that RE electricity will almost be costing the same as the average electricity generation cost from other sources. A projection of average annual investments in the power sector from various energy sources is provided in Fig. 24. Clearly solar PV and wind power systems will attract huge investments.

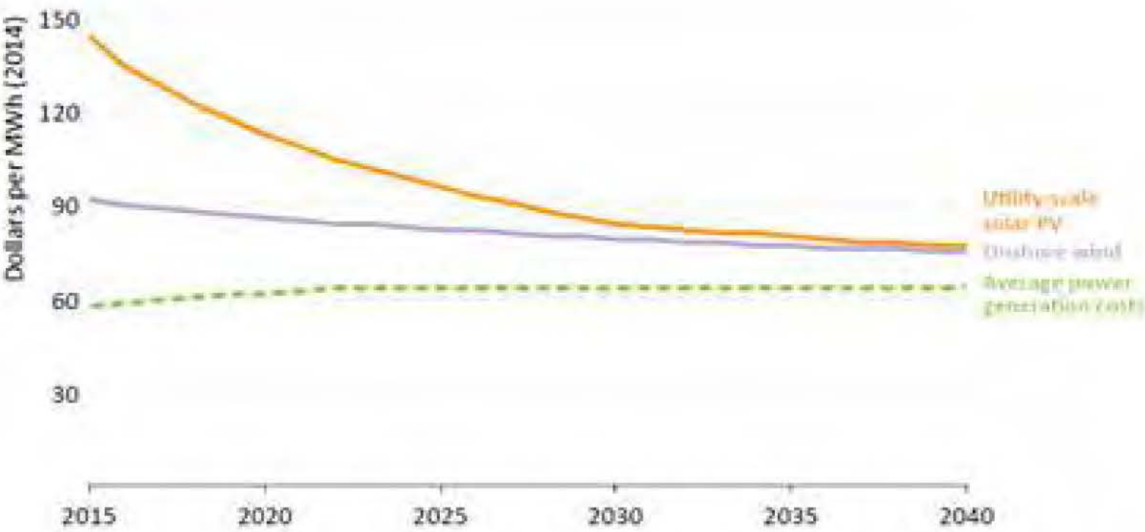


Fig. 23: Expected LCOE of solar and wind electricity generation and average power generation costs

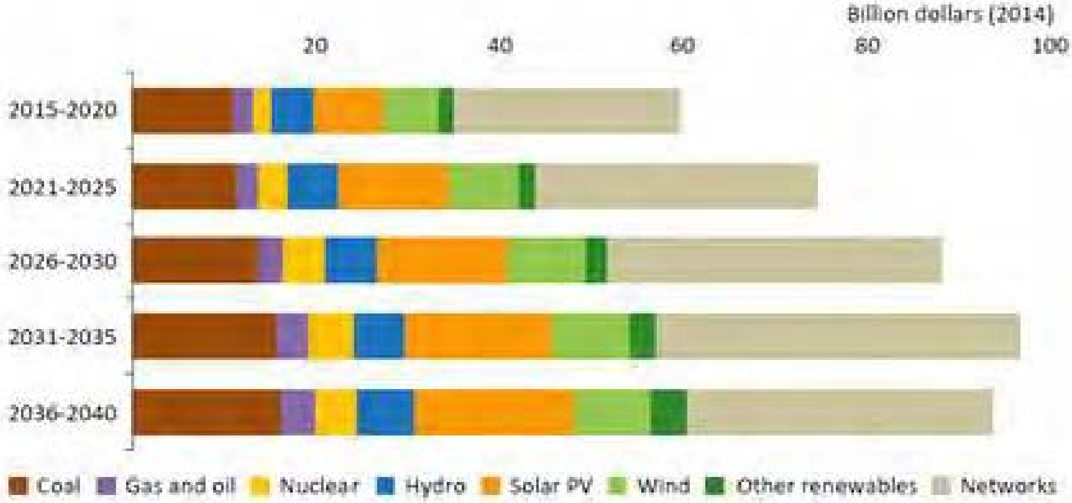


Fig. 24: Projected average annual investments in renewable technologies

For optimized utilization of renewable energy based power plants, however, the networks have to be upgraded and hence adequate huge investments requirements. It is obvious that rational use of energy and renewable energy use are preferred options for climate change mitigation, energy security and to provide universal access to clean electricity.

Chapter 4: Energy and Sustainable Transport

B.N Puri.

1. Introduction

After retirement from Govt, of India, as an advisor in the Planning Commission, I am presently the CEO of Asian Institute of Transport Development and provide advisory services to the United Nations. My contact with energy is in terms of a Solar Roof Top Systems on our building at Dwarka and we had face enormous problems in getting the revenue share promised under the VGF (Viability Gap Funding). Of course, however, energy like any other sector is the key to the development of this sector as well as to ensure sustainability in the process of development. My presentation is divided essentially in two parts, namely, energy use in transport and later to explain the importance of energy to ensure sustainable transport.

Sustainable development, for some years now, is being talked about in every sphere. The significance has been due to transition of low income group of countries to middle income ones, knows as the group of countries with emerging economics. In this period of transition, as the GDP grows, the use of energy, and other natural resources also grow. The same is true for the transportation. To maintain a GDP growth of 7 to 8%, the transport should grow at 9 to 10%. This required growth of transport sector raises the question of energy and sustainable transport for India.

2.0 Sustainable Development and Transport Energy

Sustainability refers to anything that can last long and continue to exist, on long term basis in future after meeting the legitimate existing needs. Sustainable development, though defined and understood in different contexts, aims to ensuring better quality of life for every individual and in order to do so finding ways and means to disconnect development from depletion of natural resources and adverse impact on environment. The challenge therefore before the policy makers and planners is to augment the supply of transport infrastructure and services and to ensure that the entire transport system becomes sustainable.

The definition of sustainable transport is slippery and difficult to pin down. Thus there is no universally acceptable definition of sustainable transport. According to European Union Council of Ministers of Transport, a sustainable transportation system is one that

a) Allows the basic access and development needs to individuals, companies and society and to be met safely in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.

b) Limits emission and waste within the planet's ability to absorb them. Use renewable energy sources at or below their rate of generation and use non-renewable energy sources at or below the rate of development of renewable substitutes, while minimizing the impact on use of land and generation of noise.

c) Affordable and operates fairly and efficiently and which offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development.

3.0 Energy and Transport

Energy in transport is one of the factors that determine the sustainability of this sector. Transport sector accounts for nearly 18% of total energy consumed in India, second only to the industry sector. Almost 98% of energy needs of transportation are met through petroleum products. Almost half of the total consumption of petroleum products in India occurs on account of transport activities. Use of gas and electricity in the transport sector is marginal at 2.5% of the total energy. It may go up to 3.5% in the year 2030 under a BAU scenario. The government has been making efforts to increase the use of these fuels, not only to reduce dependence on oil, but also to lower air pollutant emission.

3.1 Estimates of Energy Consumption in Transport.

In the business as usual scenario (BAU) a study of TERI estimates:

a) Total energy consumption in the transport sector is expected to increase from 81.03 mtoe in 2010 to 266.8 mtoe in 2030, more than threefold increase.

b) Road transport will be responsible for more than 90% (244.5 mtoe) of energy requirements in 2030.

c) Petroleum will be the largest fuel with diesel accounting for 85% of the total fossils in this sector.

A fuel mix in the transport sector in 2030 (BAU Scenario) is given in Fig. 1

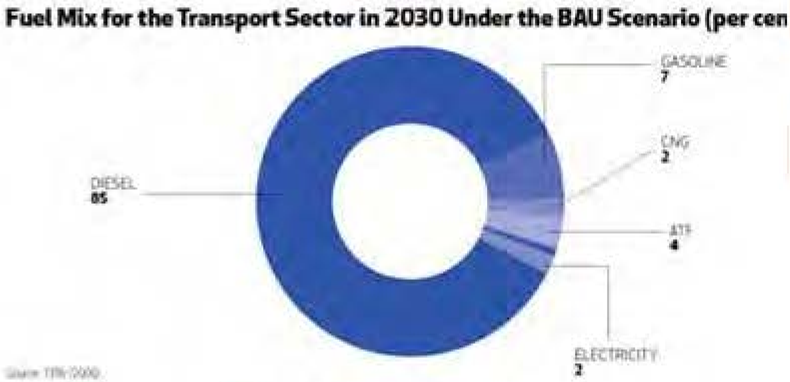


Fig. 1: Estimates of energy consumption in transport

Apportionment of total energy in various modes is illustrated in Fig.2. It is seen that road freight is expected to grow enormously in comparison to other modes.

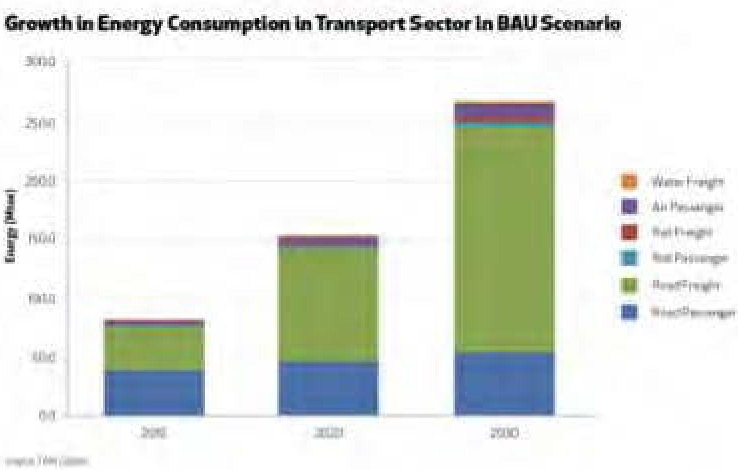


Fig. 2 : Estimates of energy consumption in various modes of the transport sector

In spite of the fact that rail transport is one of the most energy efficient and environmentally benign mode, its relative contribution to road freight as well as passenger mode will be marginal in comparison to road freight and passenger.

4.0 Emissions from the Transport

Estimates of total equivalent carbon-dioxide emission from the use of fuel in transport sector are given in Fig. 3.

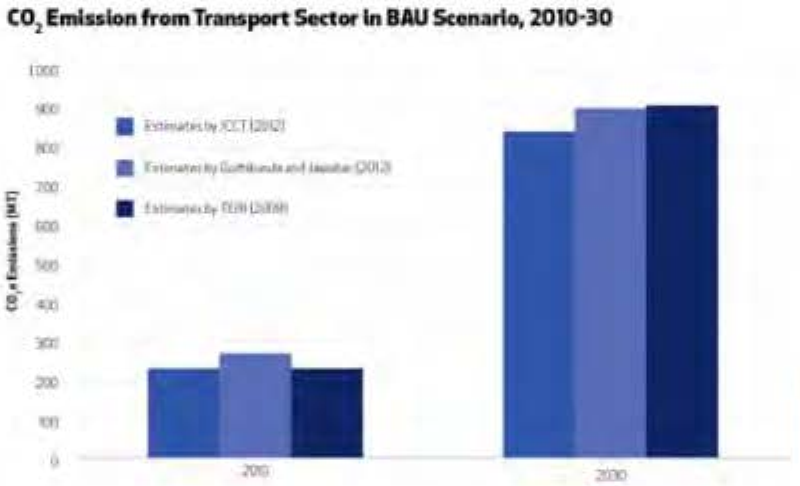


Fig. 3: CO2 equivalent emission from the transport sector

Though there are marginal differences in the three modes, all the three studies suggest 4 to 5 times increase in the GHG emissions from transport sector in India in the year 2030, in comparison to the corresponding emissions in the year 2010.

Besides the GHG emissions, the vehicular, rail as well as aviation modes of transport will lead to pollution of air, water resources as well as on the land. A few selected environmental effects are given in Table 1.

Table 1 : Selected environmental effects in various modes of transport sector

	Marine and Inland WaterTransport	Rail Transport	Road Transport	Air Transport
Air		Air pollution in populated areas, global pollution from thermal generating stations for electric traction	Air pollution (CO, HC, NOx, Particulars & fuel additives such as lead),global pollution (CO2, CFCs)	Air pollution, greenhouse & ozone depletion effects at higher altitudes due to NOx emissions
Water Resources	Discharge of ballast water, oil spills, etc. of modification water systems during port construction & canal cutting and dredging		Pollution of surface and ground water by surface run-off; modification of water system by road building	Modification of water tables, river courses and field drainage in airport construction
Land Resources	Land taken for infrastructures; dereliction of absolute port facilities & canals	Land taken for right-of-way and terminals; dereliction of absolute facilities	Land taken for infrastructure; extraction of road building materials	Land taken for infrastructures; dereliction of absolute facilities

Cont...

Table 2: Other environmental impact of the transport sector

Solid Waste	Vessels and craft withdrawn from service	Abandoned lines, equipment and rolling stock	Abandoned spoil tips and rubble from road road workers, road vehicle withdrawn from service; waste oil	Aircraft withdrawn from service
Noise		Noise & vibration around terminals and railway lines	Noise and vibration from cars, motorcycles & lorries in cities & along main roads	Noise around airports
Risk of Accidents	Bulk transport of fuels and hazardous substances	Derailment or collision of freight trains carrying hazardous substances	Deaths, injuries & property damage due to road accidents; risk in the transport of hazardous substances; risk of structural failure in old or worn road facilities	Death, injuries property damage, due to aircraft accidents
Other Impacts		Partition or destruction of neighbourhoods, farmland and wildlife habitats	Partition or destruction of neighbourhoods, farmland and wildlife habitat; congestion	

Source: State of the Environment in Asia and the Pacific (1995), UN-ESCAP/ADB, ST/ESCAP/1535, p.289.

The transport also generates solid waste, noise and increases the risk of accidents & has other impacts as summarised in Table 2. It is clear that the BAU scenario of the developments in the transport sector and use of energy are not sustainable and need to be controlled through an effective mechanism.

5.0 Conclusion & Solutions

The transport sector in India needs an effective and institutional mechanism, where the urban development and the transport are considered in a holistic approach. There is a need to strengthen the public transport and provide mechanism to discourage individual transport use. We need to consider the environmental and social costs along with the cost of fuel alone.

Periodical review is required to upgrade fuel quality and emission standards after taking into account the technology development and carrying out a cost benefit analysis. We need to develop an adequate and competent mechanism for compliance and enforcement to control vehicular emission.

Last but not the least, our public transport system should be upgraded and its use made mandatory on certain hours of the day in congested urban areas.

Chapter 5: Wind Energy: India's Option for Clean Energy.

J.K Jethani.

1. Introduction

In my presentation today, I will summarize the programme of the Ministry for New and Renewable Energy Sources, Govt. of India, to promote wind energy utilization for our growing electrical energy demand. With 979 bkWh electricity consumption per year, India stands at number four amongst major consumers of electrical energy; however its per capita consumption is amongst the lowest in the world at 783 kwh/c.a (Fig.1).

Fig.1: India's Electricity Consumption

India's power sector has grown rapidly with total installed capacity of 285.7 GW (Fig.2) on 31.12.2015, dominated by coal Fig. 2 ((61%) followed by large hydro and renewable contributing 15% and 14% respectively followed by gas and nuclear.

Thermal	Hydro	Renewable	Gas	Nuclear
174	42.6	38.8	24.5	5.8

Source: Central Electricity Authority (CEA) as on 31.12.2015

Fig. 2: India's Power Sector

Renewable power has grown very rapidly in the 12th plan (Fig.3); contributing 38.8 GW to the total installed power plants with wind contributing around 25GW and solar about 5GW.

