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SPECIAL ISSUE ON ENERGY

IC Centre for Governance
NEW DELHI

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IC Centre for Governance
Niryat Bhawan, Rao Tula Ram Marg, New Delhi-110057

The IC Centre for Governance has been set up in with the objective of collective thinking and acting on important issues of governance. It believes that public governance is too serious a matter to be left entirely to the state and that the involvement of the Civil Society is not only desirable but also essential. The Centre seeks to strengthen the capacity of Civil Society and government for ensuring good governance.

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EDITORIAL

An overview of the Energy Sector

The availability, access and affordability of commercial energy is the acknowledged lever for development, prosperity and reduction of poverty. The energy sector in India has been at the fulcrum of the rapid transformational change that India has been witnessing for nearly seven decades. While energy turns the wheels of industry and transportation, it is also an essential element of social and urban transformation. It plays a key role is increasing agriculture production, commerce, as well as and networking in integrating the country and its resources. Energy consumption in India may have increased exponentially since independence, the journey ahead is long.

Although energy use in India has almost doubled since 2000, it is still about one third of the global per capita average, and nearly 240 million remain without access to electricity. The statistics for use of commercial energy in domestic and other uses are even more stark. The urgency to reduce poverty, coupled with the compulsions of a vibrant democracy has necessitated state intervention in the extraction, supply and distribution of energy. It has also had implications in respect of inappropriate subsidies, operational inefficiencies and convoluted slow decision making. The business of energy is like any other business, and any of the above elements are normally not conducive to healthy or sustainable business. However, the good news is that there is greater public attention and debate on these issues, and there is continued action by successor governments in recent years to jettison some of the avoidable or less merited burdens, improve efficiencies, linking them to global benchmarks, and also move away from being prisoners of dated political ideologies. With the induction of private players and international investors, governmental controls are giving way to independent regulatory bodies. The development of an acceptable market mechanism could take a little more time.

In recent years, the energy debate has moved beyond equity and efficiency and got firmly locked into environmental and climate change implications. The global concerns over the accelerating warming, pollution and consequent economic and health implications are forcing the shift from fossil fuels to renewables, essentially the new renewables. As always, the saturated rich, will continue to demand a greater attitudinal shift, if not abstinence, from the poor. A recent statistic by BP showed that the combined energy use of India, China and Brazil added up to 50% of energy use of US in 2015. It is inevitable that for considerations of the environment as well as energy security, we move as swiftly as possible to affordable new renewables and nuclear, to pursue a low carbon growth trajectory. However, care has to be taken to ensure that the path we undertake is affordable, ensuring that reliable 24X7 energy is delivered to consumers, while working steadfastly on efficiencies, demand side management, transmission and distribution system realities. The development of indigenous capabilities, has to move well ahead of installation plans, so that we do not lose out on operational parameters or equipment self reliance. While we may have the sunshine, we should also have control over equipment manufacture. Having had long years of colonial or feudal governance, we should try and avoid mindless journeys on bandwagons or "alaap" of Raag Darbari. The road map has to be deliverable and sustainable.

Energy use worldwide is expected to grow by one-third by 2040, driven primarily by India, China, Africa, the Middle East and South East Asia. India, which has one sixth of the world's population, and is the world's third largest economy, accounts for only 6 percent of global energy use. With rising incomes and sustained rate of high economic growth, as well as an additional 315 million people anticipated to live in India's cities by 2040, it is expected to account for the largest share in energy growth, nearly a quarter of the global demand. It is imperative that we continue to devote the greatest attention to energy security, skill development and employability. We can be nearby self sufficient in our thermal coal availability. However, in the coming years oil imports could rise to 90% and lesser quantities of gas. Availability of on-shore wind could have been better. The large hydro power sources which are yet to be harnessed lie in ecologically sensitive areas. While we are short on natural uranium, we have ample reserves of thorium, and a commendable mastery over nuclear power technology. We have plenty of sunshine, but have a long road to cover for the manufacture of solar PV equipment. The power transmission network is strong, but not yet equipped to handle very large amounts of solar power into the grid. Smarter grids are an imperative.

Coal will continue to be the mainstay of the Indian energy sector for some decades. The opening up of the coal sector for commercial mining could provide good competition to Coal India, which has shown impressive improvements of late. However coal based power generating plants would need to switch very soon to cleaner super critical and ultra super critical technology for higher efficiencies and lower emissions. Inefficient coal based plants should be phased out or inefficiency penalties imposed on them. The pipeline of coal based power plants is drying up and a large world class indigenous super critical manufacturing capability is very short on orders. Underground mining has to be accelerated, keeping in view limited land availability and medium term environment degradation. In view of the abundance of coal, and the very large import dependence for oil and gas, India needs to aggressively pursue coal to gas and coal to liquid technologies. Low oil and gas prices may not stay for long.

The share of hydro power as a percentage of installed grid connected capacity has fallen over the decades from 50% to less than 15%, and the share of power generated is even lower. For managing our very large interconnected electric grid, hydro power is an absolute balancing operational necessity. With the large scale advent of solar and wind power which are intermittent and not necessarily related to peak load requirement, the development of primary or pumped storage hydro calls for simultaneous development, in addition to storage requirements for new renewables.

The thrust on new renewables has luckily coincided with the steep drop in the delivered price of Solar PV power at the generating end. It would need to be largely coupled with off grid application or local mini grids. Solar pumps should be promoted more aggressively in shallow water table areas. This would reduce dependence on diesel pumps, and also mitigate agriculture power tariff issues to an extent. Land is the biggest guzzler for solar panels. A multi layer array of solar panels could become the norm, as well as the development of solar panel maintenance agencies, providing skilled employment as well as expertise. Renewable Purchase Obligation (RPOs) for electricity distribution companies has not been a success in the past. The New Tariff Policy announced by the Government of India will need to be adopted by all state governments and regulatory commissions, (as electric power is a Concurrent subject) for the success of the massively escalated solar and wind energy targets, of 175, 000 MW of installed renewable capacity, excluding large renewables.

Just as there was a paradigm shift in conventional power generation capacity in the Eleventh Plan, a bigger scale shift to new renewables could be the hallmark of the Thirteenth Plan period. The shift in the balance for new capacity addition from fossil fuels based power generation is imminent. As the saying goes, its time has come. The timing has to coincide with affordability. The shift in generation technology has to be accompanied by a simultaneous shift in transmission technology and end use load management.

Today India has a massive extra high voltage transmission system of 3,36,560 circuit KM which has facilitated the seamless transfer of power across the country. Besides signifying a unified India, it has helped in the creation of a vibrant electricity market across the country. The spot market price of electricity which used to very significantly across the country's electricity regions has narrowed substantially. For the first time in the country's history, the spot market price across the country on Dec 29, 2015 was a single price at Rs. 2.30 per unit. No mean achievement. In the future Right of Way issues will have to be tackled through legislation. Grid stability could be jeopardised if Green Energy Corridors of sufficient strength are not developed expeditiously along with weather forecasting facilities for power scheduling and management. Simultaneously an aggressive Demand Side Management (DSM) and a mandatory energy efficiency programme with a frequency related tariff structure will have to be implemented. Self healing Smart Grids and consumer friendly and participative consumer metering will have to be introduced. The consumers of renewable power will also be the producers of renewable power into the system, heralding the birth of "PROSUMERS" in the power sector. The changes across the value chain will not be limited to electric power. Mobility will get plugged to the electric grid. Electric vehicles with plug-on facility to the grid, and also acting as power reservoirs could soon replace the fossil fuel driven vehicle in this Smart Grid/Smart the City/Smart Mobility scenario. The perils of conventional fuel supply glitches could get replaced by the sensitivities and vulnerability of the smart system. Cyber Security and surveillance would be the guardians of the new lifelines. A very exciting scenario, much beyond the pale of macho slogans and accompanying resonant activity.

On the side of governance in the energy sector, there has been a very positive development. The integration of power, coal and new renewables under a single minister has been an extremely positive development, which had been advocated by the author some time back. The oil and the nuclear sectors are still separate. This integration could be in the next phase, after the present integration has stabilized. The present integration has already shown very positive results, besides reduction in the blame game. The modified rural electrification scheme and the UDAY scheme as a bailout package for the bleeding power distribution companies will hopefully bring greater systems efficiencies and consumer comfort, besides giving relief to the financial sector. However, the acid test lies in more efficient and transparent functioning of the distribution sector, its 'depoliticisation' and a much more professional, active, hands-on electricity regulatory apparatus at the state level, which must acknowledge and discharge the allocated burdens of governance and concomitant accountability.

The volatility in the oil sector is a recurrent periodic phenomenon. The current sharp dip in oil prices has given relief to large oil importing countries like India. However, the flip side is that the present prevailing oil prices could stall big investments in oil exploration, particularly deep sea deposits and also in unconventional shale and gas hydrates. This huge fall in oil prices has played havoc with the economies of oil producing countries and commercial entities. It also displays the extent of disproportionate profits that an oligarchy of oil producers could impose on hapless consumer countries and marginal income consumers. This scenario will also reflect in a decline in foreign remittances from Indian expats, if not their return, as well as a dip in the value of exports of refinery products. There has to be no let up in the drive for automobile fuel efficiency targets. This phase could also coincide with a large scale toning down, if not exit of fuel subsidies. On the environment front, the Government of India has already announced Bharat Stage VI emission norms to be enforced by 2020. Besides a massive expenditure on refineries, it would also entail a stupendous task of automobile engine modification or retrofit of engines. It should not end up as a bonanza or windfall for the automobile sector, much to the chagrin of the middle class consumer. Reduction of vehicular pollution will not come from fuel or engine modification alone. It has to be accompanied by a paradigm shift in urban planning and last mile connectivity solutions for the working population, the aged, and the disabled. It would be prudent not to bite more than we can chew.

The Nuclear Sector has to receive high priority if India is to proceed on a low carbon pathway. If we have to reduce carbon intensity in our GDP by 30-35% of 2005 levels even by 2040, nearly 50% of new electricity generation capacity would have to come from nuclear and new renewables. If global temperature rise is to be contained within 20C, the share of nuclear as base load power will need to be raised in multiples. Chernobyl and Fukushima have certainly stalled the march of nuclear power. Opponents of this power have sometimes magnified the risk from this power. India has been in the forefront of adopting a closed fuel cycle. The 500 MWe Prototype Fast Breeder Reactor should be commissioned soon and a 300 MWe Advanced Heavy Water Rector design utilizing Thorium is ready. Its construction should be taken up. An exciting prospect in the nuclear industry is Low Energy Nuclear Reactions (LENR) technology which seems to be resurrecting itself from the ashes or forced premature exile of cold fusion technology. The recent reported commercial interest in LENR should not be brushed aside in scientific arrogance. Science has always been the playground of heretics, who must come forth at the appropriate time and prove the scientific basis and universal replicability of their beliefs.

The energy sector is a highly capital intensive sector. The International Energy Agency has estimated that India needs an investment of US$ 2.8 trillion till 2040. This could be a conservative estimation, if concomitant change in technology at the transmission, distribution and consumer end is taken into account, as well as forced changes on account of environmental considerations. The management of this sector and its regulation will need to be much more professional, transparent and accountable. The extent of public investment through financial institutions is enough to jeopardize the financial sector itself. However, it is necessary for the economic progress of the millions of aspiring Indians.

This issue of the IC Journal has tried to highlight some of the topical issues which are relevant to the present and the future. We are grateful to the contributors for their valuable time and effort. Owing to space and time constraints we could not accommodate more contributions. We must leave something to the next time the Journal turns its specific gaze on Energy.

ANIL RAZDAN

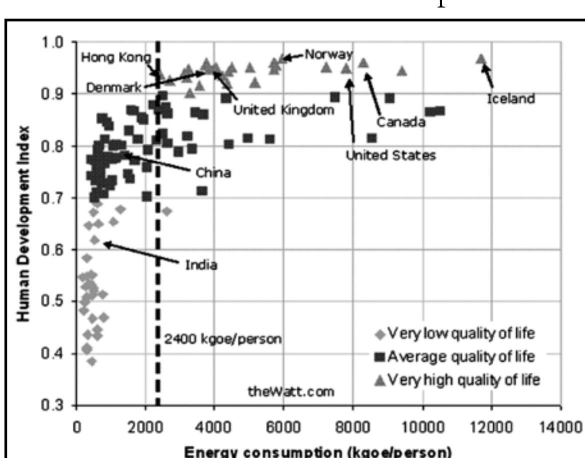
Anil Kakodkar

Low Carbon Pathways for India: An Inevitable Choice

Introduction

It is well known that energy is the key to augmented capability and improved quality of life of human beings. This is particularly true for countries or societies on a developing path. Apart from energy, there are other aspects like education, health services etc. that also go to determine the Human Development Index (HDI) and that leads to scatter in the correlation between HDI and per capita energy use. Despite that scatter, an unambiguous message that one sees in the correlation is about the optimum per capita energy use. We need around 2400 kgoe per person to assure best possible HDI. Many countries already use energy at a much higher level but that does not contribute to enhanced HDI for them. People in poor countries, on the other hand, dream of living like a westerner and that would need access to higher levels of energy at least reaching up to 2400 kgoe per person.

World Energy Outlook 2015 in its recent report which apparently takes into account the pledges made by parties to UNFCC ahead of COP 21 scheduled for December 15 in Paris, projects, in the central scenario, energy demand growing by nearly a one-third between 2013 and 2040, with



all of the net growth coming from non-OECD countries and OECD demand ending up 3% lower. The energy-related CO_2 emissions are projected to be 16% higher by 2040.

World Energy Outlook's special report on India, 'India Energy Outlook' projects a rise in energy demand in India to be one quarter of the global growth between now and the year 2040. This would be the largest fraction for any country. By the year 2040, while 50% of new electricity generation capacity (estimated at 900 GWe) is expected to be coming from renewable and nuclear, the new coal based power generation capacity in India is expected to be half of net coal capacity added worldwide. The coal demand in India is thus expected to be two and half times what it is today. Oil demand is likely to approach 10 mb per day and gas consumption tripling to 175 bcm/yr. In spite of all this, the per capita energy demand in India would be 40% below the global average while CO_2 emission triples to 5 gigatons.

We thus have major challenge ahead of us even after realizing the 2030 targets specified in the Indian INDC, those of building up a 40% share of the power sector capacity through non-fossil energy and reducing our emissions intensity of GDP by 33-35% below 2005

Sr. No.	Parameter	Total	PerCapita	Remarks
1	Current(2015) Energyuseper year	0.820 Btoe	640 Kgoe	Mostof oilandsome gas andcoal imported.Importof energylikelytorise steeply.(>5-7times in 15-20yrs.)
2	Desirableenergy useperyear	4.125 Btoe	2500 Kgoe	To reachHDI of0.9+
3	TotalPrimary energyreserves (coal,oil,gas)	361.8Btoe		Actualmineableis muchless. Need technologytomake betteruseof availableresource.
4	TotalRenewable Potential(incl. Hydro,excl.Solar)	~300,000MW (peak) 0.2Btoe/yr		~5%of requirement
5	SolarResource	~45,000sq.kmwhichcorrespondstoafourthof barrenanduncultivablelandinIndiawouldbe sufficientto meetentireelectricity requirements(~20% of totalenergy requirement)		Needsemphasison solarthermal (forbothelectricity andhydrogen)
6	Nuclear Resource	Uranium ~87Btoe Thorium >600Btoe		Onthebasis ofnuclear recycle

EnergyRequirementsandResourcesinIndia

levels. The challenge is three fold, a sustainability challenge, aclimate change challenge and an afford ability challenge.Considering that much more would need to be done in terms of emission reduction and access to even greater energy supplies in the post 2040 period, we would need an aggressive twin track energy development approach. A look at the accompanying table on energy requirement and resources in India would suggest the following;

1. Quick deployment of clean coal technologies is of paramount importance since fossil energy would remain the mainstay of our energy supply for some time. We also need to accelerate deployment of technologies to augment domestic hydrocarbon supply including through use of technologies like coal to liquid and non-fossil energy derived hydrocarbons.
2. Implement a strategy to meet all our energy requirements based on non-fossil energy resources available on the Indian land mass. Luckily, India is well endowed with abundant solar energy and thorium resources. Both are large enough to meet our growing energy requirements well in to future. A strategy to exploit these and other renewable energy resources would also address all the three challenges namely the sustainability challenge, the climate change challenge and the affordability challenge.