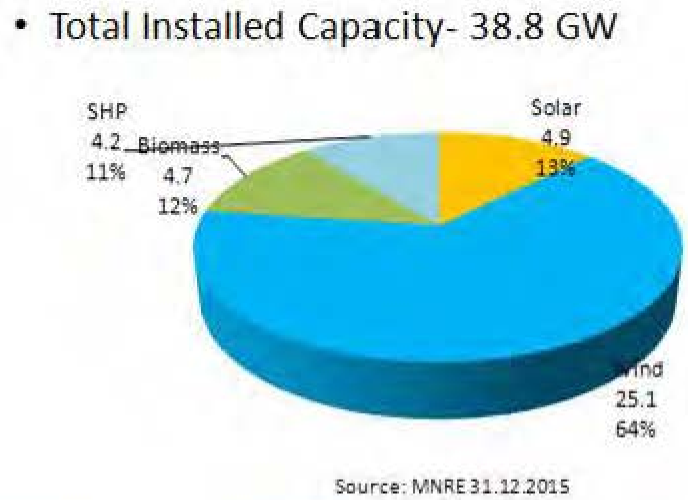
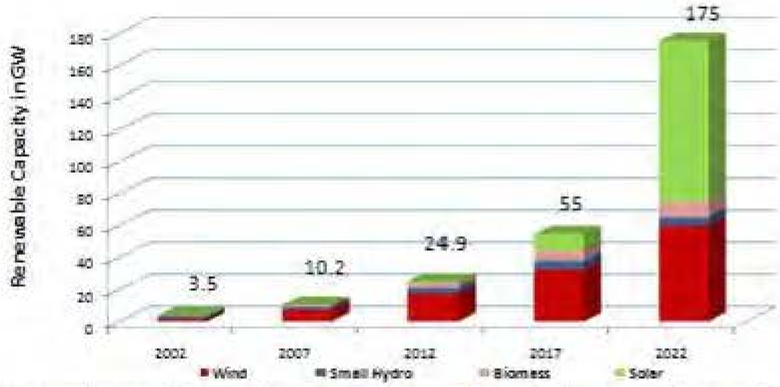


Fig.3: Renewable power capacity by the end of December 2015

In previous five year plans, renewable was given a lower priority; for example at the end of 10th plan the total installed capacity of renewable power was 3.5 GW and towards the end of 11th plan the total capacity was 15 GW only dominated by wind, while the solar was only a couple of megawatts. For the 12th plan, the previous government has fixed the renewable target at 30 GW, which now under the new government has been revised to 175 GW by the end of the year 2022; year wise planned capacity is given in Fig. 4, with major contributors from solar (100 GW) followed by wind (60 GW).



RE Resource	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Total
Solar	2,000	12,000	15,000	16,000	17,000	17,500	17,500	97,000
Wind	2400	4100	4700	5300	6000	6700	7356	60000
Biomass	400	500	750	850	950	1000	1016	10000
SHP	220	225	100	100	100	100	100	5000

Fig. 4: Growth of renewable power and future plans

2. Growth of Wind power in India

Wind power plant capacity has grown steadily in India since the year 2002 (1666 MW) to 25188 MW presently (Fig.5) and more than 35000 MW to be installed by 2022.

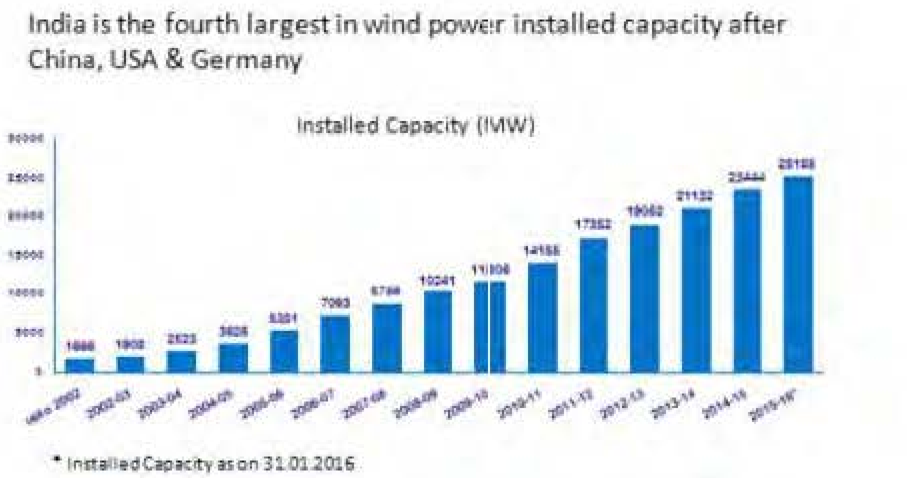


Fig.5: Growth of wind power plants in India

Wind is of course location specific with major potential in coastal areas or in the desert areas of Rajasthan. Installed wind power capacities in major Indian states are given in Table 1.

Table 1: Installed wind power in wind dominating states of India

S.No.	State	Installed Capacity* (MW)
1.	Tamil Nadu	7515
2.	Maharashtra	4638
3.	Gujarat	3878
4.	Rajasthan	3578
5.	Karnataka	2887
6.	Madhya Pradesh	1200
7.	Andhra Pradesh	1155

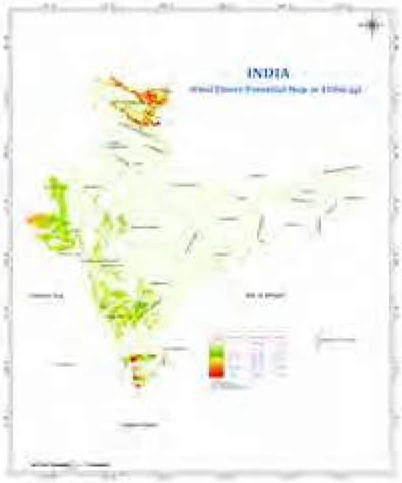
2.1 Parameters for the Growth of Wind Power

Wind power programme is one of the best planned and executed sectors for electricity generation in India. In the last twenty five years, there has been extensive wind resource assessment data with emphasis on technology development and a strong domestic manufacturing base. Quality of manufacturing has been assured by setting up standardization and testing facilities and more importantly there has been a consistent conducive policy framework for investments.

National Institute of Wind Energy (formerly C-WET) has been responsible for installing 800 monitoring stations since its inception in the year 1998, as the Centre for Wind Energy Technology and converted to National Institute of Wind Energy in the year 2010. The institute has already published eight handbooks on Wind Energy Resource Data and the detailed data sets are available to the industry on nominal payments. In the last couple of years, the institute has been measuring the wind at 100 M height and an online wind resource atlas has been made available to interested groups. The shore wind power potential at 100 M altitude has been revised to 302 GW wind power (Fig. 6).

The revised potential assessment has been carried out at a very high spatial resolution of 500 m, using advanced meso-micro complied numerical wind flows model, and with the corroboration of 1300 actual measurements spread all over India. The new wind atlas is available online at the NIWE'S website

Potential @100 M: 302 GW



The revised potential assessment at 100m has been carried out at a very high spatial resolution of 500m, using the advanced meso-micro coupled numerical wind flow model, and with the corroboration of 1300 actual measurements spread all over India, which can be stated as first of its kind. The revised wind atlas is available online at NIWE's website.

Fig. 6: On shore wind power potential in India at an altitude of 100m

3.0 Technology and Manufacturing

Indian wind energy technology and manufacturing base is the state of art comparable to best in the world. Indian manufacturers are providing wind turbines in the range of 250 KW to 3 MW in both the model namely, gear or gearless. The hub heights have been up to 141 meters and the rotor diameter upto 114 meters. There are 19 manufactureres in the country with 53 different models.

Fig. 7: State of Art Technology and Manufacturing in India

Indian wind turbines are being exported to USA, Europe, South America and other Asian countries, because the cost of Indian wind turbines is amongst the lowest in the world. Indigenization of Indian wind turbines has already reached 70% with rotor blades, gear boxes, yaw components, nacelle cover, raw material for blades being manufactured and available in India. Efforts are on to achieve 100% indigenization.

Quality of Indian wind turbines is ensured through international level testing facilities backed up by standardization and certification. Constant R & D is the backbone of Indian Wind Power Industry and National Institute of Wind Energy at Chennai constantly updates information and provides training as well as commercial services. The RLMM National Committee approves wind turbine models, revises and updates list of manufacturers of wind turbines and components.

4.0 Policy Incentives.

The Indian government, in order to promote clean energy, has provided a number of fiscal incentives. These are income tax holiday under U/S 80 1A for 10 years and full excise duty exemption on all parts of a wind project. On specified parts and components concessional import duty is levied and there is a complete exemption on the special Additional Duty (SAD) on parts and components of wind turbines.

With respect to feed in tariffs, there is a general Generation Based Incentives at the rate of Rs,0.50 per unit over and above the feed in tariff fixed by the state regulator. The GBI has a ceiling of Rs.10 million per MW which can be availed in a period of more than four years but less than ten years. The GBI is allowed to captive producers but not to any merchant in power business. In parallel with the GBI, the government also offers an accelerated depreciation of 80% on either or basis. This means either avail GBI or the accelerated depreciation. The promotional tariffs provided by various states for wind electricity, given in Table 2.

Table 2: Wind policy in states

State	Tariff
Andhra Pradesh	4.83
Gujarat	4.15
Karnataka	4.5
Madhya Pradesh	5.92
Maharashtra	3.91-5.70
Rajasthan	5.74 & 6.02
Tamil Nadu	3.51

In addition concessional wheeling, banking, electricity duty and gross-subsidy charges are provide to wind electricity producer.

5.0 Off-Shore Wind Power.

Considering the success of off shore wind power in many developed countries, India has also been planning off-shore wind power plants, because of a huge coastal line of 7600 kms (Fig. 8). The various parameters for off-shore wind installation is that the site should be available within 20 km of the sea coast/port and the average water depth should be less than 25 meters. The average wind speed should be more than 6.5 m/s at 50 m height. The Entire Exclusive Economic Zone (EEZ) must be available for off-shore wind installations and it should be outside all oil and gas activity zone, marine protected and away from submarine power communication channel, air traffic and should not pose any security risk. Additional technical criteria are cyclone and earthquake zones. The off-shore platform has to be within 20 km from on-shore substation.

Already good off-shore platform has been identified in Tamil Nadu and Gujarat and an off-shore wind policy has been notified on 6th October 2015.

6.0 National Wind Energy Mission

Considering the success of wind power plants the 12th plan document of the National Planning Commission recommended the establishment of a National Wind Energy Mission. The directive from the PM's council on climate change make it a part of National Action Policy on climate change (NAPCC). This has become necessary in view of the revised target of 60 GW of wind power to be installed by the year 2022.

The National Wind Mission is to cover integrated policies for data availability, standardization, repairing, and absorption of wind power by statics and promotion of small wind power as well as off-shore wind power sectors.

7.0 Conclusions.

Though wind power has proven to be economically and technically viable, it faces major challenges. The main challenge has been the variability of wind speeds that require accurate forecasting, scheduling and balancing by the Load Dispatch Centres. The Ministry (MNRE) is working with the CERC,Discoms and the states to resolve the issues, already

- CERC issued forecasting and scheduling regulations for interstate transmission of wind and solar power in August 2015.
- NIWE has successfully carried out pooling station level F&S for the state for Tamil Nadu with 5-10% accuracy.
- A Renewable Energy Management centre is being established.

Since wind potential is concentrated in a few states, the interstate and intrastate transmission strengthening has been taken up under green energy corridor. The tariff policy has been amended to exempt interstate transmission loss and charges for solar and wind power. An electricity act (amendments) bill has been introduced in the parliament to ensure RPO compliance by the states..

Chapter 6: Oil and Gas: Necessary for Economic Growth.

Rajiv Khanna.

1. Introduction

Oil and its products have become necessary for economic growth and this commodity remains too deep into our lives. Substituting oil with any other product has wide implications and the transformation is highly unlikely. Besides the use of oil and its products in the transport sector, most products and goods in our lives are based on oil. The fibre, detergents, plastics, medical life saving stents, fertilizer, textile etc are dependent on the use of petroleum products, namely, oil or gas. In contrast to energy crisis of 1973, the world is witnessing an era of cheap and abundant energy. After reaching an absolute peak of oil prices in the month of June 2008, at US dollar 142 per barrel, the world is witnessing sliding oil prices since 2014. The oil supply is in surplus and the demand has slowed down. The reasons are slowdown in China, Japan and many countries in Europe. The US who never exported oil, has increased its oil production by four to five times reaching 4.5 million barrels per day to become the leading oil producing country in the world and US has entered the world market of oil by allowing its export. Not only that, US has invested immensely in the area of shale gas and salt hydrates technology and the domestic production of natural gas has also been increased by four to five times. Saudi Arabia, which is the second largest oil producing country of the world after US, refuses to balance the volumes of oil production fearing loss in the revenue. India has obviously benefitted from declining oil prices in the world and in one year only about 70million dollars have been saved.

However, the oil demand is likely to grow and will mainly be driven by the transport and petrochemical product. As per the estimates of OPEC oil demand may peak at 100 million barrel/day. Till shale gas and oil become a reality, the dependence on Middle East will continue. The oil prices are certainly set to rise and US is investing heavily, in shale gas and oil exploration. Mr. George Michael has perfected the shale gas and oil production technology with horizontal drilling at 10000 feet followed by fraking. The technology is complicated and US has the ability to flex its muscles. As soon as the world oil prices reach 60 dollars a barrel, shale oil becomes competitive. This also brings to the argument that once shale gas and salt hydrate resources become available, oil and gas resources will look to be much better distributed than the present oil resources and the balance of US relationship with oil producing countries may have to be changed.

2. India's Oil Equation.

India's domestic production of oil remains stagnant at 37.5 MT, whereas the consumption of petroleum products is 165 MT, which is equivalent to 184 MTOE. This means that India's oil import dependence is 78% and the value of oil import is 113 billion US dollars a year. India has one of the most modern refinery set up in the world and produces 220 MT of petroleum products, that are also exported and fetch the country 43 billion US dollars annually.

As far as the natural gas is concerned, India's domestic production is 90 Metric Million standard cubic meter per day (mmscmd), whereas our total consumption is 132 mmscmd. Our natural gas share of imports is therefore at 32% with LNG imports at 42 mmscmd, the value being 10 billion US dollars.

With reference to annual consumption of petroleum oil at 16 MT, the distribution is LPG (18 MTOE), motor spirit (19 MTOE), Naphtha (11 MTOE), Aviation Transport Fuel (ATF) (5-6 MTOE), SKO

(71 MTOE) and HSD (69 MTOE). 70% of the HSD is used in the transport sector and 30% for non-transport use. About 45% of the total oil, namely 72 MT, is used in the transport sector and its is increasing at a CAGD of 4-6% per annum.

Note: 1 BCM(Billion Cubic Meter)/ year of gas is equivalent to 2.74 mmscmd, 365days a year.

3. Domestic Oil Production Outlook

The domestic production of oil is stagnant at 37.5 MT and this production has been predominantly coming from ageing manufacturing fields. No major step is either taken up recently or even expected in short or medium term. There is no line of sight for any large potential discoveries or finding or new emerging provinces/basin. Due to increasing domestic demand of a growing economy, the intensity of oil imports will therefore continue to rise.

The projection for oil demand since 2011 has been provided in Table. 1.