Technology is the key to realize success on both the tracks mentioned above. We must also recognize that some of the technologies that we need are unlikely to be available elsewhere simply because our key energy resources are different from others. For example our coal with high ash content poses special challenges, dust load in our atmosphere is high for efficient functioning of solar installations, our key nuclear resource is thorium which is not of any immediate interest to other countries, nuclear recycle which is inevitable for exploiting thorium is a taboo for many countries and is considered too sensitive to be a matter of international commerce. Inputs from domestic R&D are thus of paramount importance. In absence of strong domestic R&D linkages, we may either end up pursuing inappropriate technologies or suffer obsolescence after a period for technologies that are specific to India.

Non-fossilelectricitygenerationscene-India

	potential	currentdeployment (31.8.15)
LargeHydro	1,48,701MW36,878MW.	
Solar	5,000trillionkWhper yearsolarinsolation	4,229MW
Wind	1,02,788MW	24,088MW
Biomass	23,000MW	4,418MW
Smallhydro	20,000MW	4,146MW
Offgridcaptive		1,218MW
Nuclear	> 2,000,000MWetaking into accountdomestic+imported uranium	5,780MW
TotalNon-fossil		81,757MW (30%oftotal)

Moving to non-fossil energy future

The next question that one must address is whether as a part of our non-fossil energy based energy future we need both renewable as well as nuclear energy. The answer to this question is unequivocal yes. The reason is simple. Substantive renewable capacity is intermittent and requires significant additional investment for storage either at source or in the power system. Nuclear energy on the other hand is available on 24X7 bases. Further when seen in the context of level of energy use that we are aiming at, we really have only two choices; Solar and Nuclear and energy basket of the country must have diversity. We must thus aggressively move to rapidly expand our solar and nuclear capacity to a level that can meet almost entire energy needs of the country between them.

Unfortunately, the climate change debate all along seems to deliberately ignore the centrality of nuclear energy in protecting mother earth. The reality is that given the limited carbon space available and unfulfilled development aspirations of a large fraction of humanity, an important role of nuclear energy is inevitable for protecting our earth. Many eminent thinkers including some who were pioneers of green peace have recognized this. It is time, nuclear energy is brought centre stage in our climate action plan.

Fukushima accident in 2011 was caused by Tohoku earthquake and tsunami which killed nearly 16000 people. Nobody died from radiation. Indications are that no discernible increase in incidence of radiation related health effects are expected. Chernobyl accident was a direct result of faulty design and faulty operator actions. Fewer than 65-70 people have been reported to have died as a result of Chernobyl accident. On the other hand, using the estimates of health effects per TWh, the worldwide health toll in the year 2010 from air pollution due to coal combustion could be around 210,000 deaths, almost 2 million serious illnesses, and over 151 million minor illnesses per year, not including the effects of climate change.1 Impact of climate change could be far worse.

According to World Nuclear Association at least 80% of the world's electricity must be low- carbon by 2050 to keep the world within 2°C of warming. This is a massive global challenge that requires the use of all available low-carbon energy technologies. According to the International Energy Agency, nuclear energy has already avoided the release of around 56 Gt of CO_2 since 1971. In India's context, solar and nuclear energy are both consistent with our domestic resource base (in fact they are the only two domestic energy resources that are capable of addressing our needs in distant future), our technological capability and have low carbon foot print. Basing our energy future on aggressive development of nuclear and solar energy therefore makes eminent sense.

Nuclear Energy

Sensitivity and strategic dimension of nuclear energy was recognized right since the inception of our nuclear programme in mid fifties. Self reliance was thus adopted as a key driver of

[1]Erica Burt, Peter Orris, Susan Buchanan, 'Scientific Evidence of Health Effects from Coal Use in Energy Generation', University of Illino is at Chicago School of Public Health, APRIL 2013

the programme. Following the 1974 peaceful nuclear explosion experiment, the commitment to self reliance enabled us to carry on with comprehensive development of technology despite the embargo imposed by the international community. We not only carried on with evolving our own technology and deploy it on commercial basis, but achieved a level of excellence that was recognized globally. Some of our home built power reactors recorded top level performance as recognized by the global community. We even moved the technology development process to build new technologies that were either unique or mastered by few countries. Construction of 500MWe prototype fast breeder reactor (PFBR) was launched. The project is expected to go on stream soon.

300MWe Advanced Heavy Water Reactor that would produce a substantial part of its energy from thorium and virtually eliminate any adverse impact in public domain was conceptualized and configured following the Chernobyl accident. The reactor design is now ready, awaiting launch of its construction. The nuclear propulsion reactor for submarines was built and delivered. Several advancements in the area of nuclear fuel cycle technology (both front end and backend) took place in parallel with development of nuclear reactor technology. India came to be recognized as a responsible country with advanced nuclear technology, given that all this was achieved through domestic efforts without infringing any of our agreements.

The year 1998 saw India demonstrate its nuclear weapons capability following the conclusion of CTBT negotiations to address security threat perceived from its two nuclear neighbours. The restrictions on high technology trade became tighter. International community soon realized that while this had little effect on India's strategic advancement, the progress on nuclear energy front remained slow with substantial loss of market opportunities in high technology area including nuclear. This coupled with favourable contemporary geopolitics, fast growing economy, emerging threat of climate change

[1] Erica Burt, Peter Orris, Susan Buchanan, 'Scientific Evidence of Health Effects from Coal Use in Energy Generation', University of Illinois at Chicago School of Public Health, APRIL 2013

as well as price volatility and its link with rapidly expanding use of fossil energy in India and a few other such factors led to a positive atmosphere for mainstreaming India by removing restrictions imposed on it by the international community.

Today, over and above the growth in nuclear capacity based on domestic programme, we have the possibility to augment the rate of growth through international co-operation. Also we have the possibility of importing uranium to augment energy supply. Access to uranium not only enhances the immediate energy supply but also constitutes a source for the future through the possibility of recycle of spent fuel. In terms of expeditious actions to mitigate climate change threat through rapid augmentation of non-fossil energy supply as well as to move closer to our goal of thorium utilization on a large scale, this is of crucial importance.

A few hurdles however still remain. The newly enacted liability law has posed a major challenge not only to foreign vendors but also to the Indian vendors who have been traditionally active in the domestic programme. Also several PSUs wanting to invest in nuclear energy are unable to do so presumably pending an amendment to the atomic energy act. We have already lost precious years. These issues, which are more interpretational in nature rather than fundamental policy matters, need to be quickly resolved and the programme pushed proactively forward.

At some point of time in the past, we were simultaneously working at five or six sites. With large unit sizes that prevail today, after an initial mobilization period, capacity addition at the rate of 5000 to 10,000MWe per year can in fact be aimed at provided requisite finance can be mobilised. Programme mode of implementation in which manufacturing shops as well as construction sites are continuously kept busy through approvals and financial closure for all units to be set up at a site in one go as well as contracts covering manufacture of multiple standardized equipment for several plants, would be the key to gaining momentum to nuclear capacity addition.

Spent fuel disposal is often touted as a major challenge to deployment of nuclear energy.

While this indeed is an unresolved issue for countries reluctant to adopt closed fuel cycle, for a country like ours where pursuing closed fuel cycle has been a part of policy imperative right since the beginning, the spent fuel is actually an energy resource. Once the fissile and fertile resources from spent fuel are recycled the residual material left is a very small fraction. Even here, using advanced technology, one can separate and recycle minor actinides and remove useful materials like cesium for use in radiation processing. Thankfully, India not only possesses comprehensive industrial scale technology for back end fuel cycle but also has significantly advanced in actinide and cesium separation technologies. Indeed it is possible to pursue a targeted R&D programme that would bring radio-toxicity of nuclear waste to levels comparable with that in a uranium mine in a time frame of a few hundred years, thus eliminating the perceived larger radioactive waste problem within an institutional life time.

In parallel with rapid growth of uranium based power plants, we should also start thinking of ways and means to gain momentum to the fast reactor programme following commissioning of PFBR. This involves both replication and scale up based on PFBR as well as further technologies to augment breeding through deployment of metal fueled fast reactors. Similarly, while AHWR is a technology demonstrator for large scale thorium utilization, we need to work on more optimum thorium energy technologies such as molten salt reactor systems and accelerator driven subcritical reactor systems. In even longer run fusion energy is expected to address the energy needs of mankind providing adequate energy supply for all without any unacceptable earth burden. Even here India is in the forefront of technology development and is an equal partner in the International Thermonuclear Experimental Reactor project coming up at Cadarache France.

Solar Energy

India is endowed with abundant sunshine with large enough solar insolation to meet our entire augmented energy requirement. Recently the JNNSM targets were enhanced to 100,000MWe solar energy capacity by the year 2022. 40,000MWe out of this are to be in the form of roof top installations and balance coming from medium and large capacity plants. This indeed is a very welcome development.

Solar energy being a diffused source requires a large collection area. Being omnipresent, it makes sense to locate the distributed generation close to users. We should thus maximize roof top installations as well as other available opportunities which do not place specific demand for land. Realizing large solar generation capacity (hundreds of gigawatts) is however possible only through large capacity plants for which large tracts of land is necessary. Since India is a country with one of the highest population density, we need to be very conscious of land use conflicts that large scale solar energy deployment could cause. A survey of land data on Indian land mass indicates that there is sufficient barren and uncultivable land available for meeting our entire requirement. Desserts and barren mountains appear most attractive in this context as they are unlikely to cause any land use conflict and should be preferred for locating such large capacity plants. This however would mean that the plants would need to be located in remote areas away from population centers with long distance power transmission infrastructure.

Solar energy being intermittent in nature also needs significant energy storage capacity either at the generation point or in the power system at large. This means additional capital investments which could become very large when the proportion of such fluctuating generation component in comparison to overall power system capacity becomes large. Solar thermal systems deserve greater attention in this context since they can be easily integrated with adequate energy storage capacity in a cost effective manner. We should also recognize very significant power conversion efficiency advantage at larger capacities (>100MWe) as well as economy of scale with solar thermal technology. Assessments show that domestically built large capacity solar thermal power plants capable of operating on 24X7 bases could be cost competitive with respect to other electricity generation options including photovoltaics. This aspect needs our due attention not only because of it potential competitive advantage but also because of much larger domestic value addition potential that is possible with solar thermal and which would create additional jobs and help further spur our economy.

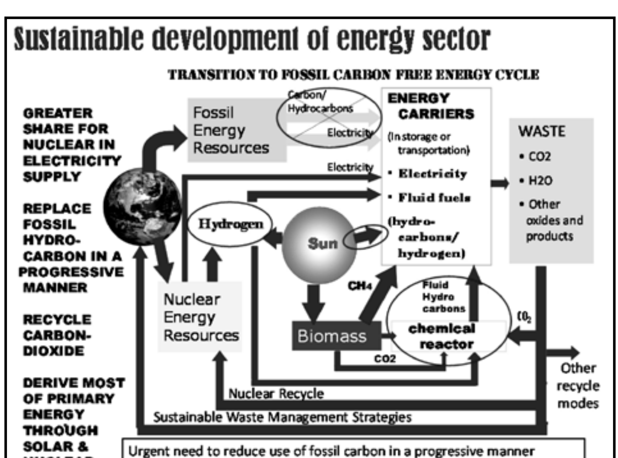
To realize such an objective, we need to set up significant scale (a few megawatts) demonstration projects from where credible cost projections to assess financial viability of the technology can be made. Currently BARC and ONGC with support from MNRE are setting up a 2MWe beam down plant. With heat receiver on ground, the technology would also be useful in making use of solar heat for pyro-chemical and pyro-metallurgical processes. Similarly, IIT Bombay along with NTPC is working on a 3.5MWe dual technology plant capable of 24X7 operation. Demonstration of these and such other technologies on multi megawatt scale should pave the way for setting up large capacity of competitive solar thermal technology with near full domestic supply chain on one hand and also open up the role of solar energy for high temperature chemical and metallurgical processes on the other.

It has been seen time and again that making high technology products in India based on domestic development creates large cost advantage. In case of solar energy technology (both PV and thermal), since large investments would be involved, we should specially promote competitive development of various technology products jointly by industry and academic research institutions. This would create our domestic capability that would not only sustain competitiveness for a long time in future but also build capability for further innovations that should develop and sustain our cutting edge capability.

In this context, we should also recognize that while competitive technologies come out from high tech innovation ecosystems with high level of excellence and we must be a significant part of such global innovation process, there are always India specific technology needs. We should be in a position of advantage in developing products that address such needs. For example, in case of solar energy, higher dust load and its impact on design and performance of large scale surfaces that are involved in both photovoltaic as well as in solar thermal is a specific challenge in India. Similarly blowing sands in case of installations located in dessert could pose challenges needing solutions. Aggressive research to increase conversion efficiency and minimize cost of harnessing solar energy is being pursued across the world. In this context hybrid between direct energy conversion at high temperatures and heat conversion through thermodynamic route could prove to be promising. It is important that the drivers for our research are based on our national priority needs rather that just following a band wagon approach and complimentary capabilities that one might need to realize a development objective are mobilized through networking of our laboratories and industries.

Silicon is and would continue to remain key material for solar energy for quite some time. As a part of strategy to enhance domestic content in solar energy supply chain, it is important that we have a reasonable domestic capacity for silicon production. Silicon is also a key material for electronics as well as for a variety of detectors. A silicon production plant therefore needs to be configured including its energy needs in a manner that would fulfill these needs in a cost competitive manner.

Solar and nuclear as non fossil primary energy Electricity constitutes a very convenient form of energy that can be transported through conductors and power a large variety of end appliances to meet most of our needs. As the development in a society moves forward, so also the proportion of electricity use increases. Even so electricity occupies around 20-30 percent of total energy use. Another major mode of transportation and use of energy is in the form of fluid hydrocarbons. As a part of our ambition to move towards fossil



energy free world without constraining development, we need to be able to derive fluid fuels (liquid hydrocarbons, gaseous hydrocarbons and hydrogen) from non-fossil primary energy in the form of solar and nuclear energy. This would require solar and nuclear energy to be available as high temperature heat in addition to electricity. In case of nuclear this can be done through high temperature reactors and in case of solar energy this can be realized through concentrated solar thermal technology. In addition to producing electricity and high temperature heat through nuclear and solar, we need a number of other technologies such as steam electrolysis, thermo-chemical splitting of water, hydro- carbon substitutes using hydrogen and bio-mass, CO_2 sequestration to produce useable hydrocarbons etc. While development work is taking place in some of these areas, we need to mobilize development work in remaining areas and accelerate the whole process.