Table 1: Oil demand projections in India in MMT

Year	Projected oil demand (MMT)
2012-13	152.9 (157.1)
2013-14	160.4 (158.4)
2015-16	168.5 (165.0)
2016-17	177.0
2017-18	197.4
2018-19	209.2
2019-20	220.7
2020-21	232.6
2021-22	245.0

The figures in the bracket for past years indicate actual consumption. The projections have been made at a CAGR of 4.8% and if the economy grows above 8%, the crude requirement may increase at a CAGR of 5-6%; namely a requirement of 206 MMT with year 2017-18 and of 270MMT in the year 2021-22. The import dependency will then be 85% or more.

4. Domestic Natural Gas Production and Demand.

The 1980's oil glut was a serious surplus of crude oil caused by falling demand that followed the 1970's energy crisis. In the year 1986, the oil prices fell fellow US dollar 10, and the emitting gas was considered to be a nuisance and used to get flared into the atmosphere. In the year 1990, however, petroleum gas became a product for fertilizer and many other applications like producing electricity. Because of low gestation periods, India planned electrical power plant capacity of 85000 MW using natural gas and today we are nowhere near it. The gas plant capacity of 23.33 GW runs only at 30% CUF or less due to scarcity of gas. Our domestic gas production outlook as envisage in the 12th and 13th plans is given in Table 2.

Table 2: Domestic Gas Production Outlook (12th & 13th plans)
Gas production outlook in(mmscd)

Year	Gas Production outlook	Year	Gas Production outlook
2012-13	192 (109)	2017-18	255
2013-14	198 (95)	2018-19	262
2014-15	203 (90)	2019-20	270
2015-16	239	2020-21	278
2016-17	247	2021-22	287

The figures in the bracket shows actual gas production and one may conclude that actual production is much below the projected figures and therefore the projected growth of the domestic gas production is very unlikely. There has been a big pull down from the eastern shore and the new projects are delayed. The laying of pipe line from Oman or Iran is difficult due to geopolitical regions.

The demand for natural gas in the country is however, set to raise; table 3 gives the projected demands in recent years and in the future.

Table 3 : Natural Gas Demand in India (mmscd)

Year	Natural Gas Demand	Year	Natural Gas Demand
2012-13	293 (148)	2017-18	494
2013-14	371 (133)	2018-19	523
2014-15	405 (131)	2019-20	552
2015-16	446	2020-21	586
2016-17	473	2021-22	606

The figures in the bracket indicates the actual availability and its shows that availability of natural gas is far below the projections. The demand for natural gas is projected to increase due to the following sectors.

Power 135 mmscd (2012-13) – 307 mmscd (21-22)

Fertilizer 62 mmscd (2012-13) – 113 mmscd (21-22)

City Gas 15 mmscd (2012-13) – 57 mmscd (21-22)

Refined Petroleum Products 54 mmscd (2012-13) – 82 mmscd (21-22)

If the projected demand targets are to be met, India needs to concentrate immensely on the supply side.

5. IEA India Energy Outlook -2015.

A study of the International Energy Agency for India's Energy Needs as also stated by the speakers, earlier shows the growing energy demand in the country, that more than doubles by the year 2040. The domestic energy supplies, including the coal, will lag demand and the total primary energy imports may reach 40% of the total energy consumption. India's oil demand may reach 10 million bbld/d and the dependency on imports will be 9 million bbl/d, which is more than ninety percent of total demand. The requirement for the natural gas should triple to 175 bcm/a (or 48 mmscd). The domestic gas production is projected to be 245 mmscmd and even if the projected output is met, on additional 235 mmscmd natural gas will have to be imported. The growing oil demand will be fuelled by massive increase in the transport sector; which is likely to add 250 million passenger cars , 185 million two and three wheelers and 30 million trucks/commercial vehicles.

6. Recent National Initiatives impacting Future Oil & Gas Demand

The recent policy initiatives of the Indian government like Make in India, climate change commitments and Green Corridors will fuel India's energy demand in general and that of Oil & Gas in particular. In future, due to Make in India approach, the manufacturing in GDP is set to grow significantly. This requires energy. A manufacturing industry requires ten times more energy than the corresponding growth in the service sector. In the recent Paris convention, India has pledged to reduce carbon emission intensity of GDP by 33% to 35% by the year 2030. The bridging fuel in this regard is the Gas. Globally gas is considered to play a larger role. India's has also planned to set up 175 GW of renewable power driven by solar and wind. Both the sources are intermittent and the grid balancing and stability requires inherent operational flexibilities of gas based power units.

India has also planned green corridors that require interstate movement of CNG vehicles. In the US, China and Europe, the trend of gas or CNG use is mainly in medium to heavy vehicles. In US, however, lot of transport is happening by the use of liquefied Natural Gas. The benefit is that a heavy vehicle, with LNG tank, can go up to 800-900 Kms. Such a distance reduces the number of CNG stations along the green corridors. TATA is considering the establishment of such a green corridor in India.

Another factor that will fuel oil & gas demand is the growing urbanization, which drives the demand for consumer goods with more than 100 cities that may be added in next ten to fifteen years, the CGD net work will grow. If the pollution of increasing number of vehicles is to be checked, gas is important to manage urban pollution created by transport, small scale industry and commercial sector.

In the important agriculture sector, the rising population and growing income will fuel the requirement of high food production. A "Second Green Revolution" may be needed that will necessitate huge fertilizer production that prefers gas as the feedstock. For gas, Eastern India could be developed into a big gas market.

7. Energy Policy and Strategic and Focussed Attention.

India lacks a solid energy policy and lack of focussed attention on the energy supply, mainly for gas and oil. As far as the energy resources are concerned we are much better endowed with them than countries like South Korea & Japan. We need a political will and a strategic focussed attention to enhance domestic oil and gas supply. The three supply enables are the resource availability market connectivity and competitive pricing. All the three are supply enablers as explained in Fig. 1.

India is yet to concentrate on its hydrocarbon resource endowment. The prognostic resources of conventional oil and gas are about 28.1 billion toe (18.2 billion off shore), where as in place reserves are only 11.23 billion toe as on 01.01.2015. There is therefore a scope of up gradation by 40%. There as estimated potential of unconventional oil and gas resources in India like 2600 bcm of Coal Bed Methane, and potential to find shale oil and gas. The EIA estimates of 2013 give a potential of 16,515 bcm gas and 87 billion bbl oil. The ONGC estimates of 2013 are only 5300 bcm gas. However ONGC explorative equipment is outdated. It is also estimated that India has huge deposits of off shore gas hydrates. The country needs to invest to strengthen domestic oil and gas supply and a consistent policy to support the industry. US spends 100 million dollars a year to develop the industry for newly find energy sources like shale gas and gas hydrates. India is not doing enough on exploration and appraisal of domestic petroleum resources. More than 50% of the conventional fields are yet to be appraised. In this 50%, 65% are on land, 15% in shallow waters and 49% in deep waters. Marginal work is underway in Coal Bed Methane and work on shale oil and gas is in very early stages. Considering hydrates as futuristic recourses, some work is being planned by the government in this direction.

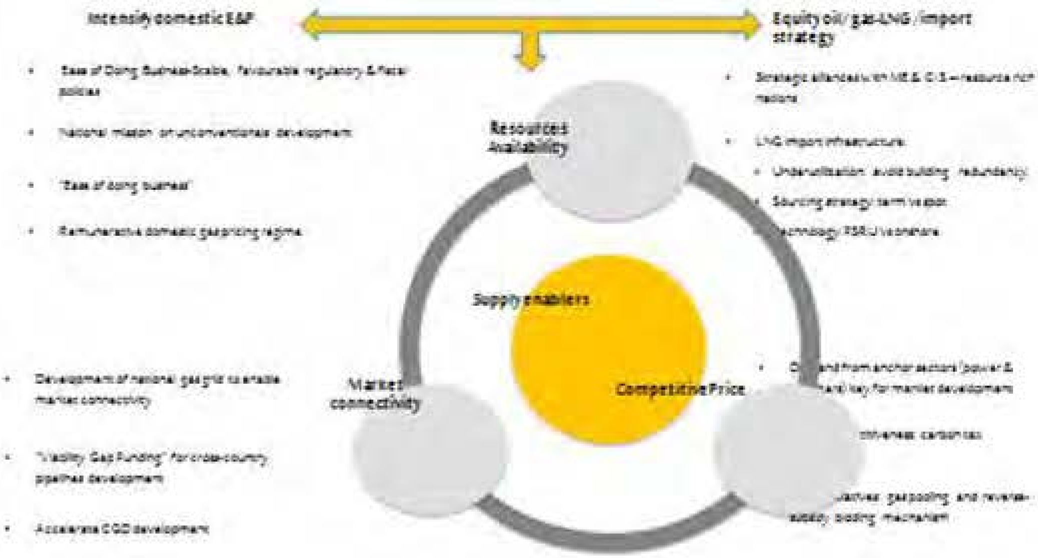


Fig. 1: India needs a strategic and focussed policy towards gas and oil supply

8. Conclusions.

Considering India's huge present and future energy demand, India needs a more reliable energy demand assessment and long terms strategic position on its energy needs and supply options. Since the investments will be heavy, the country will require private capital. To attract the same, comprehensive and consistent enabling policies and regulation need to be in place. New economic growth models required growing needs for oil and gas, necessary to build the economy. The use of natural gas also aligns well with the "Emission Reduction" agenda and the INDC.

India requires technologies to understand and exploit its energy resources, including the futuristic ones. India needs larger collaboration with global players in the domain of unconventional & deep water exploration. The country should strongly pursue its bio fuel programs and underground coal gasification.

Chapter 7: Challenges in Management of Large Power Stations.

K.B Dubey.

1. Introduction

I have been working in the power sector for the last thirty five years and I promise that my learning will provide good lessons to our grand children, who intend to work in this sector in India. Today India's power sector is not in a very good shape. The largest public power corporate, namely the NTPC, is suffering huge losses and the operational and managerial staff is highly frustrated. I left the NTPC in the year 2009, when Dadri unit was operating at 100% PLF and Singrauli at 120% PLF. Today Singrauli power plant of 2000 MW is completely closed, because there is no buyer for power. The NTPC has constructed a natural gas based power plant at Faridabad in the 2000 of capacity 430 MW and we had signed a PPA with Haryana government to sell electricity at the rate of Rs.1.19 per unit. However, the plant became operation in record time of seventeen months and the NTPC had to revise the cost of electricity at Rs.1.16 per unit. Today there is no gas for the plant and it is closed. Similar is the fate of other natural gas power plants with a total capacity of 5000 MW, which is lying idle.

There are immense challenges in managing and operation of power plants and a bulk of these challenges emanate from the governmental policies from time to time. Due to a number of these challenges ranging from regulatory, technical and environmental etc., NTPC plants are running at an all India average of 70% PLF, which earlier used to be 85%. Due to non-availability of gas and quality coal, as well as from the regulatory and environmental challenges, the Indian power sector is constrained and face problems that need to be identified and solved as soon as possible. I will like to deliberate on such issues and also hunt a solution to overcome the same.

2. India's Installed Power capacity.

Sector wise installed power capacity in India, by the state, by the centre and by the private sector is given in Table 1. The private sector comes in the category of non-regulatory power.

Table 1 : Installed Electrical Power in India.

Sector	Capacity	Percentage of Total
State	97,951.00	34%
Centre	74,807.00	26%
Private	1,15,248.00	40%
Total	2,88,006.00	100%

Fuel wise installed power plant capacity is given in Table 2. The largest base for power plant capacity is by coal, and this will remain so,

Table 2: Fuelwise Installed Power Plants in India.

Fuel	Capacity (MW)	Percentage (%)
Thermal	2,00,740.00	69.7
Coal	1,75,238.00	60.8
Gas	24,509.00	8.5
Oil	94.00	0.3
Hydro	42,663.00	14.8
Nuclear	5780.00	2.0
RES	38,822	13.5
Total	**2,88,006.00**	**100**

Because of its domestic availability for a couple of hundred years and this source will be the energy source to provide the base loa. It is there for evident that 76.7% of electricity generation comes from coal (as on January 2016) as given in Table 3.

Table 3: Electricity generated by various fuels. (as on 31.01.2016)

Fuel	Generation (BU)	Percentage (%)
Thermal	777.570	80.75
Coal	738.787	76.73
Gas	38.459	3.99
Oil	324.00	0.03
Hydro	108.322	11.25
Nuclear	30.809	3.2
RES	46.201	4.8

3. Power Plants.

Ever since its inception, NTPC has been able to overcome the problems of old power stations in India that used to run on a very low PLF. The NTPC had set a growth target of 10 to 12% before the swearing in of the NDA government. The Minister for Energy, Power, Coal, and Oil recently announced that India is a power surplus country. The announcement however ignores the realities. The federal states have an easy option of not buying power in case of revenue loss, especially in the case of promising cheaper or free power in the villages. The result is the declining PLF and idle capacities of the state or central owned power plants. Fig.1 shows the declining PLF and capacity utilization of NTPC owned power plants. Unused capacity of NTPC Power plants is 5000 MW and though the public company can operate at 92% PLF, it is forced to operate at 77.7% PLF presently and able to use only 61.7% capacity utilization. Operating power plants at partial loads leads to inefficiencies and the cost of power increases. Additionally, the auxiliary power consumption per unit generation goes up making the operation still costlier. Another related factor w.r.t partial load operation is the insufficient availability of fly ash that is being utilized by the klinker manufactures'. Dadri power plant produces 3800 tons of fly ash daily, if it operates at 100% PLF. At present PLF of the plant is 70%, it is therefore not able to supply the required amount of fly ash to three klinker manufactures who have established klinker facilities near the power plant. The result is that they are thinking of closing the units and shift somewhere else.

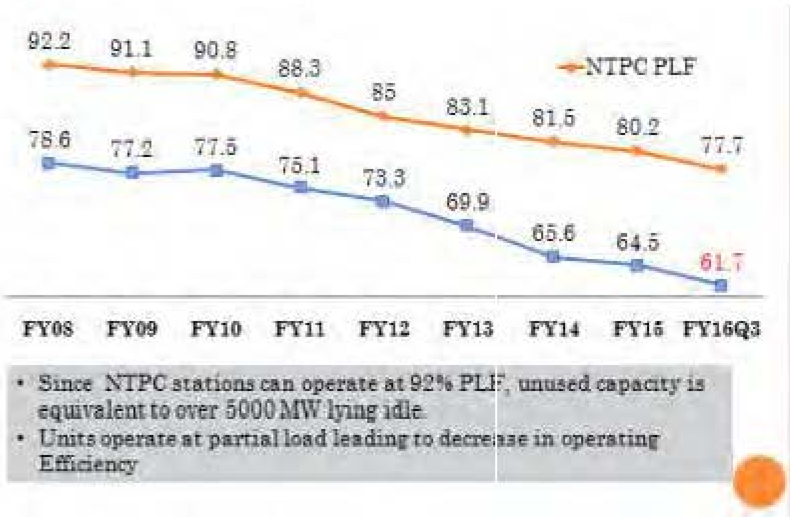


Fig. 1: Declining trends in the plant load factors

4.0 Challenges faced by large Thermal Power Stations.

Today large thermal power plants face immense challenges from regulators, from technology, from the environment, operational challenges, competition and others.

Like all business people, the public corporate also have their comfort zones. Regarding auxiliary consumption, NTPC shows 12% as auxiliary power consumption for operation of their own plants. This of course also includes free power to NTPC townships. After retirement, some of the NTPC officials became members of regulatory commissions. They use the inside information to squeeze public corporate and now finalized the auxiliary power consumption to 7%, thus taking away the comfort zone, the NTPC used to have.