Closing remarks

To sum up, we now have much greater awareness about the threat of climate change even as there is highly inadequate carbon space left to accommodate development aspirations of a large country like India. In the business as usual mode, managing both development as well as immunity from climate change threat does not appear possible. Further India's energy resource position to meet long term needs does in fact suggest use of solar and nuclear (thorium) energy both of which are in the nature of non-fossil energy. We must therefore accelerate our three stage nuclear power development, develop solar thermal technology for setting up large scale solar plants and intensify our R & D to address all challenges on the way. As a part of transition strategy to move from fossil energy to non-fossil energy, we must aggressively pursue energy conversion technologies to produce and supply requisite quantities of fluid hydrocarbons and eventually hydrogen derived from solar energy, nuclear energy, biomass, water and perhaps recycled CO^2.

Clearly this is a non-trivial challenge that needs coordinated engagement of our research laboratories, energy manufacturing and services industry, financial institutions and Government policy.

Krishan Dhawan, Deepak Gupta, Vrinda Sarda

Demand Side Management

The Unseen Resource in India's Power Sector

India is witnessing rapid economic growth and steady population growth. By 2030, it is expected to be the most populous country in the world and one of the largest consumers of energy. India's electricity demand is presently increasing at the rate of about 5% every year. Despite an installed capacity of more than 279 Gigawatt[1] (GW), a modest power consumption rate of 914 kilowatt-Hour[2] (kWh) per capita annually, and only 78% of the population connected to the grid – we are still a power deficit country with an overall peak shortage of 5%[3], and an overall energy shortage of more than 4%[4]. Providing the much needed energy access to the currently unserved 400 million people and higher levels of energy use as a result of economic growth and urbanization, may well lead to a demand-supply mismatch. Meeting the energy challenge is, therefore, of fundamental importance to India's economic growth and its efforts to raise its level of human development.

The National Institution for Transforming India (NITI) Aayog estimates that in 2031-2032, India will need 2,628 Billion Units (BUs) of electricity, which is more than double the current demand of 1,049 BUs. Historically, India has set up more power plants to build supply, promoting all kinds of supply sources – fossil fuels, renewable sources and other non-conventional sources. In times of depleting conventional resources and growing climate change

1 http://powermin.nic.in/power-sector-glance-all-india

2 http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS The world average per capita power consumption rate is at 2,429 kWh

3 http://cea.nic.in/reports/annual/lgbr/lgbr-2014.pdf

4 http://cea.nic.in/reports/annual/lgbr/lgbr-2014.pdf

concerns, significant reliance on conventional supply alone may not be an ideal energy blueprint. Further, such efforts have been constrained by various challenges around coal and gas allocation, environment clearances, land acquisition and financing. As a result, only a few new projects have been set up.

While it is important to strengthen the supply side infrastructure, such measures are largely time intensive and have long gestation periods. There is a need to complement such efforts with measures that can yield quicker and sustainable results. Energy efficiency and Demand Side Management (DSM)[5] , offers one of the fastest, cleanest and most cost effective ways to meet our growing energy needs. Such efforts will help us significantly bridge the demand supply gaps in a relatively shorter time frame, bring down our future demand trajectories, and will be far cheaper than building new power plants and laying new transmission and distribution infrastructure.

India's Intended Nationally Determined Contributions (INDCs) pledge to reduce greenhouse gas emissions intensity by 33-35% of its 2005 levels by 2030[6] further strengthen the case for aggressive DSM interventions.

WHAT IS DEMAND SIDE MANAGEMENT?

The Ministry of Power defines DSM as actions taken by the electric utility to alter the end-use of electricity consumption beyond the customer meter. These actions may be taken to increase demand, or decrease it, or shift it between high and low peak periods, or manage it when there are intermittent load demands. This can be carried out in two different ways – either by load reduction techniques or by load management techniques.

Load reduction techniques reduce the kilowatt hours (kWh) consumed without altering the overall level of services being availed by the customers. They encompass both energy efficiency and energy

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[5]Demand Side Management (DSM) refers to actions taken by the electric utility (discoms) to alter the end-use of electricity consumption beyond the customer meter

[6]Press Information Bureau, Government of India, Ministry of Environment and Forests, 02-October-2015; http://pib.nic.in/newsite/PrintRelease.aspx?relid=128403

conservation measures. The former lead to the adoption of energy efficient technologies and end use appliances, while the latter lead to lifestyle or behavioural changes resulting in the efficient use of various end-use applications.

Load management techniques are employed by utilities when there is a need to modify customer load profiles and thereby reduce, or shift demand from one period to another – typically peak to off-peak – with the overall aim to flatten the load curve. A few examples of widely adopted load management techniques include Demand Response, a voluntary load curtailment scheme, and time of use tariffs structure, in which different rates are applicable for use of electricity at a given time.

The DSM intervention adopted by the distribution utility (henceforth Discom) usually depends on the objective of the utility in question – whether it is peak clipping, load shifting, strategic load conservation or load growth. While the terms DSM and Energy Efficiency are often used interchangeably, they are in fact not the same. It is important to note that DSM explicitly refers to actions that involve deliberate interventions by the Discom to alter the consumer's load profile.

WHO NEEDS DEMAND SIDE MANAGEMENT?

For decades, the Indian power sector has remained chronically inefficient due to its complex nature and legacy issues. While the reforms proposed by the Electricity Act, 2003 have made headway in both the generation and the transmission segments, not much has changed on the distribution side.

The distribution segment shoulders the most critical role in the overall power supply value chain. It delivers the generated and transmitted electricity to electricity consumers and collects revenues, which is necessary to keep the sector going. Over many years, the distribution sector has become financially unstable due to three main reasons: high aggregate technical and commercial (AT&C) losses (approximately 27% against a target of 10%); heavy subsidy to select consumer categories; and poor metering and billing. As a result, Discoms are in a financially stressed condition, where they are unable to make investments in their network and systems. They are caught in a vicious cycle where serving customers will require them to procure more power, which is increasingly expensive, but revenue collection is insufficient to meet the increasing costs of supply.

This is where DSM can play a critical role. DSM has the ability to mitigate peak load as well as base load (energy demand) at much lower costs (since efficiency is cheap). Therefore, it can reduce the demand for expensive power purchases by Discoms, during peak as well as off peak times, while reducing shortages immediately.

BENEFITS OF DEMAND SIDE MANAGEMENT

Scaling up DSM will result in improved end-use efficiency, which in turn will reduce the expected increase for overall power demand in future. DSM also offers improved service quality and reliability by filling the demand-supply gap. With reduced power procurement costs, the financial condition of Discoms will improve, enabling them to provide reliable and cost-effective electric supply to their consumers. This in turn will help consumers make timely payments of their reduced electricity bills – thus breaking the Discoms' operational and financial deadlock.

Further, DSM programs targeted at low paying and subsidised consumers can help bring down the overall cost of electricity delivery for Discoms and for the state. Thus, DSM can support the enforcement of the Electricity Act 2003, and has the potential to address the challenges faced by the distribution sector including high subsidy allocation and pilferage in some consumer segments. Considering these benefits, most Discoms will recognize that demand management is a key solution for reforming the sector. And, it is better to save electricity at lower per unit (kilowatt hours - kWh) costs than to invest in expensive generation and transmission networks. On the other hand, most consumers will find it an attractive proposition to support DSM, since they can avail of incentives from the Discoms, without changing their overall service needs. The efficiency supported by Discoms is a far more attractive option than leaving it purely to consumer adoption in the markets.

Other key stakeholders of the power sector i.e. the Regulator and the Government, with their responsibility towards consumers, also believe DSM to be an attractive option, since it helps them reflect the benefits of efficiency in the electricity tariff structures for Discoms.

THE CONVERSATION AROUND DEMAND SIDE MANAGEMENT

A large number of state officials, regulators and Discoms are now expressing interest in implementing DSM measures. Significant progress has been made in the DSM policy and practice space. Sixteen state regulators have already notified DSM regulations, and the Discoms in these states have now started to look for innovative measures to gain savings and optimise their existing energy mix. This is a marked shift from early 2009 where much of the Indian DSM policy and regulatory conversation was limited to setting standards and labels as well as debate over the efficacy of CFL lighting. In contrast, the value linkage between efficient electricity demand and consumption and an efficient and cost-effective power system has become more conventional wisdom, both in the Central Government and amongst State Electricity Regulators.

In another positive development, DSM conversations in policy circles focus on fuelling market-transformation across a broad cross-section of energy-using equipment. There is a significantly enhanced understanding of the linkages between scaled-up DSM activities and reduction in electricity shortages.

HOW TO DESIGN A DSM PROGRAM

To design effective DSM programmes across consumer categories, it is important to assess how and when electricity is used. It is also important to understand the consumer's choice of appliances and usage patterns. Load Research, which is the process through which Discoms study how consumers use electricity either in total or by end use, is the first step towards the development of an effective DSM plan. Load Research provides data on consumer load profiles and load patterns by using local sub-metering data, consumer bill analysis, walk through audits, consumer surveys and market research.

Subsequently, these outputs are converted into a DSM action plan and detailed program designs.

Program design is an integral component of the DSM plan. It aims to reach out to consumers and motivate them with incentive payments and awareness campaigns. A few widely accepted program designs adopted by various Discoms are discussed below:

Rebate Programs - These programs typically involve a rebate/ discount on the capital cost of the energy efficient equipment to offset the high differential cost involved in the purchase of the energy efficient appliance. The rebate is usually paid directly to the buyer, but on the submission of proof of purchase in the case of an end user or proof of sale in the case of a retail or a distributor. A perfect example of this is the Bachat Lamp Yojana (BLY), which was implemented by the Bureau of Energy Efficiency in 2009. Under this, any domestic consumer could get up to four energy efficient Compact Fluorescent Lights (CFLs) in exchange for working Incandescent Bulbs (ICLs), each at a discounted (rebate) price of 15. Rebate programs are of much benefit to consumers since they mitigate the high upfront cost of the energy efficient appliance and offer the appliance at a lower cost.

Standard Offer Programs (SOP) - The SOP is an innovative approach to augment energy efficiency deployment. It treats energy efficiency as a commodity comparable to generated electricity. Under this arrangement, an energy efficiency resource acquirer (typically a Discom) purchases future energy savings or demand reductions from an energy user (say, a utility customer) or third party energy efficiency implementation agencies (such as an Energy Service Companies) at a pre-determined price. The SOP is comparable to Feed-in-Tariffs used to promote renewable energy. A perfect example of this is the Domestic Efficient Lighting Program (DELP) implemented by Energy Efficiency Services Limited (EESL)[7] in Puducherry and Andhra Pradesh. Under this program, EESL along with respective State Governments offered self-ballasted Light Emitting Diode

[7] A prominent public sector Energy Service Company (ESCo)

(LED) lamps to domestic households at discounted prices. Further, both the Puducherry and Andhra Pradesh utility committed to compensate EESL's investments at a price in the range of 1 to 2 per unit of verified energy savings. These projects have been structured as standard offer contracts with EESL and respective Discoms as counterparties. It is possible to structure Demand Response programs under similar structures, where consumer can be paid by the Discom at a fixed or competitive rate via a third party (say a demand aggregator), for the demand curtailed by the consumer upon the Discoms' request.

On-Bill Financing Programs - This is a mechanism through which a utility provides the capital cost of the energy efficient equipment to consumers for meeting the upfront cost of an energy efficient equipment. This cost is subsequently recovered from the consumer by including its repayment in the consumer's electricity bill. At times, the capital cost itself and its interest is also subsidised. It can be likened to a loan provided by the Discom to the consumer for bridging the high cost of an energy efficient appliance, with or without an additional subsidy. A perfect example of this is the DELP program implemented by EESL in Delhi and Rajasthan. Under this program, Discoms along with EESL are providing up to four 7W LED's to all domestic households at a wholesale price of 93/LED in Delhi and 150/LED in Rajasthan. The consumer may either buy it upfront at these prices or make a down-payment of 10 and pay the balance through their electricity bills over a period of 9 months and 12 months in Delhi and Rajasthan respectively. Such a program is highly cost effective for the utility as there is a complete recovery or costs through bills.

APPLICATIONS FOR DEMAND SIDE MANAGEMENT INTERVENTIONS

Discoms can use any of the above program designs or a combination thereof to develop DSM programs across various consumer categories including residential, agriculture, commercial, municipal and industrial. DSM has immense potential for achieving efficiency across dominant end uses applications like lighting, cooling, heating, refrigeration, motors, pumping etc. Key applications suitable for DSM interventions are discussed below:

Lighting[8] - Lighting accounts for around 18% of India's total power consumption, which is much higher than the average of 12-15% in developed countries, thus suggesting the need for energy efficiency. The lighting industry has made enormous leaps, growing from 8500 crores in 2010 to 13,500 crores in 2013 – a 53% growth in three years. The growth of the lamp segment was driven by CFLs while ICLs and Fluorescent Tube Lights (FTL's) saw minimal growth in their volume. The Bachat Lamp Yojana (which replaced ICLs with CFLs) improved CFL adoption considerably. The LEDs segment with high procurement cost (about 500 and above per LED) as compared to its counterparts (CFLs at less than 200 and ICLs at less than 20), moved at a slow space till 2013, but expanded significantly after.

LEDs offer a significant efficiency opportunity providing a higher level of service as a CFL lamp at less than half the power consumption. In replacing all CFLs with LEDs, and assuming we do not use any ICLs, the share of lighting demand in India would be halved. With ICLs still widely used in rural areas and even in urban areas, the efficiency opportunity is enormous.

India is already undertaking national level initiatives for promoting LEDs and enabling the transformation of the LED market. These initiatives have the potential to lower the base load requirement – across the day and year, and will help discoms decrease subsidy requirements. A few recent initiatives include replacing street lighting with LEDs, providing free LED lights to below poverty line houses, and distributing LEDs to domestic consumers under the Domestic Efficient Lighting Program in various states. This combined with changing consumer preferences and steadily dropping prices, the LED market is expected to grow to 60% of the total lighting industry by 2020.

[8]All numbers under 'Lighting' can be found here: http://www.elcomaindia.com/wp-content/uploads/ELCOMA-Vision-2020.pdf

Cooling / Air Circulation (Ceiling Fans)[9] - After lights, ceiling fans are the most common electric appliance with a 20% share in current domestic electricity consumption and an expected growth of 10% each year in sales. It is also expected that 70% of the ceiling fans in 2020 would have been added only since 2009. With a useful life of around 15-20 years, ceiling fans have a long replacement cycle, thus locking in the inefficiency for an extended period of time. Cooling fan technology that is available today (but not yet commonly used in India) at 30-35W is twice as efficient as commonly used technology (at about 60-90W), and four times more efficient than the technology that was used 15 years ago. The challenge here is that the cost of such efficient fans is more than double the cost of ordinary fans. While in most cases, the payback of additional costs is less than three years, consumers tend to purchase less efficient fans, owing largely to a lack of awareness or motivation.

Recognizing the need for intervention, the government is working with Discoms to influence consumers through awareness building campaigns, standard setting and incentives. The Bureau of Energy Efficiency has floated a request for proposals (RFP) for the selection of manufacturers and will incentivise them to offer efficient fans at costs comparable to standard fans under the Super-Efficient Equipment Programme (SEEP). In addition to fans, efforts are also being made to develop policy guidelines and infrastructure frameworks to expand SEEP to other appliances.