The other challenge that is being faced by the coal power producer today is the quality of coal. Indian coal is known to have large content of ash. Hence, in the UPA regime, it was allowed to blend domestic coal with 20% imported coal of higher quality. Now the Govt. of India wants us to use Indian coal and get the payment from the dispatched centres. This leads to lot of problems. Heat norms are historically based on GCV value; however the GCV measurement is now changed to the received basis. There are often huge differences in the quality of coal received at the power plant and the one loaded at the dispatched centres. The Government wants to share all the gains but put losses in the account of the generator only.

There are problems with the auxiliary services of the power plant also like better frequency control and the grid stability. The later has been discussed also in relation to renewable power integration with the grid. The tariff policy of the government needs to change with new rules and regulations. As an example, at Sholapur 1320 MW power plant was promised provision of water from the municipality, Maharashtra Government, however, is now insisting that the company should use recycled water for the plant's operation. NTPC is investing Rs.9500 crore in this plant using supercritical technology, and the cost of a recycling plant will further increase the cost and therefore the electricity tariffs. In addition, the NTPC personnel fear that recycled water could damage critical equipment. Also there is social stigma attached to recycled sewage water, particularly for its use in the households. The project on account of these problems associated with the policy change is likely to get delayed, escalating the project cost and affecting the power tariff.

The power plant technology is also facing the problems under the new power policies. Due to excess capacity, the power plant operators are running the units at lower load below the technical minimum. At lower load the power plant runs under strain effecting machinery as well as the efficiency. Also, the NTPC is forced to operate many plants in two shifts instead of three shifts which was happening earlier. This reduces revenue and the flexibility of pricing is taken away.

Under the new renewable energy policy, particularly for solar and wind, NTPC has been asked to bundle renewable power with coal generated power and adjust the electricity tariff accordingly. Bundling of solar and wind generated electricity increases the tariff and secondly the fluctuations in the wind and solar generated power will necessitate advance control mechanisms, particularly for wind, that are not yet in place. Also there are administrative problems due to lack of coordination amongst various agencies. At Dadri coal power station of, NTPC has installed a 10 MW solar PV power plant. It took NTPC three years to sign the PPA with the state discom. It is therefore obvious that bundling in all situations is not easy and difficulties are posed in view of the poor financial health of the state discoms.

The other challenge that is being faced by the NTPC is the renovation and modernization of units that are more than 25 years old. A total of 34,300 MW units need to be renovated and modernized. Additionally, no new plants are being planned and the growth is stagnating.

New environment norms that need to be followed by coal based thermal power plants are very stringent. The existing power plants were originally designed to comply with less stringent norms. Massive investments are required to make the old units compatible to new environmental norms. Also during renovation and modernization phase, there are losses of revenue that affects the overall financial health of the corporate.

Besides the challenges of regulators and environment faced by the thermal based power generation units, there are a number of operational challenges. This include running units at low load and hence efficiency loss, frequency changes in load leading to reduced equipment life, difficulties in low load operation of super-critical units requiring changes from dry to wet mode and overall increased maintenance cost .

The other issues of concerns are retaining experienced manpower, safety of power plants and the waste issues. In the later, fly ash management is posing problems because utilization level is negligible in comparison to the quantity of ash produced. Development of further ash holding capacities by adding more area or raising the dyke are the only options.

5.0 Conclusions

Conventional power plants especially based on coal are facing major challenges due to new energy and environmental policies. The government decision to use only low quality domestic coal reduces life of coal based components and results in increased maintenance cost. In addition, there is loss in efficiency and increase in auxiliary power consumption.

The policies of solar and wind power capacities up to 175 GW induce mismatch in installed capacity and demand and result in decreased PLF. The coal based power plants are strained due to excess capacities and changing national and international environmental laws.

The need nowadays is to have a regulation related to base load generation, spinning reserve and time of the day etc. The new units need to be designed with advance control systems to take care of renewable power integration. Forecasting of solar radiation and electricity generation accurately to load dispatch centres may become necessary due to planned solar capacity. We need to focus on waste disposal especially the utilization of fly ash and also proper manpower development in new technologies that can meet the challenges based by changing power scenario in the country.

Chapter 8: Role of Bioenergy in Providing Energy Security for India.

A. R .Shukla.

1. Introduction

When we speak of energy security for Indian, then the question comes, for whom? Energy is required for existence, subsistence and economic activities for rural areas, semi-urban areas, and urban areas, for rural industry as well as other industries, and for not only those who can offered to pay but also to those rural and urban poor, who can't pay. In the Integrated Energy Policy Report of the planning commission, section 8.3 of chapter on "Household Energy Security: Electricity and clean Fuels for All", the energy security recommends to provide life line entitlement of 30 units of electricity and 6 kg of LPG or equivalent amount of kerosene for or both life line energy needs through a system of smart/debit cards with varying levels of cash support to the targeted households. It is in this context, bio-energy holds the promise to fulfil the energy needs of the rural people.

2. Bio-energy for Cooking and Lighting Energy Needs.

Minimum cooking and lighting energy needs can be provided through solid (dry or wet) and liquid biomass waste by using efficient combustion or gasification systems or through anaerobic digestion in bio gas fertiliser plants. With respect to providing LPG, the requirements are huge. A lifetime cooking energy of 6 kg of LPG per month to all BPL families, who constitute nearly 23 million families, then the monthly total requirements of LPG are 138 million kg. This is huge and too costly and perhaps unmanageable on the other hand biogas plants of 1.5 to 2m3 capacity for each family are capable of providing the lifeline energy.

3. Biogas requirements for Replacing Firewood, Crop residue and Cattle dung cakes or Crop residue.

Out of a total number of 191 million households in India, an estimated 120 million use fire wood, cattle dung cakes or crop residue. If one wishes to replace these biomass resources by biogas, then the estimated daily biogas requirement will be 240 million cubic meter, at a rate of 2 cubic meter biogas per household daily.

The potential of biogas generation in India is 60,443 million cubic meter per year, this is equivalent to 26.28 million tonnes of LPG annually. This is much more than the requirements of the BPL families. The extra amount of biogas, if filled in cylinders, can also be used for vehicular requirements. This Bureau of Indian Standards (BIS) has issued a standard, IS 16087: 2013, for the biogas composition suitable for automobile applications. The Ministry of Road Transport issued gazette notification on 16th June 2015 permitting use of Bio-CNG following the standard are in progress.

4. Managing Availability of Biomass.

Biomass based energy production like biogas or producer gas often suffer from the problems of supply chain due to different weather and climatic conditions. Biomass time cycle for production require huge land area to mange 4 Fs, namely, Fuel, Food, Fodder and Fertilizer (Organic fertilizer or bio-fertilizer). These 4 Fs need to be balanced. The policies, strategies, projects and programmes have to be will knitted to meet compelling needs of land for industries, energy, housing, institutional and agriculture sectors.

For biomass production of any kind, the necessary inputs are soil, fertilizer water, and solar radiation. Use of biomass and food lead to biomass waste, which may also be used for completing the cycle and send them back to soil to protect ecology, environment and to mitigate the effects of climate change.

There are many sources of biomass waste that can be used for energy and fertiliser production. Animal and poultry waste, loose and leafy agriculture and forest residues, agriculture waste like rice straw, banana stem, maze stalks etc., sugar mill press mud, distilleries spent wash, sewage plant effluent, all can be used for biogas production or for any other organic or thermo-chemical produce. In addition, municipal solid and liquid waste, waste from slaughter houses vegetable markets and domestic and commercial kitchens are rich source for biomass conversion purposes.

It must, however, be borne in mind that all types of biomass are not suitable for all biomass conversion processes. Particular variety of biomass waste needs to earmarked for combustion, gasification, bio-methanation, bio-alcohol or biodiesel production. For bio-methanation, loose and leafy wet biomass waste and dung are most suitable resources. The hard and woody biomass are more suitable for combustion or gasification technologies or for second generation bio fuel production. In order to overcome the problems of availability of biomass at the time of its requirement, namely the supply chain, decentralised Biomass Waste. Resource Banks (BWRBs) can be established for collection, sizing and storing biomass waste.

5. Biomass based Demonstration Programmes.

The ministry of New and Renewable Energy Sources, Govt. of India, has initiated a number of biomass technology demonstration and dissemination programmes. This includes demonstration of integrated Technology Package or Biogas – Fertiliser Plants (BGFP) for generation, purification/enrichment, bottling and pipe distribution of biogas. This has now been converted into a regular programme. This government has also established a business model for demonstrating an Integrated Technology Package for creation of smokeless villages using biogas or bio-energy systems to meet the lifeline energy as envisaged in the 'Integrated Energy Policy' . In this context several biomass gasifier based distributed and off grid systems have been established in many rural areas. There are a few grid connected programmes also mainly in rice mills and other non-biogas industries, in the sugar industry many biogas based cogeneration plants are working in the country. In a few projects, however, the shortage of biomass availability has been a problem leading to reduced performance of the systems.

India has also a sizeable bio-liquid fuel programme such as biodiesel, which is produced from non-edible oil seeds such as Jatropha, Pongamia, Karanjia etc. Assessment of Jatropha plantations in 9 states showed high mortality and very low yield seeds. The quality of planting material was not good and scientific methods of cultivation and maintenance of Jatropha crop were not followed. In order to improve the yield, a coordinated programme was launched in co-operation with other government departments and institutions, namely, DBT, CSIR, ICAR, DRDO and NOVOD board to identify 15 superior types of Jatropha. Facilities for large scale micro-propagation and demonstration projects of elite Jatropha genotypes have been taken up.

Bio-ethanol is presently produced only from molasses in India and its use as bio-fuel depends upon competing demands and pricing. R & D efforts on production of second generation bio-fuels have been taken up on the use of ligno-cellulose & algae biomass as feed stocks. There are also plans to set up bio-refineries in future.

6. National Programme on Improved cook stoves.

Till the year 2002-03, the MNRE implemented a National Programme on Improved cook stoves (NPIC) for a period of two decades, in which 35.2 million improved cook stoves were installed, though the total potential was estimated as 120 million. In the year 2003-04 the programme was transferred to the state governments. Most states have discontinued the programme and only couple of states are still supporting it.

There have been some standard initiatives in the cook stove now like the preparation and publication of BIS standards IS 13152 (Part-1) in 2013. Targets have been fixed to install 5 million or more improved stoves through various state governments.

7. Decentralized Rural Energy Generation & supply.

Any village or any habitat requires energy of all three forms, namely:

- Electricity for domestic, irrigation/drinking water supply and village industry needs.
- Thermal energy for cooking and small industries
- Bio-fuels for motive power.

The ministry initiated several programmes to assess village energy requirements, assessments of locally available natural resources and develop a long terms sustenance strategy.

In the decentralised rural energy generation and supply, biomass was brought at the centre stage, where Programme for Biogas Fertiliser Plants (PBGFP) were nucleus of a hybrid energy centre (HEC). A HEC will house electricity, liquid, solid and gaseous fuels with an auto switching, remote control smart metering facility hooked to village micro-grid. A HEC will also have a Fuel Processing Unit (FPU) for processing of solid, liquid and gaseous fuels, which are biomass based.

Biomass energy source in a decentralized rural energy system will have the technology to integrate solar, wind, and other sources like small hydro depending upon the location & availability of the natural energy sources.

8. Business and Entrepreneurship Development:

The biomass utilization can be successful only if it is given a shape of business model under a PPP programme. The three main elements of the programme are:

- Biomass resource availability : farming, plantation & waste
- Biomass resource potential
- Biomass technology for family, community & industry sizes. Use of organic fertilizer.
- Financing of biogas fertilizer sector.

Various steps in promoting this programme are :

- Promotion of pre-fabricated biogas plants based on HDPE, RCC, FRP, ferro-cement, membrane based flexible or metallic combination.
- Development and registration of biogas/bio-energy fertilizer company.
- Financing through CDM and /or low interest loans.

In order to achieve success, make the installation of Biogas-fertiliser plants mandatory for wet biomass generators and also make the purchase of biogas mandatory for public and private gas utility companies. Simultaneously, the organic fertilizer that is produced in the bio-methanation process should be purchased by the public and private sector fertilizer companies.

Chapter 9: Energy Efficiency in Indian Buildings: Status and Opportunities

Jyotirmay Mathur

1.1 Introduction

Energy consumption in buildings offers a large scope for improving efficiency. The building sector includes residential and non-industrial buildings. The latter are also called commercial buildings and include offices, hospitals, hotels, retail outlets, educational buildings and public services including government offices.

Buildings offer energy saving potential through two parallel routes. One is via the potential to reduce energy consumption through improvement in efficiency of appliances and equipment. The second one focuses on approach through which buildings can be made more energy efficient by designs that reduce the need for lighting, heating, ventilation and air conditioning. This paper largely covers the second route of designing the building efficient.

The sector-wise electricity consumption in India is shown in Figure 1.1. The residential and commercial sectors account for 29 percent of the total electricity consumption and is rising at a rate of 8 percent annually (CWF, 2010). Significant part of this goes into heating, cooling and lighting. In order to work out the likely opportunities to reduce emission intensity we need to first project the likely growth in buildings of different categories. The energy demand by buildings will continue to grow with the growth of IT, ITES and the hospitality sectors.

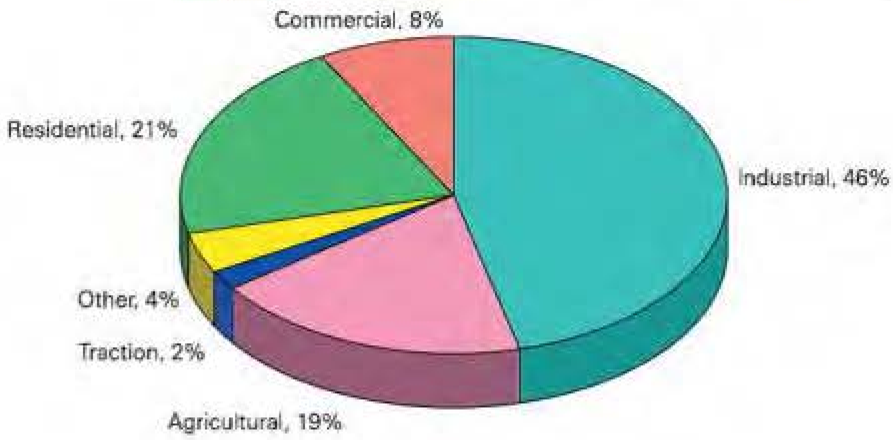


Figure 1.1: Primary Electricity Consumption in India (sector-wise)

Source: International Energy Association, 2008

1.2 Residential Sector

Due to population increase, higher GDP, growing urbanization, rise in income levels & the change in lifestyles and favourable public policies, the Indian residential sector has witnessed phenomenal growth over the last 15 years.

In 1961, the urban population of India was 78.9 million i.e. 18 percent of the total population. By 2001 it reached 285.5 million i.e. 27.8 percent of the total population. The urban populations are predicted to rise to 550 million by 2030 or 42.0 percent of the total population (Roberts, Brian and Trevor Kanaley, 2005). This urban growth, combined with rapid growth in the economy, has resulted in putting enormous pressure on housing requirements, urban infrastructure and other services. As can be seen in Figure 1.1, the residential sector accounts for 21 percent of the total electricity consumption in India. A representative break-up of end-use electricity consumption (excluding cooking) in the residential sector is indicated below in Figure 1.2.

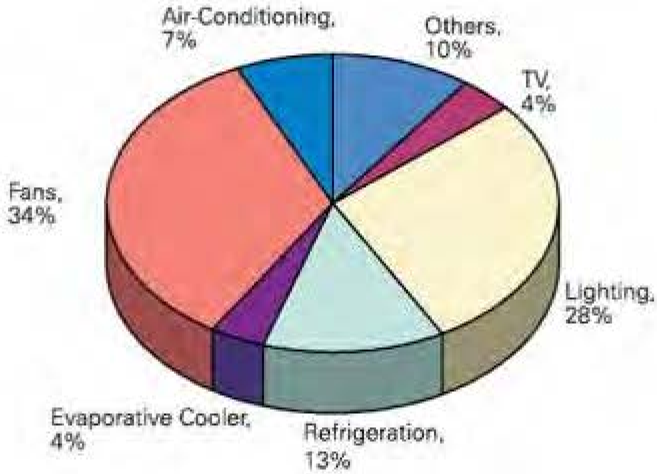


Figure 1.2: Energy Consumption Distribution in Residential Buildings

It is evident that ceiling fans and lighting constitute major energy use (62 percent) in the residential buildings. A matter of concern is that this break-up is changing fast in urban areas with increasing share of air-conditioning and others that include appliances. Hence any effort to control energy consumption in residential buildings can identify these two areas as primary focus.

1.3 Commercial Sector

A representative end use wise break-up of energy consumption in commercial buildings is shown in Figure 1.3. The major energy consuming equipments in commercial sector are lighting (25 percent), heating, ventilation and air conditioning (HVAC) (55 percent), and other office related equipment (20 percent). This break-up is significantly dependent upon building design and its usage, however, through the figure it can be identified that air-conditioning and lighting are two major areas of attention for attaining energy efficiency.

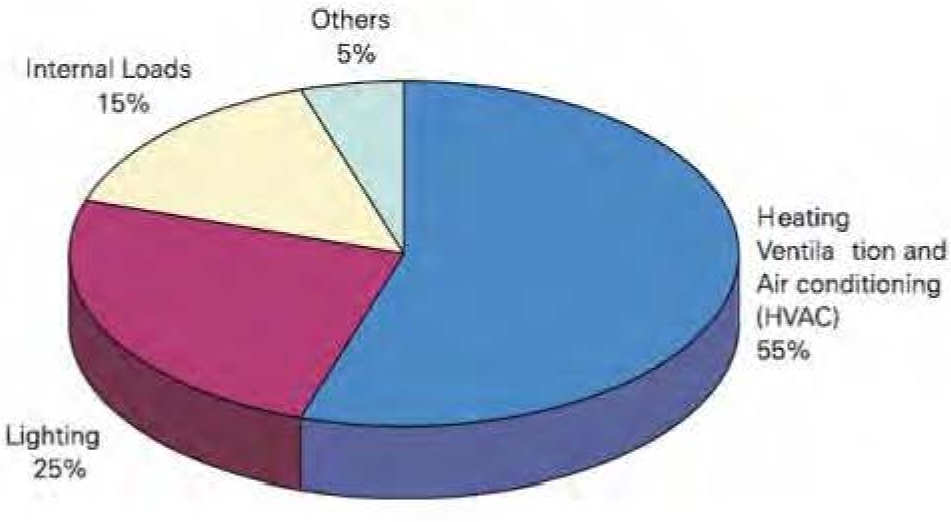


Figure 1.3: Energy Consumption Distribution in Commercial Building

1.4 Codes and Standards for Energy Efficiency

Codes and Standards can significantly enable the reduction of energy demand in the building sector. The country has done well in developing various standards like National Building Code (NBC), Energy Conservation Building Codes (ECBC), Bureau of Energy Efficiency rating programs for appliances and the more recent energy rating program for the existing buildings. The market-driven voluntary Green Building Rating Programs have significantly transformed the way buildings are designed. Green buildings have the potential to save upto 40 to 50 percent energy vis-à-vis the conventional practices. Some of the widely used building codes in India are discussed below.

1.4.1 Energy Conservation Building Code

The Energy Conservation Building Code (ECBC) was developed by the Govt. of India for new commercial buildings on 27th May 2007. ECBC sets minimum energy standards for new commercial buildings having a connected load of 100 kW or contract demand of 120 KVA and above. While the Central Government has powers under the EC Act 2001, the state governments have the flexibility to modify the code to suit local or regional needs and notify them. Presently, the code is in voluntary phase of implementation. While the ECBC has been developed by BEE, its enforcement lies with the State governments and urban local bodies through notification within their states. Many states have already amended the ECBC for their state with Odisha, Rajasthan, Karnataka, Uttar Pradesh, Telangana and Uttarakhand having already implemented the code after some amendments to suit their local requirements. States such as Kerala, Punjab, Haryana, and Gujarat are in the process of implementing ECBC for their state.

Consequent to the notification of mandatory adoption of the code by the states, integration of the provisions of the code in to the bye-laws is essential. BEE has developed model building bye-laws to mandate minimum energy standards for residential and commercial buildings/ complexes for formulation of draft National Sustainable Habitat parameters on energy efficiency. Simultaneously, inclusion of recommendations of ECBC in the National Building Code (NBC) 2015 is at its final stage which would be adopted in all future constructions in the country.

To promote adoption of ECBC in the built environment, several enabling measures were taken up by various stakeholder groups. These included (1) empanelment of ECBC expert architects, (2) development of technical reference material such as ECBC User Guide, Tip Sheets for lighting, envelope, HVAC, simulation; (3) development of conformance/compliance check tool (ECOnirman) to help architects/ design professionals and code compliance officials to assess conformance with code requirements, (4) Standard ECBC Training Modules covering various aspects of the code (5) Training of Master Trainers for ECBC.

In order to promote a market pull for energy efficient buildings, Bureau of Energy Efficiency has developed a Star Rating Programme for buildings which is based on actual performance of the building, in terms of energy usage in the building over its area expressed in kWh/sq m/year. This Programme rates buildings on a 1-5 star scale, with 5-Star labelled buildings being the most energy efficient. Star labelling programme (Voluntary) for day use office buildings, BPOs and Shopping complexes has been developed.

1.4.2 Green Building Rating Systems

Green building rating systems have helped energy efficiency improvement of buildings in a big way. Major Green building rating systems currently operating in India is:

- **LEED (The Leadership in Energy and Environmental Design)**
  The LEED rating system of Indian Green Building Council (IGBC), as well as US Green Building Council (USGBC), requires buildings to meet or beat the ECBC or ASHRAE90.1 level of energy efficiency.

- **IGBC Ratings**
  In addition to promoting LEED based rating systems, IGBC also started other sector specific rating systems such as IGBC Green Home, Green Factory Building, Green Existing Buildings, Green Metro, Green Township. Each of these rating systems has significant focus on improving energy efficiency, besides covering other aspects of green.

- **GRIHA (Green Rating for Integrated Habitat Assessment)**
  In addition to LEED, GRIHA rating system promoted by ADARSH, adopts both the prescriptive and mandatory provisions of ECBC for obtaining a rating. Energy Performance Index (EPI) values developed by BEE for different categories of buildings have been adopted under the GRIHA rating system. Consequently all buildings rated under the Green Rating for Integrated Habitat Assessment (GRIHA) can be considered to be compliant to ECBC.

1.5 Case Studies of Energy Efficiency Improvement

Several ECBC compliant green buildings have revealed significant energy saving potential throughout the country. Following is summary of some major studies that are documented in the form of case studies and are being referred by professionals.

The study conducted by MNIT Jaipur on six different types of existing buildings concluded that there is a vast potential for energy savings through implementation of ECBC in the country. The study was conducted through simulation models developed taking details of six different types of buildings including hotel, retail mall, hospital, institutional building, private office building and government office building located in Jaipur, and examining through modelling, the potential of energy savings through adoption of ECBC in these six buildings. It was observed that different buildings have different energy saving potential depending on the construction specifications, usage, systems and equipment installed, conditioned area and other factors. Analysed buildings show the energy savings potential ranges from 17 to 42 percent. The study also indicates that there exists further more potential for energy saving through adoption of advanced energy conservation measures; however, it might not be financially attractive for the general public at this stage due to their economy of scale.

On the campus of MNIT Jaipur, a new building Prabha Bhavan, has been built using insulation in walls and roof, low-e glass with double glazed UPVC windows, LED lights, VRF based cooling systems. The building is estimated to be about 30% more efficient as compared to the ECBC.

The headquarters of Tata Group, Bombay House in Mumbai, was successful in reducing the energy consumption from 172 kWh/m2/year to 145 kWh/m2/yr, resulting into about 16% energy saving. The following modifications were used:

1) Old Chillers and pumps were replaced by energy Efficient machines

2) Energy efficient T-5 lamps with electronic ballasts were installed in 90% areas

3) Variable Frequency Drives (VFD) were installed on Cooling Water pumps

4) Individual Energy metering is done for 90% offices in the building

5) A Building Management System (BMS) was installed and is operational

The payback period for this investment will be 2 years since the electricity tariff at Bombay House will be around Rs 12.5/kWh over the two year period.

In another building located in Mumbai, Godrej Bhavan; retrofitting resulted in about 12% reduction in electricity consumption. This new system, equipped with a screw chiller, water-cooled condenser, and electronic expansion valve, has a double coefficient of performance (COP) of 5.5, compared to the former 35-year old direct-expansion unit with 2.2 COP. Elsewhere in the building, high-efficiency T-5 fluorescent tube lamps and increased natural lighting improve lighting efficiency. Double-glazed clear windows and shading devices also reduce heat. With the newly installed Building Energy Management System, the building's maintenance managers can now track and adjust electricity usage for maximum efficiency.

Based upon the energy saving potential as revealed from above mentioned studies, estimation of energy saving and consequent CO2 emission reduction potential can be estimated.

1.6 CO2 Mitigation Opportunities in Building Sector

Building sector hold significant potential of contributing towards meeting India's INDC. There are opportunities to maximize the energy efficiency and thereby reducing the GHG emissions in the building sector. These opportunities are available in both existing and new stock, covering both commercial and residential sector. As per the estimated of Indian Green Building Council , it is expected that there is a potential to abate 142 Million Tonnes of CO2 per year by 2020 and 296 Million Tonnes of CO2 per year by 2030 respectively.

Analysis of Commercial Sector

The projected area of commercial buildings is shown below in Table 1.1.

Table 1.1 Projected area of Commercial Buildings

Building Type	Area (million Sq. ft)	Growth Percentage	Area (million Sq. ft)	Area (million Sq. ft)	Area (million Sq. ft)
	2005		2012	2020	2030
Commercial office space	2900	8	4970	9199	19861
Hospitality	730	10	1423	3049	7909
Retail	950	8	1628	3014	6506
Total	4580	-	8021	15262	34276

The existing consumption pattern in conventional buildings and the consumption trends in some of the recently constructed energy efficient buildings, which would be ECBC compliant, have been analyzed. The ECBC compliant buildings are considered to be 20 to 30 percent more efficient than conventional buildings.

The current baseline for CO2 emissions for conventional buildings is estimated at 40,000 tonnes of CO2 per million Sq.ft or 430,570 tonnes of CO2 per million Sq.m of building area. At this rate, the expected emissions from the commercial building sector will be 610 million tonnes of CO2 in 2020 and 1,370 million tonnes of CO2 in 2030.

During the current voluntary phase of the ECBC, motivated early adopters are designing compliant commercial buildings which achieve savings that are much higher than what can be achieved by minimum ECBC compliance. Post the notification of ECBC in most states, it is expected that the vast section of new commercial buildings shall meet only the minimum code compliance requirements with relatively few achieving higher levels of savings than what is currently being achieved. In assessing the CO2 abatement in the commercial buildings due to implementation of the ECBC, the following scenarios are considered:

Determined Effort Scenario till 2020

- 10 percent of the new buildings (i.e. the buildings built between year 2007 and 2020) will surpass the ECBC requirements and their CO2 and energy use will be 50 percent of the existing baseline.
- A further 10 percent of the new buildings (i.e. built between 2007 &2020) will meet the ECBC requirements, and the CO2 emissions will be 70 percent of the existing baseline (i.e. reduction of 30 percent).
- 10 percent of the existing buildings and 30 percent of new buildings may not meet the full ECBC requirements, but will at least have an energy performance comparable to that of a retrofitted building and save 18 percent of the existing baseline.

Aggressive Effort Scenario till 2020

- 15 percent of the new buildings (i.e. the buildings built between year 2007 and 2020) will surpass the ECBC requirements and their CO2 and energy use will be 50 percent of the existing baseline.
- A further 35 percent of the new buildings (i.e. built between 2007 & 2020) will meet ECBC requirements, and the CO2 emissions will be 70 percent of the existing baseline (i.e. reduction of 30 percent).
- 20 percent of the existing buildings and 50 percent of new buildings may not meet the full ECBC requirements, but will at least have an energy performance comparable to that of a retrofitted building and save 18 percent of the existing baseline.

The potential CO2 mitigation by the years 2020 is worked out and is summarized below in Table 1.2. The following assumptions are made to work out the additional emission savings between 2020 and 2030:

- 100 percent of additional area added between 2020-2030 is ECBC compliant
- 50 percent of existing Buildings are Retrofitted
- 20 percent of new Buildings surpass the Requirements of ECBC

It is pertinent to mention that enforcement of buildings code is not entirely in the hands of the Central Government, and it will take time before the systems are put into place at the level of the State and Local Governments.

Table 1.2: Emission Savings from the Commercial Building Sector in 2020

S.No.	Determined Effort Scenario	Million Tonnes of CO2 Abated
1	10 % new buildings respond to market penetration of rating systems and save 50% of emissions	22
2	10% of new buildings ECBC compliant save 30% of emission	12
3	10% of the existing buildings are retrofitted and 30 % of new buildings save 18% of emissions	26
	Total Emissions Abated	60

S.No.	Aggressive Effort Scenario	Million Tonnes of CO2 Abated
1	15% buildings respond to market penetration of rating systems and save 50% of emissions	32
2	35% of new buildings ECBC compliant save 30% of emissions	45
3	20% of the existing buildings are retrofitted and 50% of new buildings save 18% of emissions	45
	Total Emissions Abated	122

Considering base line emission 40,000 tonnes of CO2 per million sq.ft

1.7 Conclusion

The Indian construction sector, which is one of the major contributors to the National GDP, has been growing and is also poised to grow faster than most sectors in the coming years. This offers great and one time opportunity to realize energy saving opportunities. There is a need for several interventions – encouraging public policies, enhancing awareness, capacity building, absorption of new trends and technologies. Besides these, there is a need to strengthen development and implementation of indigenous standards & codes as well as facilities for testing & verification. By adopting the strategies and recommendations made above, it is possible to abate approximately 60 Mt and 122 Mt of CO2 per year by 2020 in the determined and aggressive scenarios respectively. The savings by 2030, from the commercial buildings sector, can be 400 Mt to 440 Mt of CO2 per year in respective scenario.

Chapter 10: India's Energy Options for Economic and Environment Security with Respect to Solar Thermal Systems.

Tushar Mavani.

1. Introduction

There are many forms of natural or renewable energy sources, which are available to us to produce heat or electricity in an environmentally benign method. For example solar, wind, geothermal, hydro and biomass can all be converted in to usable energy forms by using technology that is appropriate to the application and the given location.

As already told by some speakers, Sun is the ultimate source of energy. Sun radiates the earth with electromagnetic energy, which includes light, infrared, ultraviolet and radio waves. It also gives a stream of particles, which reaches the earth as "solar wind". The source of all this energy is the reaction in the star sun, which turns hydrogen into helium and in the process huge amount energy is released. The energy of the Sun consists of two parts, namely solar thermal and solar light (solar photovoltaic PV). The entire spectrum of solar radiation can be converted into thermal energy, whereas, the visible portion of the spectrum can be converted into electricity using solar photovoltaic systems.