Space Cooling (Air Conditioners) - According to 'India Air Conditioners Market Forecast and Opportunities, 2020', the Indian air conditioner (AC) market is likely to grow at a Compound Annual Growth Rate (CAGR) of over 10% during 2015-20. The AC market is divided into two major segments: commercial ACs (Variable Refrigerant Flow (VRF), Chillers and Others) and Room ACs (Split and Window air conditioners), among which, residential AC segment witnessed a higher revenue share in 2014. This rise in ownership of residential ACs is mainly associated with rising incomes

[9]All numbers under 'Cooling (fans)' can be found here: file:///C:/Users/Vrinda/Downloads/ceiling_fans_the_overlooked_appliance_107A01%20(2).pdf

and urbanisation, falling technology costs and rising temperatures for most part of the year in almost all areas of the country.

Box 1: Super-Efficient Equipment Programme (SEEP)

SEEP has been designed by the Bureau of Energy Efficiency under the National Mission for Enhanced Energy Efficiency (NMEEE). It aims to bring accelerated market transformation for super-efficient (SE) appliances by providing financial stimulus in an innovative manner at critical points of intervention.

SEEP has been initiated to cover ceiling fans with the aim of leapfrogging them to an efficiency level that is around 50% more than the market average. The program will provide manufacturers financial incentives to enable them to produce SE ceiling fans and sell them at a discounted price. It focuses on introducing SE fans of 35W or less in the market as against the current average ceiling fan of 70W.

The selection of manufacturers is based on the reverse bidding mechanism. The BEE will provide an incentive to manufactures subject to a maximum of 500 per unit to produce and sell it at price equal to the price of conventional ceiling fans. More details about the program are expected to be available soon in the public domain.

A study by the Lawrence Berkeley National Laboratory (LBNL)[10] projects that the electricity demand from just room ACs is expected to increase from 8 BUs in 2010 to 239 BUs by 2030, which in turn translates to a peak demand contribution of 143 GW. It is expected that meeting such a demand will require significant amounts of new generating capacity. This will have a huge impact on the power sector and the emission inventory envisaged for India. While most of this AC stock is yet to be purchased, there is a potential for peak demand savings of 60 GW by 2030 if urgent and appropriate measures are taken to enhance efficiency of room ACs. Coordinated efforts must be made by taking care of both market push (standards) and market pull (awards, labels and incentives) options. Efforts such as DSM and DR programs targeting ACs, and improved building design are necessary to drive this change.

[10]https://ies.lbl.gov/sites/all/files/lbnl-6674e.pdf

Here too, Discoms can play a critical role, primarily for domestic ACs, and also for commercial ACs by enhancing awareness levels, and offering incentives for the adoption of efficient technologies.

Pumping - Pumping involves lifting or transferring water or other liquids in a variety of applications like agriculture (irrigation), municipalities (water supply and waste water), industry and domestic (houses, commercial buildings). According to the 'India Water Pumps Market Forecast and Opportunities, 2020', the water pump market is expected to grow at a CAGR of around 12% till 2020. Despite the availability of efficient pumps, the sector has remained inefficient in both agriculture and municipalities. The huge subsidy allocation to the agriculture sector aids farmers to install independent irrigation facilities, giving them no reason to opt for efficient pumps, thus leading to the depletion of groundwater as well as energy resources. Similarly, most municipal authorities being public have no incentives to be energy-efficient. Interventions by Discoms make perfect sense here, as both the agriculture and municipal sectors are subsidized and energy savings will help Discoms improve their financial condition.

For the agriculture sector, energy efficient electric pumps make an excellent business case for a third party like an Energy Services Companies (ESCo), provided clear policy and business models are made available by Discoms. There is also a need for government intervention for solar pumps due to their high cost. Realising this, the Union Budget of 2014-2015 has allocated 400 crores for the installation of 1 lakh solar agricultural pump sets. Further, various models are being adopted based on funding and subsidy structures and implementation institutions in Uttar Pradesh, Andhra Pradesh and Bihar[11] , amongst other states.

In the municipal pumping sector, most efficiency interventions have been largely implemented for large municipal corporations under ESCO based models. However, it was assessed that there is immense potential and economies of scale for the development of

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[11]Please view this for more details: http://shaktifoundation.in/report/guideline-design-implementation-framework-solar-agriculture-pump-programme/

models around utility-DSM projects even in small and medium size municipalities. A study for a utility in Gujarat suggested a payback period of less than a year for the replacement of inefficient electric pumps with efficient ones. Further, a detailed energy audit of water pumps at Nagarpalikas revealed an average energy efficiency potential of 23%. Therefore, the need and rationale for the implementation of DSM projects by the utility in Nagarpalikas becomes important not only from the perspective of demand management but also as an opportunity to reduce its commercial losses.

In addition to applications cited above, there are other possible interventions like motors (industrial and small), demand response, demand shifting – all of which have the ability to offer significant savings to Discoms, if designed and implemented appropriately.

OPPORTUNITIES FOR ADVANCING UTILITY LED DSM IN INDIA

Despite significant developments in the sector, there is still widespread disagreement on whether DSM is a cost effective proposition. As a result, DSM implementation has been restricted to pilots for the most part. Discoms continue to rely on (involuntary) load shedding during supply constraint situations, which they often term as one of their traditional ways of 'load management'. The lack of adequate regulations on load shedding is also the biggest deterrent in establishing the need and urgency for DSM.

DSM programmes can be rapidly scaled up if there is an appropriate focus on relevant technical, financial and institutional factors. These are discussed in the following table.

Table 1: Upscaling DSM in India

Technical	Financial	Institutional and Operational	Legal and Policy
• Standard program models and commercial arrangements	• Improved financial health of the distribution companies	• Enhanced understanding and expertise regarding DSM amongst the Discom staff	• Specific provision related to Utility driven DSM program in either

• Proper frameworks for assessing the baseline leading to more cost effective DSM programs • Standard measurement and verification protocols • Sufficient market players – manufacturers, retailers, service providers.	• Adequate incentives and rebates for consumers • Lowering down the cost of the some of the prohibitively costly energy efficient appliances • Lowering down transaction costs incurred by the implementer during the disposal of old appliances	• Availability of sufficient and trained (on DSM) manpower in Discoms • Stability in the Discom leadership • Sorting out of legacy issues of the power sector.	the Energy Conservation Act, 2001 or the Electricity Act, 2003. • Effective enforcement of DSM regulations by State Electricity Regulators

To realize the opportunity in the DSM space, there is a need for the Central Government and State Governments to work in tandem with Discoms. The adoption of a national mandate on DSM can lay the foundation for the demand side of the power sector. This mandate must be complemented with a robust regulatory framework to help assess the benefits of DSM programs in a transparent manner. And then, regulations that require Discoms to improve reliability by avoiding load shedding must be strictly enforced.

Discoms will require support to bring the aforementioned goals to fruition. A few examples of such support could include technical assistance through professional training, consumer awareness and outreach, liaising with ESCOs and providing financial incentives through rebates, soft loans, etc. On the technical front, cost-effective implementation frameworks, stronger M&V protocols and increased third party auditing of DSM programs will further foster the Discom's interest and faith in the concept and benefits of virtual energy generation or energy savings.

It is important to highlight the recently enhanced government focus on DSM and energy efficiency with an active role envisaged for Discoms on this front. The BEE has initiated a DSM capacity building program for Discoms in collaboration with EESL. Under the program, 30 Discoms are being provided with capacity building and technical support to conduct load research studies, design DSM program and develop DSM action plans. In addition, efforts like DELP and SEEP will be able to provide a level playing field for energy efficient appliances and expand the market opportunity for third party technology and service providers. Above all, continuous stakeholder consultations involving Discoms and regulatory leadership and their cooperation will enhance the implementation of such programs.

CONCLUSION

DSM programs have been successful in many countries and are gaining pace in India. While it is true that the Discoms have immediate priorities such as power procurement, tariff rationalisation and distribution operations, there is nothing that will keep Discoms and consumers from implementing DSM programs, once the value proposition of DSM is well understood. Demand side resources can be used in tandem with supply augmentation efforts to meet the make the power sector more reliable and environmentally sustainable.

For such interventions to be successful, it is important that the true costs of power are reflected across all consumer segments building the value for each unit of power generated. At the same time, Discoms must be mandated to serve load and enhance supply quality and standards so that the consumers do not resort to non-payment of their electricity bills or rely on polluting and costly alternatives like diesel generator sets. Policy makers and regulators must realise that providing subsidies to the agriculture sector or repeated restructuring of the tenuous financial position of Discoms may not be sustainable solutions.

In addition to DSM, other recent developments that will require a transformational shift in the way the power sector include:

- Deployment of new and disruptive technologies like variable renewable energy, small distributed generation and energy storage changing the technical aspects of power sector e.g.

wind and solar variability requires that they be integrated over large balancing areas.

- Transformation of consumers into 'prosumers' with individual homeowners and communities becoming legitimate electricity generators e.g. in case of solar rooftop systems.
- Changing market dynamics with the introduction of policy support mechanisms for clean energy, and increased competition.
- Introduction of information and communication technology in all electricity system processes.

These developments pose a new set of questions regarding the technical, institutional, and economic structures necessary for their integration in mainstream power sector planning and hence turn these seemingly system threats (to the Discoms, and in some cases to regulators) into opportunities.

It is high time to put necessary policies and institutional frameworks in place, and start implementing large scale programs around unconventional resources like DSM, Energy Efficiency and Renewable Energy. In line with the well-known proverb that "Energy Saved is Energy Generated", the potential of a demand side acting as a major resource will have to be realised, if not today, then later and at par with the incumbent power generators since it provides a way for optimizing infrastructure investments by assuring clean and efficient growth.

**The views in the article are individual views and do not necessarily reflect those of Shakti Sustainable Energy Foundation.*

Vikram Singh Mehta

The Future of Oil*

Two questions need to be posted.

What is the future of oil now that the debate on climate change is over and scientists and politicians are agreed that the planet is warming and that economic growth must be shifted onto a low carbon trajectory?

What is the future of oil in the face of exponential technological progress and the efforts to create competitive and scalable alternatives to fossil fuels?

There is no easy answer to these questions but they do suggest that "The Future of Oil" is headed towards an interesting crossroad. It is not clear as to when it will reach this marker but when it does one direction will move it forward linearly and it will continue to dominate the energy market. The other will lead it into uncharted territory. The pathway will not be signposted; there will be many twists and turns and no one will quite know the specifics of the destination and when and how it will be reached. But everyone will know that oil is headed towards a future in which it will lose its preeminence in the energy landscape.

The need to reflect on both of these directions.

In the short to medium term future and let me assume for the sake of specificity a 5 year time period, I have no doubt Oil will along with coal and natural gas, dominate the energy basket. It will provide the energy to fuel transportation, run industry, generate

* Based on the 22nd Lovraj Kumar Memorial Lecture delivered on 18th November, 2015, organized by Lovraj Kumar Memorial Trust in association with Indian Institute of Chemical Engineers

power and electrify homes. It will remain one of the bulwarks of the global energy system. I say this with conviction because during this time period we will not see the emergence of scalable or competitive alternatives to liquid fuels for transportation.

Today the world consumes 91 million barrels a day of Oil. The transportation sector which covers motor vehicles, airlines, inland waterways and ocean going ships absorbs nearly 60% of this number. The balance is consumed by industry (25%); residential homes and commercial properties (10%) and electricity (6%).

Oil rests, in other words, on the pillar of mobility.

Looking forward 5 years or so, three realities stand out.

One, this pillar will not be replaced by another fuel source. Sure, natural gas will make further inroads through CNG and LNG. China is, for instance, already running 100000 trucks on gas and the US is moving to open 100 LNG stations along its highways. Sure also, there is the possibility of Bio diesel and bio ethanol as potential liquid substitutes. But neither of these alternatives will make a substantive dent within this frame. Auto and truck manufacturers will have to modify engines to use natural gas and petroleum companies will have to create the appropriate retail network. Bio fuels will also have to overcome similar technology and infrastructure related hurdles but in addition they will face competition from agriculture. The cellulosic option that does not compete with food is expensive and cannot be produced in bulk. I should add that ethanol contains only about 70% of the energy relative to gasoline.

Second, it will not be possible to create a non liquids fuel based mobility infrastructure within this time period. I am reminded of the time it took for American factories to convert from steam power to electric power. Thomas Edison illuminated the lower half of Manhattan sometime in the mid 1880's. But it was not until the mid 1930's that the factories in the mid west of America had converted to electric power. It took them so long to accept this revolutionary new technology because they had to be redesigned and in some cases completely rebuilt. The fact is that our energy infrastructure for transport is built around liquid fuels. It will take many years and massive investment to create an alternative that can transport, distribute and market non liquids.

Third, 2.5 billion people live in countries where on an average 1 person in 50 owns a car. The ratio in China is 50 cars per 1000 people; in India it is 12 per 1000. This is in comparison to 500 cars per 1000 in OECD countries. Ownership of cars is a hallmark of middle class standing. Those of us who have to navigate the traffic congestion of our roads may wish for tighter regulation on car ownership. But that is a self-serving wish. The reality is that millions wish to trade up from a cycle to a two wheeler to eventually a car. There is a huge latent demand for cars and as income levels rise and people move into urban settings this demand will surface and the demand for oil will correspondingly rise. OPEC and BP have estimated separately the demand for oil increasing from 91 million barrels a day today to 111 million barrels by 2035. They expect that this incremental demand will come mainly from China, India and the Middle East and that 89% of the fuel demand for transportation will be met from liquids and the balance 11% from alternatives predominantly natural gas.

These three realities provide the structural underpinnings for the argument that oil will continue to dominate the energy basket in the short term. There are in addition two geo-economics drivers.

The bulk of the reserves of conventional and relatively low cost oil are concentrated in a handful of countries in the Gulf, Iran, Iraq, Nigeria, Russia and one or two others. These countries are almost totally dependent on oil and in the face of low oil prices they are facing huge internal financial, economic and social challenges. The IMF has for instance estimated that if the price of oil hovers around USD 50/ barrel the 5 Gulf countries (Saudi, Qatar, Kuwait, Oman and Bahrain) will face an accumulated deficit of USD 700 Bln by 2020. Five years back they had a combined surplus of USD 600 Bln. The Russian economy is on the skids; Nigeria is riven by civil strife and Venezuela may well be headed towards a coup. The point is that oil is pivotal to geo political stability. Political and social upheaval caused by the diminishing significance of oil in the energy basket will have global ramifications and so if for no other reason than to safeguard against the consequential implications (especially in light of the spread of fundamentalism and extremism) most governments would (and perhaps should) prefer a slow and predictable transition to a non-oil energy system. To that extent there is an inherent geopolitical dynamic in support of Oil.

Businesses reinforce this dynamic. The Petroleum companies, the petrochemical plants, the automobile manufacturers, the process industries have billions invested in the oil economy. Their business interests are hard wired around this commodity and they have a vested interest in prolonging its future.

My argument so far has been set within a short term framework. During this period I do not foresee a significant shift in oil's position in the energy basket. I see it as proceeding along a linear pathway.

But looking beyond this time frame I can picture a possibly different future. I can see oil moving off the linear pathway and onto uncharted territory. This is not a prediction but in the tradition of scenario planning a description of an alternative future.

The contours of such a picture.

Two forces will definitively influence the longer term future of oils. These are Global warming and the continuing advance of technology.

On May 6, 2014 the NY Times published on its front page the declaration of the US Climate Association. This Association comprises 60 people including representatives from the oil companies. The declaration stated that "climate change once considered an issue for the distant future has moved firmly into the present". It projected that mean sea levels would rise between 1 and 4 feet by 2100 if the current rate of emissions of Green House Gases (GHG) is not arrested. The low lying regions of the world including India which has a 7000 kms long coastline with 150 million people living alongside would be severely impacted.