2. Solar Thermal Energy

Forty percent of the world's energy requirements are thermal or heat for heating of buildings, hot water and process heat. Another twenty five percent is kinetic or pneumatic, which can also be generated using thermal energy route. Like electricity, thermal energy can be the base of all energy needs of the world. Solar energy, as received from the sun, can be used for solar cooking for domestic as well as industrial purposes, solar hot water, solar steam generators for process heat, solar steam general or power plants and other applications that use hot air.

Fig. 1 gives the distribution of solar radiation all over the country. The average radiation on the earth's surface is 5.5 kWh/m2/d. The devices that are used to convert this energy into thermal energy, have efficiencies ranging from 30% to 70%, which is much higher than the efficiency of PV modules of efficiencies 18-20 %. Efficiency of various solar thermal devices can be further improved by appropriate R & D. The heart of solar thermal systems consists of a receiver and a reflector. The reflectors are of good quality and have very little scope for further improvements. The receivers need to be conceptualised and further developed by the industry in collaboration with appropriate R & D institutions.

The receiver is actually a heat exchanger and we may also call is RHE. For cooking purposes, if we use an evacuated tube, the receiver can be fin type, whereas for hot water and steam generation, we can have plate tube receiver that uses a turbulent flow. For hot air generation, we can have fin tube heat exchanger within the tube.

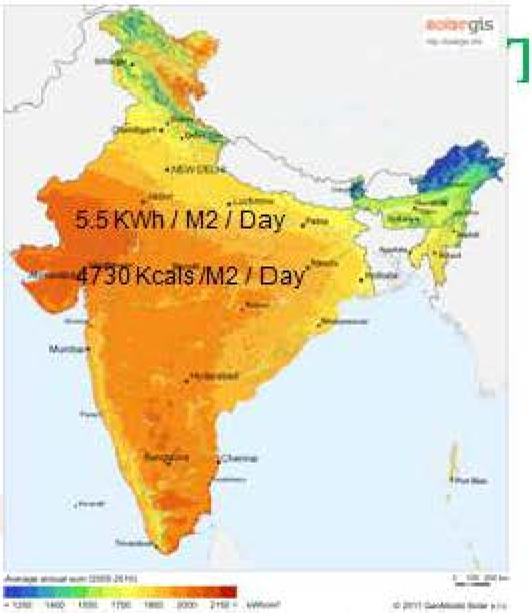


Fig. 1: Average solar radiation across various regions of India

3. Solar Cookers.

Various types of domestic solar cookers are shown in Fig. 2.

Fig. 2 : Models of a few domestic solar cookers

The industrial or institutional solar cooers are based on the principles of Scheffler cooker (Fig.3), in which the reflector has to track the sun from east to west.

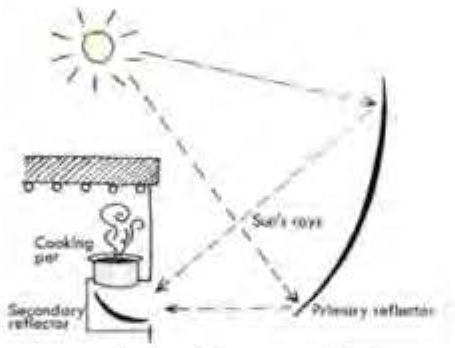


Fig.3 ; Schematic of Scheffler type of solar cooker

This kind of reflector is actually a part of a compound parabolic concentrator (CPC) which reflects the radiation to a focal point (Fig.4).

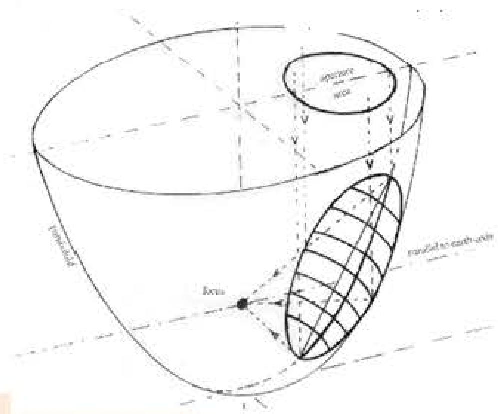


Fig.4 ; A compound parabolic concentrator used in Scheffler model

Seasonal changes in the angle of the axis towards north-south have to be made w.r.t. 23o declination (Fig.5)

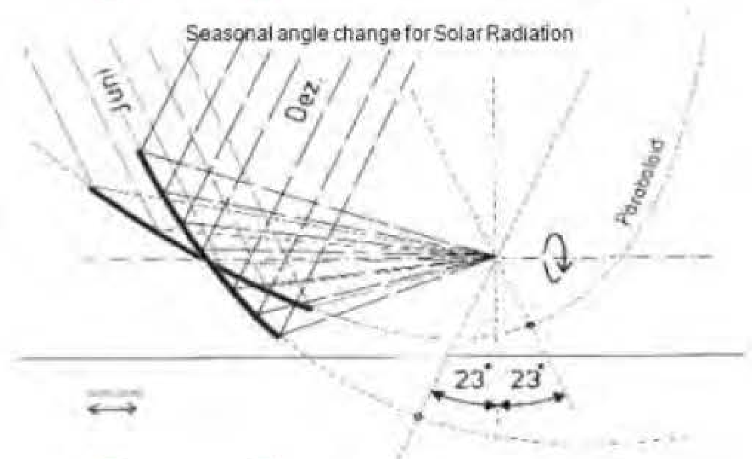


Fig. 5: Seasonal changes in north-south axis of Scheffler concentrator

A photograph of two Scheffler dishes produced by TARPHIN is shown in Fig.6.

Fig. 6 : Schaeffler concentrators developed by TARPHIN

4. **Tube HE and Solar Hot Water Systems.**

Details of the glass tube manufactured by TARPHIN are give n in Fig. 7.

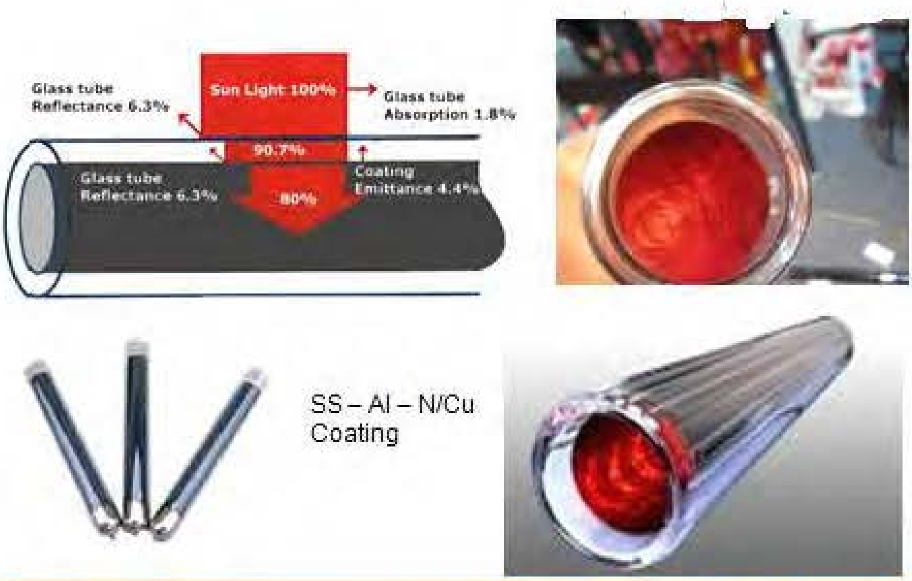


Fig. 7 : Glass tube absorber developed by TARPHIN

The glass tube has a coating of SS-Al-Ni-cu and a fin receiver is contained inside the tube. Fig. 8 shows a solar hot water installation using such receivers in an industry in Gujarat.

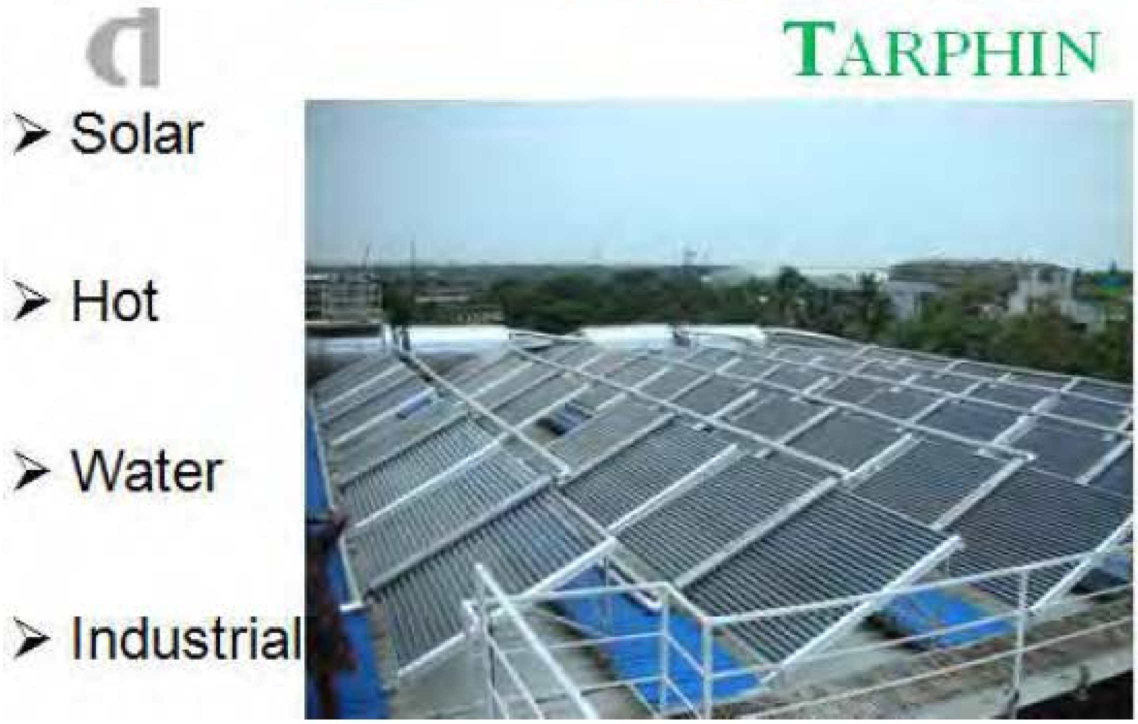


Fig. 8 : Solar hot water installation using tubular receiver in an industry in Gujarat

Cost effective solutions were provide to supply hot water at 80oC with a total capacity of 13000 lpd and the cost of generated hot water came out to be Rs. 180/litre.

5. Solar Steam Generators for Power Plants.

Normally parabolic trough collectors are used to generate steam for a power plant, a 340 MW solar thermal power plant has been in operation at California for the last two decades or more. However, for lower temperatures of 140oC and 10 bar pressures, it may be better to use a non-imaging type of the CPC (Fig.9), which is a non-imaging concentrators, that can also collect diffuse radiation with a proportion of 1/c (C of 1.5 will pick up 2/3 of diffuse radiation).

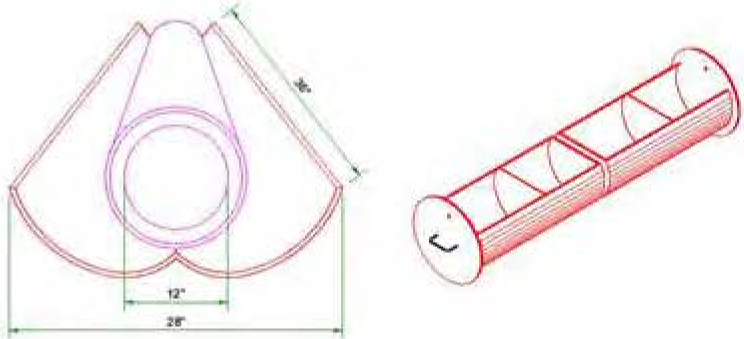


Fig. 9 : Non-imaging type of solar concentrator

6. Other Applications.

TARPHIN has developed many other systems such as solar dryers, solar bakers and solar hot air generators (Fig. 10) also.

Fig. 10: TARPHIN solar thermal systems

7. Economics & Cost

A total daily solar radiation of 4730 kcal/m2/d, absorbed with an efficiency of 70% will provide 3341 kcal/m2/d. The cost of different receiver technologies are Rs.5000/sqm for ETC for hot water to Rs.10000/sqm for Scheffler and Rs.12000/sqm for the FPC (at 65oC) and Rs.18000/sqm (at 80oC). These costs are for the total systems.

For solar cooking, as an example, we need 250 kcal/meal, with a square meter of collector, we can cook at least 12.5 meals/d. With Scheffler cooker of 16 sq. m., the total Scheffler cooker costs Rs.1,60,000 and, we can cook 200 meals/d or a cost of Rs.800 for meals per day. The cost of one meal is Rs.4 and the kcal cost only Rs.0.016 giving us a pay back of 200 days only.

For hot water systems providing 80oC and using the FPC, the required temperature difference is 50 to 60oC. At a temperature difference of 60oC, we need 60 kcal/litre and therefore at 3311 kcal/d, we can heat 55 litre of hot water. Cost of a sq.m of FPC is Rs.18000 and hence per litre cost of hot water is Rs/327/liter and kcal cost is Rs.0.05 giving us a pay back of three years.

For getting distilled water, we need 540 kcal, litre of energy for evaporation. Using a sqm of the absorber we can evaporate 6 litres/d of hot water. The cost of this evaporation process is Rs.3000/litres, which is costly. The system therefore needs hybridization with solar concentrators using spray nozzles and perhaps we may have to control the atmospheric pressure.

8. Conclusion

Our suggestions are to develop models for solar cookers using 10/12" dia ETC with inner steel tube using CPC for cooking for 10 people . For 200 people or more use Scheffler dishes with modified receivers. We need to develop vacuum receivers and use Scheffler dishes for steam generation and solar cooking. For higher temperature up to 250oC, the research needs to be done with bigger diameter tubes of ETC and CPC so that tracking is avoided.

Scheffler dish with modified vacuum receiver can be applied for process heat in the form of hot water or steam. However, the space is always a major problem with the industry and the roofs are not of concrete. There is a need to work for proper design suiting the Industrial architecture.

For energy security, we have to develop appropriate products and manufacture these for the masses. We need to have big volumes for small solutions.

In conclusion, please follow an Energy code at every moment of your life.

Chapter 11: Emerging Trends in Energy Sector.

Pranav R. Mehta

1. Introduction

Conventional conversion of coal to electricity is associated with colossal waste of energy and water as shown in Fig.1 of the entire chain of the energy conversion process.

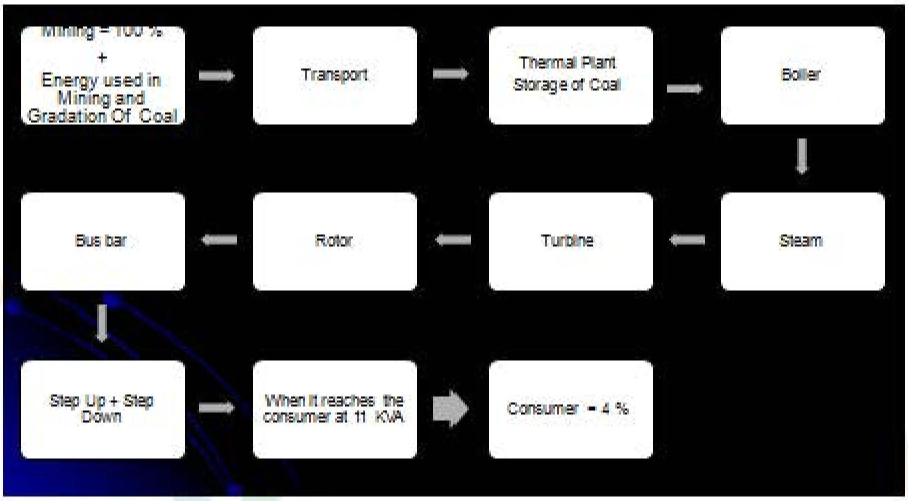


Fig. 1: Waste of energy and water in conventional grid

The 100% of energy of the coal ultimately provides only 4% of its energy to the consumer. Since there is always a nexus between energy and water, the water is also wasted in the same proportion. Maximum waste takes place between steam to turbine and rotor, before the electrical energy reaches the bus bar. Considering the challenges posed by energy security and environmental challenges, it is not possible to bear these wasteful processes any more.

2. Renewable Energy as Clean Energy

It is clear that the mankind is at the cusp of "Energy Evolution" from the fossil fuel era to the new era of renewable and clean Energy - the so called "Energy Wende" or Energy Transition. Renewable Energy can greatly help in empowering people and poverty alleviation. There is a rising awareness worldwide that RE and energy efficiency can greatly help in the greatest challenge the mankind is facing today, namely, global warming and climate change. Over the past decade and particularly in recent years, due to advances in RE technologies, global increase incapacity, rapid cost reduction have been achieved in renewable electricity generation. It is beyond any reasonable doubt that a large renewable energy opportunity is staring at us welcomingly with great opportunity for business and greater opportunity to serve the mankind as a whole and save the planet from climate disaster.

3. RE opportunities

RE has opened many opportunities not only in their core area but also in associated fields. This includes strengthening and improving the DISCOMS and the grid infrastructure. The decentralised systems need promotion and deployment of mini and micro grids to provide benefits to energy deprived communities. We need to develop energy smart cities and of course integrate renewable energy for this purpose.

We have opportunity to strengthen India's alternative energy institutions. Joint efforts are needed to transfer technology from R & D institutions to deployment in the commercial world. We need to invest in incubating India's clear energy start-ups

4. Concrete Suggestions.

Besides solar PV, we need to concentrate on Solar Thermal Power also. In this context we may be a part to commercialize MTI patented and licensed CSP technology with storage. The NREL'S 40 percent plus solar cell efficiency also need to be supported and similar developments need coordinated efforts. We should have joint promotion of storage technologies and develop rapid charge electrical batteries for transport applications.

National Solar Energy Federation of India (NSEFI) offers help to facilitate Solar and Renewable Energy business.

5. NSEFI Support.

NSEFI has sixty five members consisting of leading manufactures and entrepreneurs providing an umbrella to manufacturers, developers, EPC contractors, MNRE channel partners, financial institutions, balance of plant, component manufacturers and suppliers other stake holders include power exchanges , solar appliances manufacturers, service provides & NGOs etc.

The ultimate air of the NSEFIS is to make solar energy affordable for all and to ensure widespread use and speedier growth as well as global competitiveness of solar industry in India and thereby serve the cause of global warming and climate change. We intend to be a part of national building by working in close cooperation and in a complementary manner with the central and state governments to achieve the envisaged national goals.

Chapter 12: Solar PV = The ability to produce energy any time and almost any where

Karan Dangayach.

1. Introduction

As already told by several speakers earlier, the total installed capacity of power plants in India is 288 GW, out of which 61% is coal, hydro 15%, Natural gas 9%, nuclear 2% and the renewable energy 12% (Fig. 1).

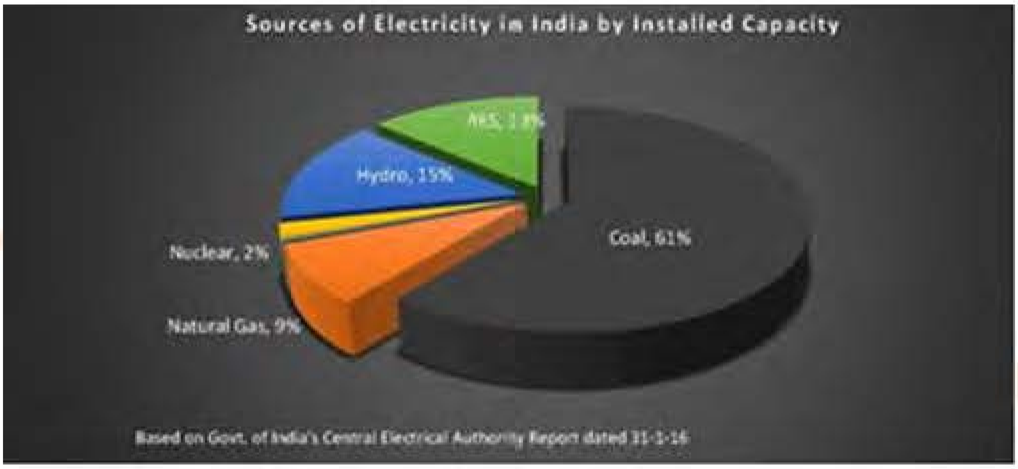


Fig. 1: India's Electrical Power Sources with percentage contribution

Considering the fact, that we had only 1200 MW of power plant capacity only, after independence the capacity addition of electric power plants in India has been remarkable. However, even today about 300 million people or 80 million households are without electricity. The criteria that the Indian Government uses to define an electrified village are:

- Base infrastructure such as the distribution transformer and distribution lines, is provided in the in habituated locality as well as in the Dalit Basti hamlet where it exists.
- The number of electrified household should be at least 10% of the total number of households in the village.

The parameters and the definition however keep evolving. Presently India has a very tepid industrial growth and most of the state DISCOMS are financially burdened. In such a case, what are the smarter solutions to provide electricity to those who don't have it? Do we produce electricity at a central place and then transmit it over long distances or should we produce locally and mange it with limited resources? It is well known that coal produced power has huge environmental and other social costs associated with the mining, transport and combustion of coal to produce power. The sequence of switching power at the consumer level is complicated and tedious. Power is generated at power stations at around 25 KV and it is stepped up to 132 KV using a transformer. This 132 KV power is transferred via thick insulated cables (aluminium covered with ceramic insulator) held up by pylons to electricity substations, which use step down transfers to 11KV and then subsequently to 240 V, which we use in our homes. The transmission losses are about 20-25% in India and the huge infrastructure is associated with large social costs that include health, environment etc. Solar photovoltaic on the other hand is simple and is a passive device capable of providing power from mW to MW.

2. Applications of Solar Photovoltaics.

.The main applications that are appropriate for rural locations include

- Solar Water Pumps (SWP)
- Solar Roof Tops
- Solar micro-grids
- Solar power plants on wastelands

Solar water pump (SWP) energised by PV module is really a boon for countries like India. There are more than a million farmers without access to electricity and more than 10 million farmers with access to intermittent power. There are 180 million pumps for irrigation purposes in India out of which 8 million run on diesel. For grid connected irrigation pump, SWPs offer major advantage to DISCOMs by providing a much better and hassle free power systems. Replacing diesel by solar is already much more economical and diesel prices will increase only and not decrease.

We have worked out the economics of solar water pump; in three cases namely;

(1) Season farming for sugarcane replacing diesel by SWP.

(2) Seasons farming for cotton, wheat and vegetables using SWP and

(3) Seasons farming for Jowar, Bajra & caster.

The results are presented in Table 1.

Table 1 : Economics of solar water irrigation pumps without subsidies

1 Season Farming With Diesel (Sugarcane)					
Year	1	2	3	4	5
Principal amount	380000	208933.3333	6505.33		
Accumulated interest	45600	25072	780.6396		
Annual savings	216666.6667	227500	238875		
Remaining principal amount	208933.3333	6505.333333	-231589.0304		

2 Season Farming With Diesel (Cotton, Wheat, Vegetables)					
Year	1	2	3	4	5
Principal amount	380000	283120	167490.4	30505.048	
Accumulated interest	45600	33974.4	20098.848	3660.60576	
Annual savings	142480	149604	157084.2	164938.41	
Remaining principal amount	283120	167490.4	30505.048	-130772.7562	

3 Season Farming With Diesel (Jowar, Bajra, Castor)					
Year	1	2	3	4	5
Principal amount	380000	326973.3333	262652.1333	185434.4893	93513.93305
Accumulated interest	45600	39236.8	31518.256	22252.13872	11221.67197
Annual savings	98626.66667	103558	108735.9	114172.695	119881.3298
Remaining principal amount	326973.3333	262652.1333	185434.4893	93513.93305	-15145.72478

It is observed that in all the three cases, the payback period is less than five years. This corresponds to returns at the rate of 14 to 15%, which are considered to be good in the present scenario of financing.

3. Solar Roof Tops

Solar roof tops is a well known concept in both the cases, namely, connected to grid for electricity export or connected to net metering allowing import from the grid as well as export to the grid. Solar PV is possible on all type of roofs (Fig.2), like residential, commercial and industrial and has a life of 25 years, with minimum maintenance requirements of cleaning the PV panels only.

Fig.2: Solar PV can be installed on any type of roof

To evaluate the economies of solar roof tops, let us consider a commercial complex with 30 KW roof top. The solar systems will generate on an average 120 units per day or 43800 units annually. Considering the commercial electricity rate at Rs.8 per unit, this amounts to a saving of Rs.3, 50,400 per year. The total cost of a 30 KW plant is Rs.20 lacs yielding a profit at IRR of 14 to 15%

4. Solar Micro-grids and Solar PV on Wastelands

In villages, where even grid is available, it is beneficial to set up smart AC micro-grids using solar PV

Fig. 3: Concept of a solar mini-grid in a rural set up

Temper proof prepaid meters are installed by some RESCO organizations and theft proof cabling is ensured with complete underground infrastructure. If there is no grid, batteries with an expected life time of 8 to 9 years may be employed to ensure reliable and un-interrupted power supply.

Solar PV installations can also be put on wastelands. Fig. 4 shows a 480 MW solar power plant installed on a fly ash pond and supplying power to a nearby village. To estimate the potential of solar PV power plants on waste lands , we made some calculations. Out of 3166 lakh hectare of land area , approximately 15% is the waste land that comes out to be 465 lakh hectares. Considering that solar PV requires 3.5 – 4 acres of land per MW, the waste land can accommodate 32000GW of solar plants. Even 5% of this will be 1600 GW. Clearly, a closer look on waste lands can provide the solar sector with optimal land for use.

Fig 4: A 480 kW solar PV power plant on wasteland in Junagarh Gujarat

A look at the economies of solar PV power plant shows and electric unit cost of less than Rs.4/- are achievable with an optimized system. Let us consider a case of 5 MWp ground mounted solar plant with capex of Rs.30 crores. The plant will generate approximately Rs.22000 units of electricity daily on an average basis. Suppose a term loan is obtained on 70% capex for 10 years at an interest rate of 12%. Considering a life of only 15 years, the total generation is 12 crores units and O & M of Rs.2.5 crores and interest accrued is Rs.16 crores annually. It is seen that the equity is recovered with in the first year (due to tax savings) and electricity unit cost is less than Rs,4/-

5. Conclusions

In the end, I will try to take some questions home for thinking namely,

- Do we need to extract coal or we can do something better?.
- Conduct an in depth study of coal, diesel and solar PV including environmental, health and economic costs.
- Make SWPs a mission and create financing mechanism for adoption.
- Bunk subsidies as these only distort the market
- Create solar parks on wastelands.

Chapter 13: Re-Designing Urban Rural Habitat

Tulsi Tawari.

1. Introduction.

Various presentations in the seminar today have been suggesting various energy options for India's energy needs and the renewable energy sources are also being considered in the same context. I will, in my presentation, not talk about supply but I will talk about demand. In the world's major economies, two types of developments have happened and which are considered to be successful namely:

- European industrial development.
- China's industrial and service sector development.

India wants to follow the model of China's success, particularly in the manufacturing. However, we should ask ourselves a question as how should we grow to achieve an inclusive growth? European industrial development model has failed because it is not sustainable. India has the golden opportunity to learn from the two models and opt for what is right and leave the wrong. If options are chosen properly, India has the opportunity to become a role model for the whole world to follow in times to come.

2. Energy, Environment and Economy

In a sustainable development model, one should try to integrate the economic and environment security. Energy is of course a subject to the model. Energy is a necessary input to stimulate economy and it is the economy that controls our lives. Fig. 1 is an empirical plot of value addition and money.

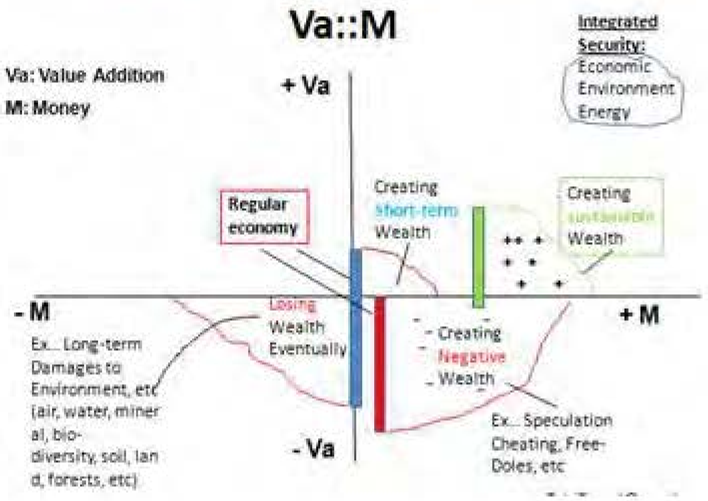


Fig. 1: Alternative approaches for an economic growth model

The figure contains three bars; blue, red and green. One tries to balance within the model the value addition and money. In a regular economy, we provide food, goods and services. This is business. However, in the process, we do long term damages to environment (air, water, mineral, biodiversity, soil, land & forest etc.), thus losing the wealth eventually. Regular economy also tends to create short term wealth, which is negative wealth earned through speculation, cheating, free doles etc. This short term wealth completely ignores the environment. Creation of sustainable wealth demands integration of economy, environment and energy represented by the green bar yielding a positive and sustainable development.

3. Material consumption

A global debate has been initiated discussing the required lifestyle changes over decades and their impact on environment and future generations. A European study shows that the present material consumption in the industrial world is about 40.0 MT/capita/year, a figure that is not sustainable. Distribution of this material consumption in to various activities, namely, housing, mobility, nutrition, leisure, household good and others is shown in Fig. 2.