More recently President Obama cancelled the Keystone XL pipeline project. This was a proposal to move 800,000 barrels a day of tar sand oil from Alberta in Canada to the US Gulf Coast refineries. In explaining his decision, the President said "ultimately if we are going to prevent large parts of the Earth from becoming not only inhospitable but uninhabitable in our lifetime we are going to have to keep some fossil fuels in the ground rather than burn them and release more dangerous pollution into the sky".

The declaration of the Association and President Obama's statement brings one fact into sharp relief. There is now no dissonant message regards Global warming. Everyone agrees that the Planet is warming and that no country can escape its consequences. Leaders may not vocalize their concerns for political reasons but they all appreciate that they must put their weight behind a green agenda. In the run up to COP 21 in Paris almost every country (145 at the time of writing) has announced their "intended nationally determined contributions" (INDC's) towards containing carbon emissions. China has announced it will reduce carbon intensity by 60-65% by 2030 from 2005 and increase the share of non-fossil fuel energy in total primary energy supply to 20%; the US has said it will reduce emissions to between 26-28% below 2005 levels by 2025 and India that it will cut back by between 33-35% by 2030 and that subject to technological and financial support from the international community it will produce 40% of its energy from non-fossil fuels. These commitments are not enough to keep temperatures from rising by more than 2 degree centigrade-the level that scientists state would push us over the edge and it remains to be seen whether the political will exists to execute an agreement in Paris that will compel countries to go beyond vaguely formulated targets and accept the obligation of differentiated responsibility but it does reflect perhaps for the first time since this issue came onto the international agenda, a common urgency to move economic growth onto a low carbon trajectory.

The second predetermined force is the continuing advance of technology. Its advance so far has been exponential and transformational. Moore gave us a hint of what to expect but I doubt anyone foresaw the dramatic impact of compounding. Moore's law, as I am sure most of you know, posited that computing power would double every 18-24 months.

To fully grasp its implications imagine you drove your car at 5 miles an hour for the first minute, then at 10 miles an hour for the second minutes and thereafter you doubled the speed every minute. In the first minute you would have covered 440 feet, in the second 1760 feet and at 80 miles an hour in the 5th minute you would have done just over a mile. Now imagine that this speed is doubled 27 times which is the number of times that computing power has doubled since 1958 when the integrated circuit board first made its appearance. Your speed would be 617 million miles an hour and you could reach Mars in 5 minutes or so.

The simple point.

Technology has exploded not because of one-off discrete innovations but because each breakthrough has built on what has been achieved before. Technology has followed what Ray Kurzweil the innovator with perhaps more patents to his name anyone else refers to as the "law of accelerating returns". This explosion has impacted not just computers and electronics. It has impacted every aspect of our lives.

Looking forward we should assume that this "law of accelerating returns" will prevail. That we will continue to see disruptive change. That we will continue to be surprised. In this vein I can see "disruptive technology" taking the edge off many of the forces that have brought oil to its current pivotal position.

Technology could render the internal combustion engine obsolete. Hybrids and electric vehicles have already made their appearance. Tesla the EV company has acquired near iconic status and whilst its share price is substantially down from the peak levels of a couple of years back because of the fall in oil prices it is still moving fast forward towards building a broader customer base. Many hurdles have of course yet to be overcome. The cars are expensive, battery and storage technology limit the range it can travel, the "plug in" infrastructure has to be put in place and the consumer has yet to be persuaded. Last year for instance only 300000 EV/hybrids were sold compared to 82 million IC cars. However these are not insuperable hurdles and as and when, not if and when, these are crossed, the impact would be game changing.

Next "Smart mobility", "smart infrastructure", "and" smart economics "could upend the current" owner-operator model for cars with downward implications for the demand for oil. Today people own cars part because they enjoy driving, part because of need and part because it signals their status in society. Purchase is an act of individuality and reflects aspiration, values, and taste. Cars are however an inherently inefficient asset. They are idle for almost 90% of the time in parking lots, garages or along the roadside. They take up scarce urban land they are a major contributor to air pollution. They are in short powerful economic, social and environmental reasons for changing the current owner operator model.

Today there is lot of work underway to develop an alternative model. The Pentagon catalyzed this development. They were interested in developing robotic military vehicles and towards that objective they sponsored a race between 15 robotic vehicles on March 13 2004. The prize money was USD 1 million for the first vehicle that crossed 150 miles of the Mojave Desert in California. The result was not impressive. None of the vehicle managed to complete even 10% of the route.

The following year in October 2005 the Pentagon organized a second race. This time they offered USD 2 million. The route was more complex. It involved navigating mountain passes with sheer drop offs on either side, hairpin turns and three tunnels. The result were astonishingly impressive. 5 vehicles completed the course. The idea of driverless cars was picked up by Google in 2008. The Chairman of Google Sergei Brin was of the view that cars should be seen as a commodity and not a luxury purchase and that smart technology could be harnessed to improve the efficiency of utilization of this asset and also unlock the value of scarce urban land. His vision was to commercialize "driverless" or "autonomous" cars and to thereby undermine the owner-operator model. Brin hired the best brains including many of the scientists that had worked on the Pentagon project. The Google project has of date made significant progress. Their driverless cars have driven over 300000 accident free miles. It has also galvanized all the leading car manufacturers to invest in robotic, autonomous and semi-autonomous models. None have so far introduced a model - they have less incentive to do so -

but Mercedes' latest S class model does have the software to drive "autonomously" in stop go traffic and on an autobahn at up to 120 miles an hour.

In a separate but related front we are seeing the onset of "on line" mobility services. UBER is a good example of an emergent trend. The millennial (people born between 1985 and 1995) are increasingly using their smart phones to access mobility than investing in an owned and inherently inefficient asset.

Both developments – the driverless car and shared mobility – will reduce the demand of cars per capita and the no of cars on the road. But here again I do not wish to run ahead of myself.

The owner – operator model is not going to be overturned soon. Cars are integral to personal identity and attitudes will have to change fundamentally before people give up the idea of ownership and regard them as items of utility. A change in the current model will also raise legal, insurance and safety issues. And it will trigger the resistance of incumbent interest groups whose businesses are threatened. UBER has had to fight off lawsuits in every market it has entered and that from only one interest group - the cab drivers. A change in the current model will provoke the opposition of a multiple of interest groups-the oil companies, the car dealers, repair shops and petrol stations.

Keynes said nothing can hold back an idea whose day has come. The idea that a warming planet needs a different model for mobility is taking root. There are no insuperable hurdles and perhaps the day is not far off when to use the acronym coined by the scientist Amory Lovins PIGS will give way to SEALS. PIGS is the acronym for "personal internal combustion gasoline and steel dominated vehicles". And SEALS is the acronym for "shared, electrified, autonomous, lightweight service vehicles".

A third force is renewable energy in particular solar and wind. This sector has made extraordinary progress. Wind accounted for 17 GW of global energy supply in 2000. And Solar a mere 1.4 GW. Last year in 2014 wind contributed 283 GW a 16 fold increase and solar 100 GW a 70 fold increase. Wind and solar based power generation has grown at double digit rates for 11 consecutive years. In 2014 it increased capacity by 12% over 2013 and accounted for 42.5% of the incremental growth in global power generation and 28% of the incremental growth in energy demand over that 12 month period. It attracted approximately USD 300 Bln of investment in 2014 as against USD 5 Bln in 2000. Nuclear is also now stirring itself. Fukushima hit the industry severely and the build rate of nuclear reactors in recent years has been modest. There are at present 67 reactors under construction. This will add only 15 GW per annum. However, a new generation of passive safety reactors is under design and this might boost the momentum.

The driver behind the success of renewable has been technology and policy.

Technology has reduced the cost of panels, inverters, turbines etc. to the extent that Wind and Solar are today competitive against oil. There are many calculations and one should be wary of citing cost figures because so much depends on context, location and above ground issues like land acquisition, approval processes and infrastructure. But to illustrate the point here with the numbers produced by the investment bank Lazards. According to them the levellised cost (i.e. average long run cost) range for wind power in the US is between US cents 3.7 to 8.1 / kWh and for thin film solar power from 7.2 cents to 8.6 cents/kWh. The comparable cost of electricity from oil prices at USD 50/ bbls would be around 14 cents/ kWh. The price of oil would have to fall to around USD 15 / bbl for it to be competitive. Government and regulatory policies have reinforced this technology driven cost competitiveness. Many countries have introduced fiscal, investment and market incentives like green certificates, carbon markets, subsidies, tax credits and emission targets. Some have legislated strict time bound targets for shifting towards renewable. The state of California which has for long set the marker for other States to follow has effectively mandated that all surface transport and grid electricity must be powered by either renewable or nuclear by 2050.

Wind and solar are today niche contributors through distributed and dispersed models. The technology for battery storage will have to be improved, the grid upgraded and in countries like ours the distribution companies recapitalized before they can make a major dent. But as in the case of EV's and autonomous driverless cars, the law of accelerating returns would suggest that these improvements and up gradations are but a matter of time. What one has to internalize is the fact that industry, residential homes, commercial establishments and electricity that currently account for 40% of the total global demand for oil will sooner than later have the option to switch to competitive, reliable and cleaner non-oil alternatives.

I have so far talked of the three forces that might knock out the props of oil demand. Let me add to that one supply driven prop that is also weakening. The integrated multinational petroleum companies. I believe their business model is under severe threat. They are in a business that requires huge upfront capital investment but they see returns only after decades. They have no control over the market and in particular the price of Oil. They face increasing competition because information technology has made it easier for smaller, specialized companies to enter and compete across every segment of their value chain; they have limited or no access to "easy" low cost oil as those reserves are owned by state owned companies like Saudi Aramco and Kuwait national oil company. They confront the prospect of stranded economic assets, as not only has the decline in the price of oil rendered many of their investments unviable but governments are increasingly denying them the right to monetize their assets. President Obama's decision on the Keystone pipeline is indicative of this approach and Shell has recently declared its worst results in years. It declared a loss of USD 6. 1 billion dollars in the 3rd quarter of 2015 compared to a profit of USD 5.1 billion in the comparable quarter of last years. Part of the reason was the fall in oil prices but a major cause is the impairment charge on its investments in the Arctic and Canada. The latter have been embroiled in regulatory and environmental pressure. Finally and perhaps most important oil companies face increasing public scrutiny. They are caught in the climate change crossfire. Recently the New York attorney General subpoenaed Exxon to explain the charge that it had sought to bury the results of a study on climate change. Oil (and coal) companies are facing a number of lawsuits holding them accountable for global warming. None have been upheld but the pressure is clearly mounting and the day cannot be far off when they face the kind of public and legal pressure that tobacco Companies faced years back.

In conclusion I need to repeat. I am not offering a prediction about the future of oil. I am merely outlining emergent trends.

Oil does, of course, have a future. It is available in abundance. And in some countries like India that are arguably entering the most energy intensive phase of economic growth with prosperity enhancing the demand for motorized vehicles and the "Make in India" policy increasing the share of manufacturing in GDP, this future could be robust. But one must not assume that the future will progress linearly. The convergence of technology and global warming is pushing Oil towards a crossroads and that as and when it reaches that point, it is possible that the combined weight of Moore's law and Kurzweils "law of accelerating returns" will see it take an abrupt and unforeseen turn off the beaten track. Such a turn could lead to a dramatic and transformationally different future. Recently I saw two photographs published side by side of the Easter parade in New York. The first photograph was taken in 1900. The second in 1913. Looking at the first you had to strain your eyes to see the first car. Looking at the second you had difficulty locating the last horse. I doubt oil will be difficult to locate - it will remain in the interstices of our energy system - but we should be prepared to move beyond the language of the present to describe its future significance.

Deepak Gupta, P.C. Maithani

Energy Access in India

The centrality of energy access in the new global development agenda is now clear and critical. The high-level plenary meeting of the UN General Assembly, held during 25-27 September 2015, adopted the post-2015 development agenda having 17 Sustainable Development Goals (SDGs). SDG-7 is for ensuring access to affordable, reliable, sustainable and modern energy for all. The vision states "A world where human habitats are safe, resilient and sustainable and where there is universal access to affordable, reliable and sustainable energy". The Millennium Development Goals (MDGs) had not covered this aspect at all. To an extent, therefore, this remained a somewhat neglected area during that time, both globally and at home. The time has come to redress this neglect.

It is universally accepted that access to modern energy services is a prerequisite for economic growth and human development and is critical in fulfilling basic needs such as cooking, lighting, mobility, water pumping etc. Absence of access to modern energy services deprives people from the bare minimum living standards and quality of life - it constrains generation of productive activities, incomes and employment in rural areas. A new poverty index recently developed by the United Nations in 2010 also stresses lack of services such as electricity as a key factor in determining poverty.

Lack of energy access is primarily a rural issue. Although a percentage of the urban population still does not have access to modern energy, particularly in Africa, the problem is acute in the rural context where it is many times greater than the urban areas, and where addressing it faces many more challenges. Poverty has declined significantly everywhere, especially in the last two decades, and it is generally agreed that 'extreme poverty, long considered an immutable fact of life in India, is finally in retreat'. Nevertheless there remains significant deprivation as the recent National Sample Survey Organisation (NSSO) census figures also show.[1] We have largely addressed the issue of income or consumption poverty. There are many studies which show that energy poverty is even worse than this. It follows that energy access reaches the most impoverished and it becomes a critical component not only to reduce rural poverty and drudgery and deprivation but also is one of the fundamental conditions for holistic rural development.

Energy access includes both electricity and cooking. Globally, as many as 1.4 billion people (over 20 per cent of the global population) do not have electricity to light their homes or conduct business. Around 2.9 billion people, almost 40 percent of the global population, rely entirely, or to a large degree, on traditional biomass for cooking and heating.[2] International Energy Agency (IEA) also projects that, if no new policy to alleviate energy poverty is introduced, 1.2 billion people (some 16 percent of the total world population) would still lack access to electricity in 2030. The numbers in India will reduce but it will still have about 300 million people without electricity access. Around 2.8 billion people will depend on biomass for meeting cooking energy needs, about 82 percent in rural areas. India has the world's largest population without modern energy access. Around 400 million people don't have electricity and twice that number use traditional biomass to cook. Clearly the burden is greatest in India and sub-Saharan Africa and to us falls the responsibility of achieving the SDG now fixed.

It is evident that electricity access in India has improved over the last two decades from 36 percent of the rural households in 1994 to around 56 percent in 2011 (and more thereafter). We claim that over 95 percent of villages are electrified but the real problem is electrification of households. This discrepancy arises because of

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[1]The Mckinsey Global Institute had in a study put the deprivation figure in India in 2012 at 680 million.

[2]Energy for All: International Energy Agency 2011

the definition of village electrification. A village is deemed electrified even if only 10 percent households have connections. It is also to be noted that while percentages may have improved, the absolute number has not reduced substantially because of rising population. Even now round 74 million rural households (45 percent of rural households) are without access to modern lighting services. These are mostly APL households because connection has been given to many BPL Households under RGGVY. It would be worthwhile to note that these people are those who seek voluntary connections. There are also great disparities in electricity access across states. For instance, while in states like Bihar, Assam, Uttar Pradesh, Odisha, and Jharkhand, the households' electrification level is strikingly low at under 40 percent, in states like Delhi, Chandigarh, Tamil Nadu, Punjab, and Andhra Pradesh, the household' electrification level is over 90 percent. The other problem relates to the number of hours when electricity is actually supplied. There is substantial non-supply in the evening hours when it is needed most, and even otherwise, there is uncertain and unreliable power supply, quite apart from it being often of poor quality.

Electricity Access

Energy for All has been a declared objective of the Central and State Governments in India since long and has been accorded high degree of priority, at least in pronouncements. Policies after Independence focused on setting up of power generating capacity in the central and state public sector, and creating a power infrastructure. However, overall progress remained tardy and the power sector gradually over the decades got into more and more trouble – of inadequate capacity; of poor generation; large transmission losses; financial deterioration of the Electricity Boards; populism in setting unrealistic and below cost electricity rates, particularly in the rural agriculture sector; corruption and theft in the supply at all levels etc. The sector hasn't recovered, even though it has received a big thrust in this century.

Electricity access can be achieved in three ways - Grid extension, as was done under the Rajiv Gandhi Grameen Vidyutikaran Yojana

(RGGVY) scheme and is now being under Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY). This could include franchisee models and tail end projects feeding into the grid; small-scale decentralized distributed generation (used by local entrepreneurs for diesel based electricity generation and also renewable energy based systems – though these are currently niche applications, but are the likely models for the future); and household level technology. The policy landscape for electricity access has so far been grid centric and supply oriented. There has been a belief, which continues even now, that universalisation can only be done by power supplied through the grid. All that is needed is to have enough generation and set up a distribution infrastructure which would take this power to the last village or hamlet. Both these were seen as the earlier constraints. But this is a simplistic view and ignores other problems. State utilities are simply unable to purchase sufficient power because of which the plant load factor today is only about 65 percent.[3] How then can they distribute it everywhere, particularly to rural areas? State utilities have little incentive to provide access to electricity to rural households as it leads to increased T&D losses and low collection, which in turn further adds to the already poor utility finances, giving rise to a vicious cycle of greater the financial losses the more power is supplied. Low village demand coming from low population densities in rural areas spread over large areas results in high capital and operational costs, while revenue collection is poor, both because of poor collection and low tariffs. The difference could be as much as Rs 4-5 per unit, and higher still, when power is suppled on the peak evening hours. The debt of utilities is increasing and currently stands at over Rs 3 lakh crore which is being sought to be currently addressed with another package, though this time making it the responsibility of the States largely to make up for the gaps. But how long, and to what extent, can this gap be subsidised?

In this context, two things need attention because they are very important for the long term, and not just for energy access. Unless

[3]The year 2014-15 recorded the lowest plant load factor in over 15 years with the country's power capacities operating at a mere 65 percent.

there is regular and calibrated tariff revision annually, as was the intention of the Electricity Act, the discoms will always be in a state of financial distress. There is a case for subsidising the urban low end and rural domestic consumers but that cost should be made up by incremental urban tariffs with those at the high end paying very high tariffs for the last slabs – say Rs 12 for consuming 2000 units a month and even more above that. Further, there must be fixed goal posts for reducing transmission losses and for other operational efficiency parameters under threat of enforceable penalties. These issues are hardly talked about. Second, it needs to be considered how sound is our approach of large scale and big grid solar projects which would involve large building of transmission infrastructure, concentration of one form of renewable energy in some cluster areas, transmission losses and costs, and need for dedicated spinning reserve (This is an area which needs to be addressed as we plan large grid capacities for both wind and solar). If electricity is to be supplied to deficit areas and to remote areas why should it not be generated at consumption points that are the beauty and the main advantage of the new technology which earlier was not available? Besides, it would lead to hundreds of generators rather than a few, and financing would also be easier. In this context the possibility of distribution tail end 500 KW to 3 MW projects must be analysed. The Solar mission started with 100 MW of such projects, and there were some pilot biomass projects, the working of which would be useful to analyse to tweak the policy. Biomass based such projects at selected places can lead to benefits to farmers of that area. The further advantage is that subsidies to such projects can be so delivered that the tariff will not result in any loss to the discom which will probably gain 6-8 percent in saving transmission losses too.

The centralized grid approach, therefore, may not be able to resolve this problem to the last mile and in thousands of villages/ hamlets the situation could remain much as it is today, with uncertain and unreliable power during the day which is largely absent when needed most in the evening hours. It is necessary, therefore, to consider alternative solutions.

Decentralised renewable energy solutions are now possible, which wasn't the case earlier which brings about a fundamental change in the situation. There are many examples all around. A large portion of population in Sunderbans islands in the state of West Bengal are meeting there lighting and productive energy needs from a combination of solar, biomass and wind energy. Small hydro systems are helping to meet the energy needs of the hilly and Himalayan region of the country. In Chembu village in the hilly Coorg District, 40 remotely located houses are meeting their energy needs through hydro installations and have witnessed a marked difference in the quality of life. In a small village, Tiket, in Kargil, Jammu & Kashmir, and near Naini Tal in Uttaranchal, a small hydro power station has provided a viable option for meeting the energy needs of the village. A rooftop solar energy plant in Meerwada village of Madhya Pradesh delivers power to 70 households, round the clock. In the state of Bihar, over 1500 villages are electrified with the use of locally available biomass and solar sources. Solar energy has been significantly meeting energy needs of Ladakh region in Jammu & Kashmir state. Decentralized solar charging stations are now providing lighting services to over 80,000 people. Grameen Banks have supplied solar home lights to thousands of households in UP. There are a few CSR projects also. Many villages in Chhattisgarh rely on off-grid solar for lighting purposes through mini-grids supported by the State. Many small, and very small, micro grids have been set up in different states as pilots with different models and support systems. At the national level over 13000 villages and hamlets are meeting subsistence level electricity needs using various combinations of renewable energy sources in an off-grid and decentralized manner.

The evidence from the large number of decentralized systems suggests that renewable energy, particularly solar, now provides a viable and desirable economic option for rural electrification including the meeting of unmet demand in some electrified villages where supply is a problem. But the essential pre-condition for developing this is first an acceptance, not grudgingly or as fait accompli only, that this is a viable doable option and perhaps the only way to achieve universal electricity access, and that these should then be considered to be part of the mainstream solution, not a transitory exercise.

Admittedly there are several challenges which the projects in the field have also revealed. The overarching requirement is of developing a sustainable energy access market that is over the course of time not dependent upon government assistance and that leads to increased penetration in rural areas with improved quality of supply and lower cost of delivery. We must realise that, as far as the rural households are concerned, irrespective of the uncertainty of power, load shedding, and rostering schedule that dampens demand for power in rural areas, grid connection remains for them the most favoured approach to rural electrification. Perhaps this is because they have no knowledge or experience of alternatives. These solutions, therefore, also have to give a feeling of electricity, have a low tariff and create a climate of paying for that service. Decentralised electricity access programmes would be contingent on widespread willingness to pay amongst rural households and energy users. A robust and sustainable solution is necessary which would come only from entrepreneur driven business models. Therefore, off-grid distribution systems cannot just focus on technical installation without paying sufficient attention to the long-term sustainability of the projects on a business model. Cost recovery is probably the single most important factor for this. And an essential part of this is the ability of the entrepreneur to have some risk free profit and capacity to generate enough surplus to change batteries periodically. It has been opined repeatedly that when cost recovery is pursued, most of the other elements fall into place. This, then, becomes the fundamental challenge.

The past experience and limited replication of renewable energy based electricity access suggests that independent small-scale initiatives alone cannot lead to desired success levels. Public intervention would be necessary for organizing the market. Some of the existing policy recommendations would need some minor adjustments to address the rural energy access issues in totality. Introduction of innovative institutional delivery models for offering electricity services in a sustainable and scalable manner would be a prerequisite. Accordingly, these services would need to be put under a framework that has sufficient government support and provides an institutional set up both at the national and the regional levels. This approach would be an entrepreneur driven business model with innovative institutional, regulatory, financing, and delivery mechanisms.

Success of electricity access programmes would depend upon how effectively the issues relating to skewed market, financial/economic inadequacies, and infrastructural bottlenecks are addressed. The Government of India's role would be to act as enabler and facilitator and also institute a mechanism to link various stakeholders. Accordingly, an off-grid renewable energy Fund through diverting energy subsidies, through exclusive budgetary allocations, the tax on coal, and through funding from Corporate Social Responsibility (CSR) or donors or Foundations, would need to be created. This is an ideal area to fund through CSR for all the mineral based/oil/coal/power companies and those whose markets are in the rural areas. This also ideally needs to be funded by a niche fund within the Global Climate Fund because they address the issue of 'poverty emissions' as also simultaneously poverty itself. Further, energy-enterprises driven electricity access programme would be based on pull approach wherein demand for action emanates from the entrepreneurs or other stakeholders. The role and responsibility of the government would be of ensuring smooth flows of required inputs to the enterprises.

Entrepreneurship based business models would not only support load development but also contribute towards viability of electrification efforts. Entrepreneurs, particularly from the local communities, would be expected to establish energy micro-enterprises to produce and to distribute energy carriers to rural households at an affordable cost. This could create a wave of rural entrepreneurship in the country which is a pressing need and will have multiplier effects. And if we are able to make the women's self-help groups the entrepreneur for the solar mini grid, we address many other issues as well. The strategy to create local enterprises would rest on skill enhancement; incubation; and facilitation of market linkages. This could be a priority component of the skill India mission, where educated girls could also become solar technicians. Entrepreneurs will have to be provided with performance-based incentives and penalties that are similar to grid-connected renewable energy projects, but cognisant of the operational difficulties in rural areas and environment. Since the cost of installation and subsequent maintenance would be high it is critical that the incentive levels should be adequate for viability of a project and not arbitrarily fixed on the cost calculations of grid based systems, or even solar roof top based systems. Higher levels of subsidy would be fully justified because these projects would be addressing essentially the rural poor. The viability gap for economic sustainability of the project can be procured by spreading the extra cost of decentralized systems across the larger base of grid-connected consumers or bridged by the government budget or simply by a redirection of subsidies for various fossil fuels, which are currently being largely provided to urban consumers. This includes raising, in a calibrated manner, the price of kerosene, to reduce adulteration as also raising the tariff for grid based electricity, since both provide artificially low levels. None of our neighbours or sub Saharan African nations have kerosene subsidy!

Prospective and existing entrepreneurs will need to be trained on various aspects of techno-economic and commercial viability of enterprises; technical information; and technology management, production, employees, markets, finance, and government policies. Other areas in which entrepreneurs would require expert help are technical and financial feasibility analysis, demand analysis, environment impact analysis, product design, etc. The success of such programs in rural regions will greatly depend on the strengthening of local entrepreneurial capacity for sustained commercial operation of energy enterprises. For this purpose there would be a need for continuous involvement of training and relevant technical institutions.

Cooking Energy Access

Around 800 million people in India or about 85 percent of rural households (Census 2011) continue to use biomass to cook their meals as their forefathers did hundreds of years ago on 3 stones or earthen traditional stoves, or later, poor quality stoves. These cause indoor air pollution which has serious adverse health impact. A recent report has estimated that in 2010, approximately 1.04 million premature deaths and 31.4 million Disability adjusted Life Years (DALYs) were attributable to household air pollution (HAP) resulting from solid cook fuels in India.[4] The worst affected are women and infants. It is indeed a travesty that while rightly pollution in Delhi caused by the lifestyle of the rich has become a burning issue there is little coverage of a similar impact covering a large part of rural India caused by the lifestyle of the poor. Cooking on traditional stoves also makes women (and girls) spend a significant amount of time and effort to collect biomass fuel (and even in cooking). It is also astonishing that this matter has not been treated as an extremely pressing gender issue, particularly for rural women. Meanwhile, the extra consumption of biomass or wood does not seem to worry people much anymore in the context of deforestation.

This interlinked problem of cooking energy, called the 'other energy crisis' by the international development community many years ago[5] , and its linkages with poverty and gender and child issues, and now the question of carbon emissions, would suggest that making access to culturally acceptable, clean and efficient cooking fuels/cook stoves should have been a priority policy concern as also a high public health priority. But somehow this seems to have been neglected over the years in almost all developing countries, as also in any worthwhile global action. This neglect largely continues.

Effective strategies for accelerating the transition to cleaner and more efficient household energy among the 3 billion people in the world whose development prospects are held back by practices that affluent nations have long since left behind, are, therefore, required as a matter of extreme urgency. This will require wider awareness of the problem, creation of a technical and regulatory framework, but most importantly, increased political commitment, and careful deployment of substantially greater financial resources than are currently allocated to this critical aspect of development. It has been argued that the basic public policy question facing the governments

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[4]Global Burden of Disease (GBD) 2010 Project (based on measurements and modeling results from India),

[5]The Other Energy Crisis: Firewood. World watch Paper (September 1975)

and the international community is whether the benefits of improved stoves are worth the financial investment that might be necessary. We believe that there cannot be any doubt any more that indeed this is so. In fact it is also a moral imperative.

In fact India, along with China, had been doing path breaking work in this area, both for family size biogas plants and for cook stoves. From as early as the 1980s, Ministry of New and Renewable Energy had launched a number of programmes to meet the cooking needs of rural households. It launched the National Project on Biogas Development. During three decades of implementation around 4.5 million family type biogas plants have been set up. The ultimate goal of Indian biogas programme is to set up biogas plants in around 12 million rural Indian households that have enough cattle to maintain a regular supply of dung. Although there has been a systematic approach to deploy biogas based cooking energy solutions, the outreach remained limited. This needs to be resurrected and supported by an appropriate subsidy and a mission approach much in the manner of the Swatch Bharat Abhiyan. And subsidy calculations will show that this would be much less than being currently given for cooking gas. Besides, there will be huge production of organic fertiliser (and concomitant savings in fertiliser subsidy). Bihar and UP would be the main gainers. There would be marginal reduction in carbon emissions too. This alone actually opens a window for international financing through a dedicated carbon gold standard – something which has not happened.

The National Programme on Improved Chulhas to provide improved biomass cook stoves to rural households was implemented from 1983-84 to 2002-03. About 35.2 million improved cook stoves were disseminated under this programme as against an estimated potential of 120 million. Thereafter, in order to facilitate implementation of the programme in a more decentralized manner, the Planning Commission transferred it to the states, and the programme withered away. Though well intentioned, and included in the then 20 point programme, there were many problems – too rudimentary in design; quality issues making stoves not long lasting; little interaction with users; large subsidies etc. In 2009 -10 MNRE tried to resurrect this programme by launching a National Biomass Cook-stoves Initiative. The main objectives were to develop various performance standards; set up testing infrastructure, help develop good quality stoves and undertake pilot projects to find what could be done in the field to reach the desired scale. Unfortunately, though there has been progress in the first two areas, there is still no effective programme for improving efficiencies of the biomass based cooking stoves, many pilot scale programmes have been launched, some by the Government and others by other organisations, but suitable models have not yet emerged. Through CSR efforts a possible stove has been developed but larger pilot projects with that have also not yet been taken up. A suitable financial package has also not been forthcoming.

Like the faith in the centralised grid to provide universal electricity access it has been the general belief, as well as policy to universalise supply of cooking gas. This was the intention of the Rajiv Gandhi LPG Vitaran Yojana launched in 2009 which would have released 55 million new connections to rural households.[6] Progress has not been very much. There are many studies which suggest that regular gas supply to the entire rural area would not be possible because of logistical issues and other factors including the issue of replacement and paying for periodic cylinders, even if they be of small size. While gas supply needs to spread around towns or block HQs or market areas, it is quite likely that the hinterland will be left behind. It is, therefore, simultaneously necessary that we plan to have improved cook stoves to cover at least 20 to 30 million rural households which would also be the poorest or located in remote areas. A rough calculation would show that if such a stove costs about Rs 2000, and lasts for 4 years, a subsidy of even 50 percent would not only be fully justified but will be much less than that which would be required for supply of cooking gas.