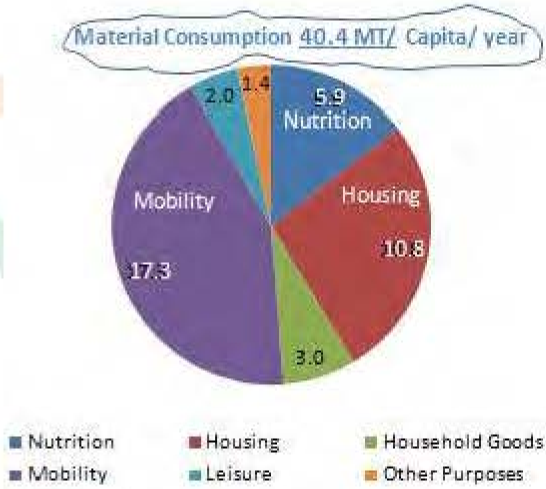


Fig. 2: Material consumption in the world(A European Study)

In the present context, the mobility and housing have the highest material consumption followed by nutrition and goods. The study also points out drastic reduction in material consumption, say, from 17.3 MT for mobility to 3.0 MT, 10.8 MT for housing to 2 MT and for nutrition from 5.9 MT to 2, so that the total material consumption does not exceed 8-10 MT per capita per year and the development process can continue in a sustainable manner. This reduction in material consumption requires redefinition of growth beyond consumption driven parameters. In the growth model so far, where economic growth measures have been restricted to parameters of material consumption, thereby increasing energy consumption. This consumption centric economic growth has resulted in increased toxicity of resources – water and air pollution. Out of our energy options, we seem to be restricted with solar, wind and hydro, which has limited success to meet peak level consumptions. Energy consumed for manufacturing and setting up solar panels and hydro power stations need to be factored to evaluate the consumption of net materials. Utilization of nuclear energy is still being debated from a catastrophic risk perspective, even as we factor the materials consumed to set up Nuclear Power Stations. Energy consumption to create material based on alloys and subsequently for recycling is another aspect of life style driven energy needs. Sustainable growth model demands lower material consumption. The growth measures need to be redefined, not only on GDP, but quality of life measures rather than consumption of materials and thereby energy. Some basic requirements to measure quality of life are clean water, clean air, access to nature (river, forest, pollution free spaces etc.), nutrition and leisure time, harmony in relationship and opportunity to explore. Achieving the radical changes requires a new "Design Approach rather than stop-gap solutions.

4. Areas that need urgent interventions.

As discussed already that a sustainable growth model requires less material consumption. Global material consumption that need corrections include mobility (17.8 MT/c/a), Housing (10.8 MT/c/a) and Nutrition (5.9 MT/c/a) and reduce these by 70 to 50% to achieve a sustainable figures of 10 MT/c/a.

Material consumption in China's growth model is given in Fig. 3.

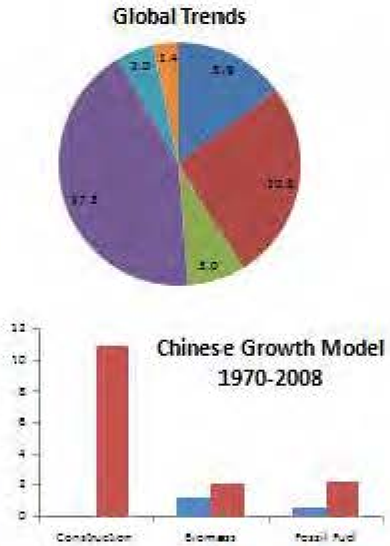


Fig. 3: Chinese growth model 1970-2008

It is seen that the material consumption in the construction sector grew from 0.1 MT in 1970 to 11.0 MT per person in the year 2008. Fossil fuel contributed the next largest growth segment from 0.6 MT to 2.2 MT in the same period.

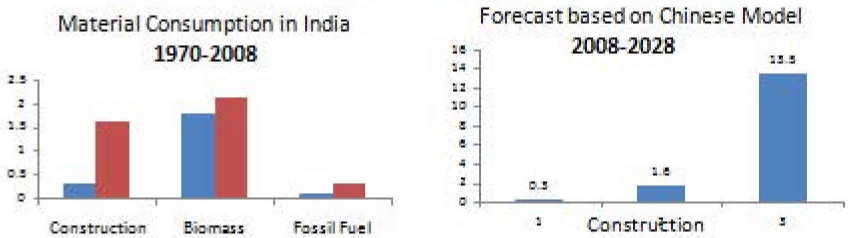


Fig. 4 : Material consumption trends in India

Fig. 4 shows material consumption in India during the same period 1970-2008, India so far, has fared well compared to China in absolute tonnage of consumption. However, the present trends are in the same direction as China especially in the construction sector and need correction. It is estimated that India may touch around 13.5 MT/person per year material consumption in construction sector in the next 20 years, if we follow Chinese growth model. We need a different approach to curb the trend and the solution lies in redesigning habitats without disruption and equitable distribution of life needs across Urban and Rural settlement.

5. Lopsided Design of Economic Development

In our model of development, the capital is concentrated in urban areas resulting in large scale migration of rural population to urban areas. This has resulted in sprawling slum dwellings killing cities and deserted villages. Fig. 5 empirically shows this urban-rural divide and unsustainable population densities (Table 1) in the metros.

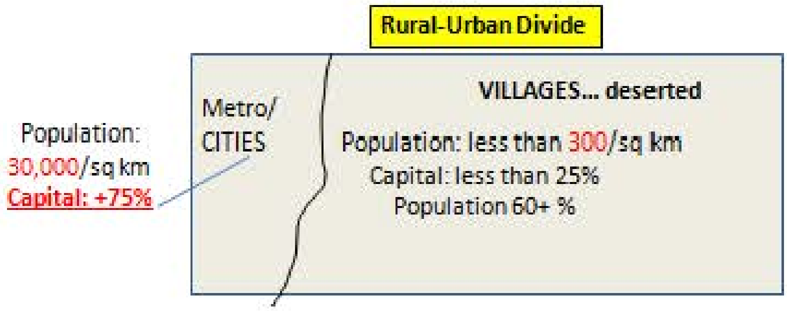


Fig. 5: Lopsided Design of economic development (crowding in cities and desertification of villages)

Table 1: Urban and rural population in Mumbai and Nandurbar district of Maharashtra

Indicative settlements in Maharashtra	Density of Population	Urban living	Rural living	Slum living
Mumbai	30,000/ Sq.km	58.2%		41.8%
Nandurbar District	300/ Sq.km	16.7%	83.3%	

Table 1 gives the population densities of Mumbai and Nandurbar district in Maharashtra. This lopsided development in India has increased the rural-urban divide severely limiting life indicators like education and basic services like sanitation for rural India (Fig. 6).

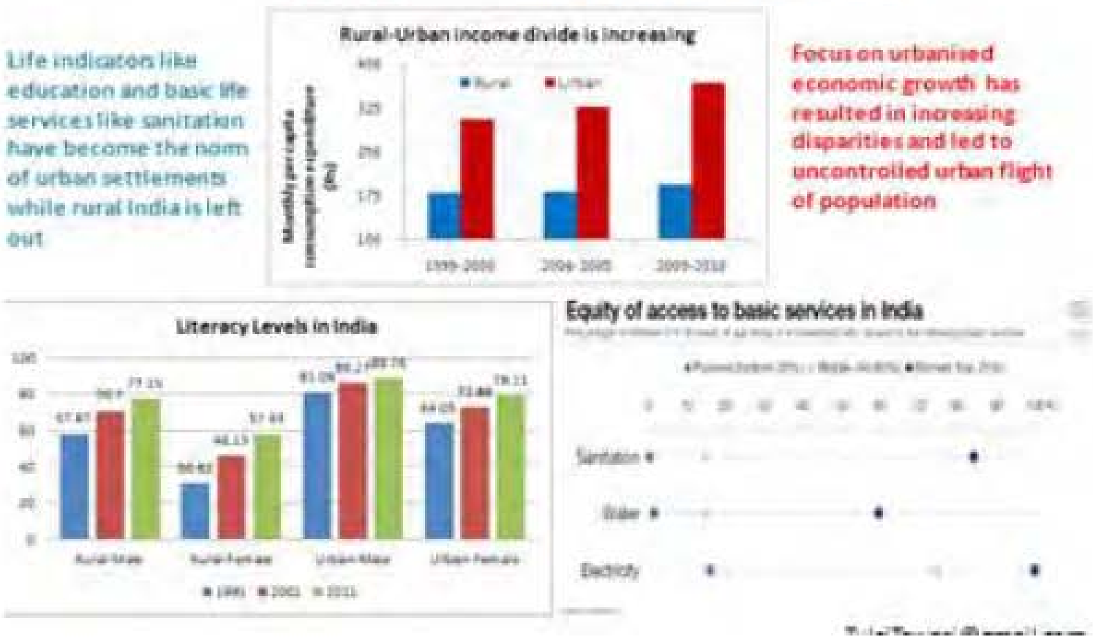


Fig. 6: Urban and rural divide in Indian development process

The economic and life style disparities are startling as we find that rural India scores higher on life style aspects (Fig.7), though income and wealth indicators are higher in the urban population.

Fig.7: Impact of lopsided economic design

6. Re-Designing U-R Habitat

Now I present a model for redesigning an urban-rural habitat for Nandurbar district in Maharshtra (Fig.8)

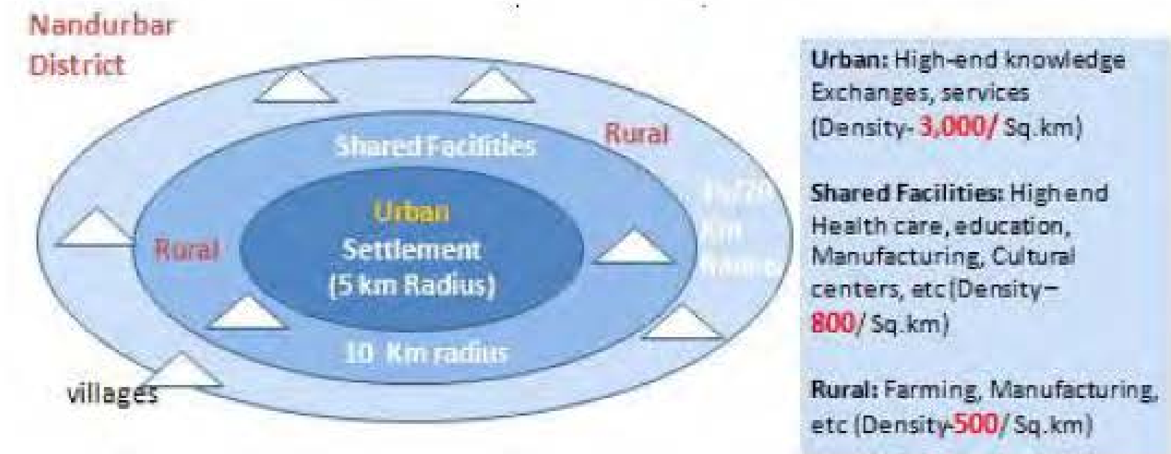


Fig.8: Redesigning Urban-Rural Habitat

The model presented us Fig. 8, shows a central urban area of 5 km radius surrounded by two rural areas of 10km and 15-20 km radius. The area from 5 km to 10 km will contain shared facilities like hospitals, educational institutions and other services. Basic life amenities will be available to both urban and rural habitats and most importantly all the areas need to be well connected by road network and public transport system. Table 2 provides data on the impact on mobility in which, the new U-R-H model of option will reduce the material consumption from 17.3 MT to 2 MT per person per year.

Table 2: Impact on the material consumption for mobility in the redesigned model

Person/ Km	Metro (now)	Town (now)	Option-B (Urbanize) as now	Option-C (U-R-H)
Car-private (1.44kg/p-km)	10% - 2hr	15%- 1 hr	20%- 2 hr	10- 1 hr
Bus (0.26-0.38 kg)	40%- 3 hr	10%- 1.5 hr	20%- 2.5 hr	20- 1 hr
Train (0.53-1.2 kg)	40%- 3 hr	10%- 1.5 hr	20%- 2.5 hr	10- 1 hr
2-wheeler (0.26 kg)	5%- 3 hr	50%- 1 hr	30%- 2 hr	30- 1 hr
Cycle	1%- 1 hr	10%- 1.5 hr	5% - 2 hr	25%- 1 hr
Others	4%- .5 hr	5%- 0.5 hr	5%- 0.5 hr	5%- .5 hr
TOTAL- Time FUEL need (weightage)	**2.9 hr 100**	**1.2 hr 50**	**2.1 hr 80**	**1 hr 30**

The model will also reduce electricity consumption as given in Table 3.

	Option-A (as now)	Option-B (urban)	Option-C (U-R-H)
Household Mumbai-metro	1200	2500	1200
Household-City	600	1500	900
Household-Village	200	300	800
INDIA-total		2000	1000
India (Avg): 2003	753.1		
Finland (EU) (Avg): 2003	9036.5	---	1000 (Goal)
USA (Avg): 2003	9538.8 kWh/p-yr		

Table 3: Impact on electricity consumption in the new model

Lower dependence on gadgets and other materials for basic urban lifestyle can help reduce energy consumption considerably in the U-R-H model. The impact on quality of life will be excellent (Table 4)

Table 4: Impact on quality of life

	Metro (now) 20-40 kms 30,000/sq km	City (now) 5-10 kms 1000/sq km	Option-B 15-25 kms 5000/sq km	Option-C (U-R-H:5/20 kms) U-2500; R-500
Travel-Time	2.9 hr	1.2 hr	2.1 hr	1 hr
Surplus-Time	Nil to little	good	little	Plenty
Travel-stress	extreme	little	extreme	Comfort
Family/Social	Little to nil	good	little	Very good
Access to Nature (rivers, fields, forests)	rare	good	little	Excellent
Housing space	Tiny, Cramped	good	Cramped	Large/ Comfortable
Public space	Little	good	Little	Excellent
Air quality	Polluted	Good	Polluted	Excellent

The positive impact on productivity due to better Quality of Life is not accounted by the current economic measures

7. Measurable Non-Economic Growth

In our growth model so far, any activity that does not add up to the agreed parameters like GDP have been neglected by our economists and policy makers. There are non-tradable parameters like identity, satisfaction, harmonious and healthy living, in contrast money is measurable and tradable. A sustainable growth model should find a balance between money and prosperity and non-economic parameters that are measures of quality of life. India can initiate a debate on redefining wealth by an integrated approach that emphasizes on high calibre and low material consuming activities to add value added wealth creation.

8. Conclusions

Due to shift in life styles and migration from rural to urban settlements, energy consumption has increased many folds and this has led to an unbalanced growth model. Growth has been mainly measured predominantly by material consumption driven economic theories. Natural resources all over the globe are stressed in this growth model and the advances in productivity through technological developments have been unfortunately lost due to concentration of capital in the cities. India a major economic booster for self and global economies, has to decide whether to engage in an integrated approach for equitable access to economic growth across rural and urban populations. Economic growth can be sustainable by developing urban centres with in rural habitats with an integrated approach to help achieve the desired quality of life as well as generation of wealth.

Innovative Thought Forum

List of Speakers

Ensuring India's Energy Security

Seminar on 24th February 2016, at India Habitat Centre, New Delhi.

01	Mr. S.B. Dangayach	Managing Director, Sintex Industries Limited, Kalol. Gujarat-382 721
02	Prof. N.K. Bansal	Ex-Vice Chancellor, SMVD University J&K, Professor (Retd.)IIT Delhi, New Delhi. Sintex Chair Professor, CEPT University Navrangpura, Ahmedabad.
03	Dr. Ashvini Kumar	Managing Director, Solar Energy Corpn. of India,
04	Prof. Amit Kumar	TERI University, Delhi.
05	Mr. B.N Puri	Former Advisor, Planning Commission, Delhi.
06	Mr. Jeevan Jethani	Ministry of New & Renewal Energy, Delhi.
07	Mr. Rajeev Khanna,	Advisor(Retd), Planning Commission, Delhi.
08	Mr. K.B Dubey	Director(Retd.), NTPC.
09	Dr. A. R. Shukla	Former Adviser, MNRE.
10	Mr. Tulsi Tawari	CEO, Ultra-Tech Laboratories P. Ltd, Mumbai.
11	Mr. Pranav Mehta.	Chairman, National Solar Energy Federation of India
12	Prof. Jyotirmay Mathur	MNIT, Jaipur.
13	Mr. Tushar Mavani.	Managing Director, Tarphin, Valsad, Gujarat.
14	Mr. Karan Dangayach	Managing Director, Shashwat Clean Tech, Ahmedabad.

Innovative Thought Forum

List of Participants.

Ensuring India's Energy Security

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