A new programme is therefore urgently needed which ensures development of proper and durable stove/s and test and establish

[6]The scheme provisions are under revision

suitability through pilot projects over the next 5 years. Technology seems now to be available.

Once that is done there would need to be a comprehensive and innovative public awareness education and information campaign regarding the health, environmental, gender and economic benefits to stimulate demand. A behavioural shift from traditional ways of cooking used over generations to a new technology is not going to be easy.

To ensure sustainability market mechanisms would be necessary. Subsidy would be in form of vouchers which can be submitted on purchase. The stoves would require creating local market places and distribution arrangements. While some ingredients of stoves would be industrially manufactured assemblies can be in districts. Imagine the increase in local economic activity generated by a possible annual market of more than 10 million stoves if all goes well!

Rural Development

Rural transformation is a sine qua non for India's development. Many things are required to be done. There cannot be any question that improved energy access would play a critical role. It results in considerable health benefits, as well as saved health care costs, better education and environment in schools, more working days to earn livelihoods, saved fuel collection and cooking time for women, better hygiene and sanitation in the village, better lighting in the evenings with more social life and liveliness, possible sources of private and public entertainment through TV, shops open till late in the evening. In current Indian conditions, energy access encompassing both lighting and cooking, would be a necessary pre-condition not only to dent deprivation but even to reach minimum levels of development.

Further, in tune with Prof Prahlad's 'bottom of the pyramid' concept serving as a potential market, we could see the potential with millions of households being covered by RE systems and provided improved stoves. There would be economic activity, entrepreneurs, incomes and local employment – all positive externalities serving as multipliers. The cascading economic, social and environmental benefits with households gaining access to modern energy would include improvement in the standards of living which will lead to pay for higher amounts and costs of energy in future. There is universal agreement that absence of access to energy leads to low economic activity and thus low demand, which turn off energy utilities to extend energy services - in a way a vicious cycle.

There is one area which we have not covered. The time has come for a very ambitious programme of deploying solar pumps. While we need large amounts of grid solar power, if we could have 5000 MW earmarked for solar pumps it would lead to another agricultural revolution, particularly in eastern India and for small and marginal farmers. Millions of pumps can be installed. If so, costs, and required subsidies, will come down. But this will increase agricultural production, and incomes, in our poorest areas. In the long run this may possibly resolve the contentious problem of low electricity tariffs as discoms get freed from suppling power for irrigation.

Conclusion

The agenda for universal energy access outlined above will have many challenges, which would be gigantic but exciting. There are several barriers which are multi -dimensional in nature as there are many inter-linking issues. These include low income levels, absence of necessary infrastructure, poor skills, absence of business models for upkeep and scaling up, availability of kerosene subsidies, absence of institutional finance etc. Therefore, on the policy front, decentralised energy access solutions will not have a magic bullet. They also require a basket approach and altogether different approaches to devise sustainable implementation strategies and creation of conducive conditions to overcome the barriers. This approach must also be multi-dimensional in nature. But these are not only doable but are now required to be done. The potential and need are enormous. We must not fail.

Ultimately, there is a moral imperative. Just because the most deprived do not have that voice, the system cannot ignore. This is not only a matter of response of the government of the day. It needs to be a societal concern and commitment. The books of Piketty and

Atkinson symbolise the growing concern about inequality in society, which also emphasize the equity and human development concerns so eloquently articulated by Prof Amartya Sen over time. Energy access helps us to address these in a substantive way.

Besides, a new paradigm is emerging in the energy sector – from a centralised, inflexible, commodity like system to a substantially decentralised, flexible, modular, integrated with multiple levels and manners of service delivery. This is important for our climate challenged world and our consumerist oriented model of development. It has been argued that there are 3 possible future systems – fossil fuel centric; high nuclear-coal centric and high renewables-highly distributed-energy efficient-low demand centric. The last model seems to be our only chance for achieving not only universal energy access, but also to lead to a safe and sustainable future.

**The views expressed in the article are the personal views of the authors.*

S.J. Chopra, Prasoom Dwivedi

Energy Education

Changing development scenario in India has pushed the policy makers to look for energy sufficiency to meet the growth targets. This has resulted in the decision makers considering energy education as an important tool to create and develop manpower to serve the growing demand and supply of energy. The purpose of energy education is multi-dimensional. It includes awareness among the school kids and the general public so that they can rationalize their consumption behavior and, more importantly, to develop the necessary techno-managerial-legal skills to serve the evolving energy market. This paper has focused on the latter part of energy education. Besides Engineering education, it emphasizes on the need of expanding the scope of energy education in management and legal education. The paper has suggested a three-tier structure of energy education programs for professional courses and has discussed the ways to develop the industry ready manpower. The authors have opined the need for coordination and communication among institutions to develop the standard set of course curricula in a holistic manner along with the need of manpower requirements and an appropriate energy education strategy esp. Government-Industry-Academia interface.

Introduction

Energy is an important element of economic activity. All economic activities can be broadly sub- divided into two categories –consumption and production. While energy is a crucial input in the process of production, it is an important item of the consumption menu. In the production process the use of energy is indispensable. At every point from the basic clerical job to the refining of ore or the complicated petrochemical/chemical process, energy is consumed. [1] Energy gained its importance as a factor of production in 1976 when K. E. Boulding suggested a modified model of factors of production which is popularly known as K.L.E.M. model where K stands for Capital, L stands for labor, E stands for Energy and M stands for Material.

Energy in itself has not been a separate discipline of education in India. Instead, the students in other disciplines (e.g. engineering, economics, management and law) were exposed to the pertinent aspects of energy and related areas. Engineering students are usually aware of topics such as mining energy sources, alteration, transmission, distribution and utilization as a part of their curriculum.

Starting late 20th century energy and economic development related areas were very popular amongst the students. However, energy education lacked focus. It was unheard of that students pursuing the disciplines of management and law will have specific courses on energy. With the introduction of energy conservation act in 2001, electricity act in 2003 and Petroleum and Natural Gas Regulatory Board Act, 2006, the energy sector started looking for specialists. Gradually, the policies and regulations widened the scope of business and created market for professionals specializing in energy sector. Similarly, the conflicting energy policy objectives (energy access, energy security and climate change) have dictated the need to establish a separate educational discipline for energy in engineering, management, economics and law.

Historically, the first oil crisis of 1973 provided attention towards energy and energy usage. Further, Iran - Iraq war made the international community conscious about the fossil fuel as important global resource. At the same time, changing development scenario in India has also pushed the policy makers to look for energy sufficiency to meet the growth targets. The Government is making special efforts towards self-sufficiency in this sector by setting the target of 1, 75,000 MW renewable energy by 2022 [2]. Recently, Indian government has filed Intended Nationally Determined Contributions (INDCs) at United Nations Climate Secretariat in Germany to reduce carbon emissions relative to its GDP by 33% to 35% from 2005 levels by

2030. It has also pledged that 40% of the country's electricity would come from non-fossil fuel based sources [3]. This has resulted in the decision makers considering energy as an important area for professional studies and also put pressure on the institutions to create and develop manpower to serve the growing demand and supply for energy.

It was also realized that almost all energy companies have their own training Centres where the new recruits are exposed not only to the domain in general but to specific requirements of the sector as well.

Visualizing the need for developing human resource base for energy sector a group of professionals created "Hydrocarbon Education and Research Society (HERS)", and submitted a project report to different state governments for creation of a domain specific University providing the sketch for developing skills and talent for energy sector in the country. Based upon this project report, the then Chief Minister of Uttarakhand, Shri. N.D. Tiwari took the initiative and established an Energy University known as University of Petroleum and Energy Studies at Dehradun, Uttarakhand under the provision of Clause (3) of Article 348 of the Constitution of India, in 2003. The purpose of the setting up this University was to develop facilities for education, training and research in the areas of petroleum and energy studies [4].

Subsequently, Pandit Deendayal Petroleum University (PDPU) was also created through an act of State Govt. of Gujarat. Thereafter, the Ministry of Petroleum and Natural Gas (MoP&NG), Government of India set up an "Institute of National Importance" the Rajiv Gandhi Institute of Petroleum Technology (RGIPT) at Rae Bareli (Uttar Pradesh), which was co-promoted by six leading companies of oil sector such as IOCL, OIL, GAIL, BPCL, HPCL and ONGC in association with the Oil Industry Development Board. The purpose of this institute is also to provide world class education to develop trained manpower to meet the growing need of the petroleum and energy sector [5]. The Ministry of Power had also set up the National Power Training Institute for the human resource development for the power sector in 1965 [6]. Similarly, there are many Institute and

Universities who have started courses on conventional and renewable energy to provide trained skills to the sector. Although, lot of efforts have been made to provide skilled manpower to the sector but still, with changing paradigm of energy sector, it is very important to understand energy as discipline so that right kind of skill sets can be developed in the country.

Current policy environment in energy sector is promoting competition in the market which adds to the requirement of management and legal professionals. Theoretically also, energy is a sectoral discipline which needs multidisciplinary education. Therefore, developing and implementing the course curricula at different levels and for different streams is complex and demands a multi-pronged approach. Some of the important issues for consideration are:

I. Estimating the manpower requirements of engineers, professionals for the energy industry,

II. Understanding energy as a discipline and defining mix of functional and domain specific subjects to ensure justified coverage to energy-education.

III. Developing content to be delivered for the students at different levels.

IV. Developing specialized courses on energy for engineers, managers and lawyers.

V. Understanding and balancing energy and climate interactions.

This paper is an attempt to understand the above aspects associated with energy education.

Understanding of energy-education:

With the growing energy demand and environmental concerns, the purpose of energy education is multi-dimensional, it includes awareness among the school kids and other people so that they can rationalize their consumption behavior and more importantly to develop the necessary techno-managerial-legal skills to serve the evolving energy market. This paper focusses on later part of energy education. Like other professional courses, energy education programs also should be designed to develop:

1. Fresh professionals
2. Working executives.
3. Ph.D. programs for developing enhanced capabilities to look at futuristic aspects

Due to public utility nature of energy sector, the learners should be made aware along with conventional and non-conventional energy sources, potential of energy resources, technologies and economics to harness them and socio-cultural and environmental aspects; about energy related policy measures, strategies for solving the energy crisis and developing understanding of food-water-energy nexus from sustainability perspective.

Classification of energy-education programs:

Energy-education programs can be categorized in a variety of ways depending upon the various characteristics like student categories, level of education and abilities to be developed besides the method of imparting education [8]. In the case of public and school level programs the programs should target towards creating awareness for energy usage and environmental effects of energy withdrawal and consumption. At the same time, such programs should aim to develop energy education for secondary school through developing knowledge and skills.

The university-level energy-education program must provide in-depth theoretical understanding and knowledge of the energy sector. Besides this, these programs should provide practical hands-on skills, industry exposure and interface.

Along with students, the faculty members are also very important pillars for developing skills related to energy sector. Therefore, it is imperative to develop their capabilities to understand and comprehend the issues and challenges of energy sector. In this context, UPES has introduced Industry Attachment Program for faculty known as 'Abhigyat'. Under this program, faculty members are attached and deputed for exposure with industry. During their stay at the industry the faculty member introduced to the specific industry, helping them to align their theoretical understanding with industry practices and developing their expertise further. This also helps the industry to share and find solutions to their working problems. It is also helps the faculty in developing an industry readiness perspective of energy education.

The energy education programs curricula has to be designed in consultation with industry experts and keeping the industry requirements into consideration.

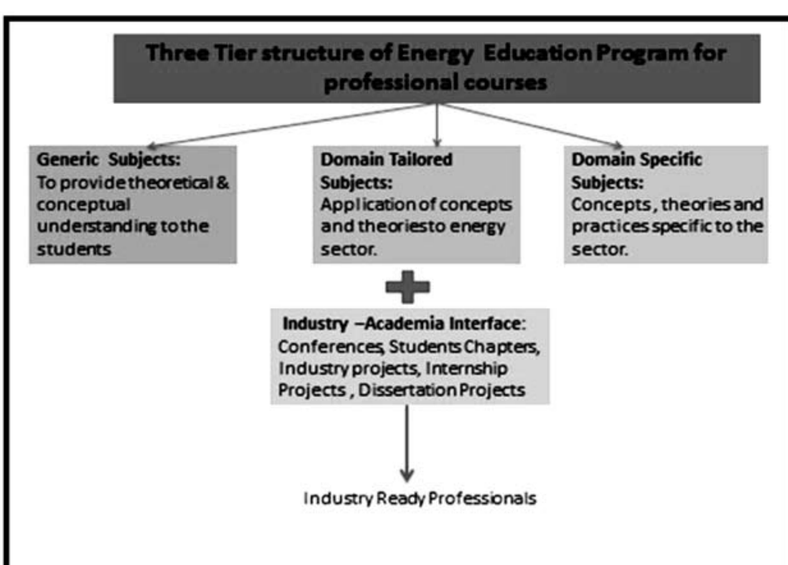
The various course module can be categorized as:

i. Generic modules which helps to understand various theoretical concepts

ii. Domain tailored modules which expose the students towards application of theory in a specific domain

iii. Domain specific modules explain the various concepts/ technologies of a specific domain.

The purpose of this categorization is to ensure a balance between theory and application of such understanding of the concepts in the industry. This categorization helps the students to be acquainted with the knowledge of a specific industry domain in a systematic manner. This is broadly represented below:



This structure also envisages the high importance of creating a platform for industry-academia interaction. Energy sector is also driven by knowledge economy and such economies are increasingly getting interconnected in changed situations. As a result, energy sector needs specialized human capital which can provide the bedrock to the sector and economy. In such emerging scenario, an integrated approach needs to be developed to strengthen Government-Industry-Academia interface for promoting energy education in the country. UPES has developed a mechanism of interface by involving industry and academia by encouraging research work, promoting research collaboration, creating interface structures, improving market access for the technology developed in the labs, nurturing private investment in technology development and research and efforts for interactions between industry and academia etc. Such efforts will provide better skills, services etc. to the nation and will contribute towards energy security and profitability. [9]

The above also results in the students studying a large number of modules in a particular semester which generates extra stress for them. The system has to realize the importance of employing psychological counsellors for ensuring that the students remain happy, healthy and on the right track.

Energy-education is evolving in the country and in any educational offering, the interconnections between energy economy and environment needs to be understood. The important aspects of these areas should be covered in a comprehensive manner. The appropriate structures should be categorized into an awareness program and a formal education program. These awareness programs must cover the following features:

a) Focus on all available energy sources.

b) Cover all aspects of energy technologies such as policy, resource assessment, techno-economics, socio-economic issues, cost benefits analysis and environmental interactions.

The undergraduate level programs focus on conceptual understanding while postgraduate programs are research based. The doctorate level programs should create literature/fresh knowledge of sector related concepts and practices. The doctoral programs also help to develop resources for academics energy domain and provide thought leaders for the various sectors.

Keeping the curricula contemporary is a very challenging task and the exercise has to be done on a yearly basis through a consultative committee. These committees should necessarily have external representatives both from industry and academia.

Energy Education in India:

As indicated in the previous section, energy education is becoming more relevant due to emerging growth targets, climate change commitments and Government plans for developing India as a manufacturing hub. The existing characteristics of the country's growth dynamics and the changing dynamics of the world, directly affect the development and establishment of energy-education program. For developing an effective energy education program, the following factors need to be taken into consideration:

The suitable curriculum development for energy education should meet the objective related to critical thinking and effective thought process [8]. It should also depend on few fundamental questions such as for whom is the curriculum being designed? What are the objectives? What methods are to be used?

This has been incorporated through the creation of Adjunct Industry Professors as well as Industry Fellows which enables the students to get exposed to the working intricacies and different technologies being used in the industry. This also provides an opportunity to the students to get a feel of the troubleshooting techniques, turnaround philosophies, handling industry relations, keeping employees updated, etc. A further support in terms of organizing conferences, workshops and initiating student chapters of various professional organizations are also available through these resources.

These adjunct professors/industry fellows also encourage students and faculty to pick up industry/internship /dissertation projects which are of relevance to their professional career. Students and faculty, both, get exposed to the sector's practices and other relevant theoretical aspects, leading sometimes to developing R&D activities beneficial to the industry at large.

Such provisions also promote effective and mutually beneficial experience sharing and interaction. This is very beneficial in structuring a balance between theoretical and practical understanding of the students so that they can meet the industry expectations, helping educational institutions to produce industry ready professionals. Such interactions also help to create a platform and encourage the students to develop as entrepreneurs in the field of energy industry. Providing diversified options to the students as a career prospects.

Conclusion:

Intensive efforts are required for comprehensive and structured curriculum development for energy education.

There are a variety of institutions imparting energy-education at different levels. However, a need exists for the coordination and communication among such institutions towards promoting a standard set of course curricula in a holistic manner.

The energy sector is growing at a fast pace. However, the assessment of manpower requirement and mechanism for Government-Industry-Academia interface needs to be developed. Keeping in view the energy sector scenario, (2047 (IESS) of NITI Aayog Govt. of India) the variety of challenges for harnessing energy resources, the availability of biomass, solar and wind as renewable energy resources must be taken into consideration while developing an appropriate energy-education strategy towards ensuring sustainable growth and development of the energy sector of India.

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Rakesh Nath

Evaluation of Electricity Regulatory System in India

Introduction

Reforms in Power Sector were initiated in the year 1991. However, despite taking initial measures and the stated desire to reform, serious problems were encountered in implementation due to poor financial condition of the State Electricity Boards (SEBs) and absence of an independent regulatory system which did not give confidence to developers and financial institutions to make investments in Indian Power Sector. One of the measures identified in the Common Minimum National Action Plan for Power 1996 to kick start reforms was establishment of independent Electricity Regulatory Commissions (ERCs). ERC Act, 1998 was enacted providing for establishment of Central and State Commissions basically with the purpose of fixing tariffs with the enabling provision that the State Governments may confer additional regulatory functions by notification. 9 States enacted their Reforms Acts and set up their ERCs during 1996 and 2003. Central Government also established the Central Commission in 1998.

The Parliament with the view to consolidate the electricity laws, for taking measures conducive to development of electricity industry, promote competition, rationalize tariffs, promote efficient and environmentally benign policies and protecting consumers' interests enacted Electricity Act,2003. The 2003 Act provided a framework for establishment of independent Electricity Regulatory Commissions and Appellate Tribunal for Electricity comprising judicial and technical members. While the 1998 Act was enacted basically for setting up an independent regulatory system for tariff determination, the 2003 Act provided for distancing the Government from all aspects of regulations, namely, licensing, tariff, specifying performance (grid code), facilitating competition through open access, promoting renewable sources of generation and adjudication of disputes.

After more than a decade of operation of the Electricity Regulatory System, one may look to access the success of the regulatory system in context of the progress made and the present state of the Electricity Sector. However, the performance and the present state of the sector have been governed by several factors beyond reasonable control of the Regulators. Evaluating the performance of the Regulatory System is a complex exercise and requires a detailed study. No systematic study seems to have been carried out by a credible and independent organization to evaluate the performance of Indian Electricity Regulatory System. In this paper an attempt has been made to examine the institutional design as provided for in the 2003 Act and whether it has been able to deliver an independent, transparent, credible and effective regulatory system.

The desirable attributes of an effective Regulatory System are independence, transparency, predictability, accountability, institutional capacity, ability to create trust of stakeholders with balanced approach and to enforce its decisions and timely disposal of cases. The provisions of the 2003 Act in respect of each one of these and the actual position and the impact of the Regulatory System on the electricity sector are discussed in the following paragraphs.

Independence

The independence has to be organizational independence as well as financial independence. The 2003 Act provides for independent Central and State ERCs with members having qualification and experience in the field of engineering, finance, economics, commerce, law or management. In order to ensure financial autonomy, the 2003 Act provides for creation of a fund from grants/loans from the Appropriate Government and fees received by the Commission which is to be used for salaries of members and staff of the Commission and other expenditure.

The ERCs have been entrusted with wide functions of regulation of tariff, to issue licenses, adjudicate disputes, specify grid code, specify and enforce standards with respect to quality, continuity and reliability of services by licensees, fix trading margins, promote renewable sources of energy, levy fees, develop power market, etc.

The ERCs have same powers as vested in civil courts under the code of civil procedure, 1908 for summoning, discovery and production of any document or material as evidence, recording evidence on affidavit, requisition of any public record, reviewing its decision, etc. The Commission also has powers to impose penalty for non-compliance of its orders. However, they lack the ability of a civil court to execute their orders. Also there is ambiguity regarding as to how can their orders be effectively executed/enforced.

The Appropriate Government has powers under the Act to give directions to the Commission in the matter of policy involving public interest and the Commission has to be guided by such directions in discharge of its function.

In actual working of the Commissions aberrations have occurred that cast doubts about their independence and effectiveness. This is on account of several factors. The roots of influence of Government on ERCs could be traced back to appointment of Regulators. In some ERCs staff has been posted on deputation or on contract from the utilities which are to be regulated by the Commission. The independence of some State ERCs has been found wanting particularly when it comes to the issues of timely determination and rationalization of retail supply tariff, providing choice to consumers through open access, timely passing on the fuel and power purchase cost adjustment during the tariff year and enforcement of decisions/ directions and the specified performance standards of the Commission on State utilities.

If State Governments failed to maintain ‘arms length’ approach in spirit and letter, there was equal failure on the part of some State Commissions as well. In a number of States tariff was not being determined by the State Commission for several years, despite increase in costs of the discoms and the companies incurring heavy losses resulting in their inability to invest in growth of their infrastructure and purchasing adequate power to ensure a reliable power supply to consumers, as the state owned companies did not file tariff petitions understandably at the behest of State Governments. The State Commissions remained silent spectators even though they had powers to initiate suo moto tariff proceedings and effective powers of court to proceed with tariff determination as held by the Tribunal in its order dated 11,11.2011.

Many State Commissions also did not allow the approved Annual Revenue Requirement of discoms to be recovered fully through retail supply tariff and created regulatory assets to limit increase in tariff and fix retail supply tariff that would be acceptable politically, knowing it well that it would create cash flow problem for the utility and attract carrying cost which whenever passed on to the consumers would result in tariff shock for the consumers. Total regulatory assets created by the ERCs today stand at over Rs 50,000 crore.

The Appellate Tribunal, on receipt of a reference from the Ministry of Power, Government of India about poor financial health of the distribution companies which was adversely affecting their performance, initiated suo moto hearing by exercising its powers under Section 121 of the Act and after hearing the State Commissions gave directions by a historic order dated 11.11.2011 to State ERCs to determine tariff every year and in case of delay in filing of petition, initiate suo moto proceedings, not to create regulatory asset in business as usual scenario and pass on increase in cost due to increase in fuel and power purchase cost at least quarterly.

The directions by the Tribunal strengthened the hands of the State ERCs and since then the ERCs have been passing annual tariff orders.

There have been some instances of State Governments giving directions to the concerned State Commissions in the matter of determination of tariff by exercise of its power under the Act and the State Commissions acting on the same mechanically. The action of the Commission was challenged in the Tribunal and the Tribunal while setting aside the order of the Commission has held that the Commission is not bound by such directions in discharging its statutory functions of tariff determination but is only to be guided by the same. For example if the Appropriate Government directs not to determine tariff in a particular year or not to issue tariff order or to determine tariff following a particular method in order to appease public, the Commission is not bound to follow such directions.

Though the Act provides for creation of a regulatory fund to give financial autonomy to ERCs, most of the States have not created such fund. Central Government has also not created the regulatory fund for the Central Commission. According to a recent newspaper report, a State Commission has reported to have stated that it did not have expertise to carry out prudence check of expenditure incurred by the distribution companies and needed services of a consultant to examine the audited accounts of the distribution companies and for which they would seek funds from the State Government. This clearly indicates that even though the intent of the Parliament while enacting the 2003 Act was to provide financial independence of the ERCs, in actual practice this has been achieved partially.

Transparency

The Act provides that the ERCs shall ensure transparency while exercising their powers and discharging their functions. Section 64 of the Act provides prior publication and deciding the application for tariff determination after considering the suggestions and objections received from public.

The transparency in functioning of the ERCs has to be maintained by following transparent procedures, encouraging public participation and by giving clear orders giving description, analysis and full discussion of underlying rationale of decision. The challenge is to balance between transparency and timely decision making in the context of the timelines imposed by the Act and Regulations thereunder.

The ERCs have been maintaining transparency in tariff determination and framing of regulations by giving public notice and obtaining suggestions and objections from public and considering the same while taking decision.

Thus, transparency is being maintained by ERCs in data collection and collation and stakeholders' participation. However, analysis of orders of ERCs indicates that some State Commissions are not maintaining complete transparency by not giving the analysis and full discussion of underlying rationale of decision. At times, the Commissions are violating their own regulations which being subordinate legislation, are binding on them. The gaps are also seen in the regulations where clauses can be interpreted in more than one way, leading to disputes. There could be several reasons for the same, like competency of staff/consultants, difficulty in envisioning the possible impact of order or regulation and political and public pressure not to enhance tariff. This can be minimized by capacity building in the ERCs and making the selection process for regulators more credible.

The matters dealt with by the ERCs being complex in nature, there is lack of adequate public debate and advocacy as common consumer is unaware of the technical and financial issues in tariff setting and therefore, not able to effectively contribute to the regulatory proceeding. ERCs have to undertake programs to educate Consumers/Consumer interest NGOs to enable them to understand the components of tariffs, the obligations of the licensees, including the service standards, etc. The efforts made by ERCs in this regard are inadequate. The ERCs should also make public the service performance of the regulated entities relating to efficiency, cost and quality with comparative performance of other comparable entities to enable the consumers to compare the performance of utilities serving them and demand better performance in the public hearings. Some ERCs have tried to benchmark the performance of the regulated entities but more scientific studies need to be carried out.

Predictability

Predictability of regulatory decisions is to be seen with regard to consistency of regulatory decisions over time so that the stakeholders are able to anticipate them with reasonable certainty. Predictability is necessary to give confidence to investors to take investment decisions and consumers of electricity to plan and budget their expenditure. The regulatory principles should be followed consistently over time and changes should be made only after public hearing. The sudden and drastic changes in the regulations should be avoided and changes should be made effective gradually as sudden and quantum shift creates a sense of uncertainty and may create viability issues in certain situations.

The Tariff Policy notified by the Government of India as per the provision of the 2003 Act provides for Multi Year Tariff Regulations. Accordingly, the ERCs have notified MYT Regulations. However, the State ERCs have not been able to determine multi-year retail supply tariffs due to inability to determine power purchase cost with reasonable accuracy. It is felt that a multi-year retail supply tariff could be determined with provision for fuel and power purchase adjustment as per formula specified by the Appropriate Commission every quarter. Initially the tariffs could be determined for a period of three years and later on after gaining the experience the period may be enhanced to five years.

There have been instances of State Commissions not following their own regulations or changing the methodology and principles abruptly or changing decisions taken by their predecessors, following different methodology in the main tariff order and in true up of uncontrollable expenditure, mainly to limit increase in retail supply tariff. However, measures to optimize power purchase cost, a major component of retail supply tariff have not been explored fully.

ERCs have to safeguard the interest of consumer and at the same time ensure recovery of cost of electricity in a reasonable manner. Thus, the regulator has to balance the interests of the consumers and the utilities/IPPs. The consumer interest is not just low tariff but also reliable power supply, quality of supply and maintenance of standard of services by the utilities.

Wartsila study on "Real cost of Power" in different cities with different reliability and quality of supply indicates that the consumers in cities having unreliable supply but having lower retail supply tariff are unwittingly paying a very high price because of power outages and expenditure incurred on back up devices such as inverters and generators. The study concludes that the real cost of power to consumers in a city like Mumbai which has benefit of 24*7 supply, but pay a higher retail supply tariff, is lower than cities having unreliable supply at a lower tariff, but incur huge cost in the form of capital cost and operating cost of back -up power devices.

Accountability

The 2003 Act provides for filing of appeal against the order of an ERC by any aggrieved person before the Appellate Tribunal for Electricity (APTEL) and the APTEL has to endeavor to dispose of the appeal within 180 days. APTEL also has powers to give directions to ERCs for failure to perform their functions under Section 121of the Act. The appeal against the judgment of APTEL lies in the Supreme Court. The accounts of ERCs have to be audited by CAG and the annual reports of the Central and the State Commissions are to be placed before the Parliament and the concerned State Assembly respectively.

In the past the Tribunal has exercised its powers under Section 121 in the following matters:

- Formation of Consumer Grievance Redressal Forum(CGRF) and appointments of Ombudsman
- Regular and timely determination of tariffs annually, true-up of accounts etc, in view of poor financial condition of DISCOMs
- Review of timely tariff determination by the State Commissions
- Directions regarding adherence to Renewable Purchase Obligation Regulations
- Directions regarding promotion of bio-mass based renewable energy generators

In PTC case the Supreme Court decided that the challenge regarding validity of regulation framed by the ERC, a delegated legislation, lies before High Court and not APTEL. Accordingly, the appeals against the regulations are being filed before High Courts. Being predominantly technical, operational and financial in nature such challenges are bound to take a long time in disposal with large back log of cases in High Court. Further, the High Courts do not have the benefit of technical assistance as available to the Appellate Tribunal to deal with complex technical, financial and commercial issues. Thus, the objective of the 2003 Act regarding constitution of an expert Tribunal for timely disposal of cases is not met fully as was stated on the objective in Supreme Court's guidance in 2002 judgment in West Bengal case.

Institutional Capacity

Commission's staff has a very important role in the functioning of ERCs as the staff has to directly interact with the regulated entities and put up staff papers on various issues inviting suggestions and objection from the stake holders. Most of the ERCs are presently being supported by engineering staff from the utilities. Right balance of experts in legal, economics, technical and financial streams are required to be developed, which is currently missing in most of the ERCs.

The increase in workload and its complexities have not been accompanied with commensurate strengthening of ERCs and Tribunal particularly Central Commission and Appellate Tribunal where there has been substantial increase in workload.

In particular at the level of regulatory commissions, there is need to bolster the understanding of legal principles of due process, transparency, sufficiency of notice/opportunity of hearing, evidentiary burden and reasoned order.

Monitoring and Enforcement of decisions

Section 142 of the Act provides for punishment for non-compliance directions by Appropriate Commission of not exceeding Rupee one lakh for each contravention and in case of continuing failure Rupees six thousand for every day during which the failure continues. Section 146 provides for non-compliance of orders or directions given under the 2003 Act, punishment of imprisonment for a term which may extend to three months or with fine, which may extend to one lakh rupee, or both and the additional fine of which may not exceed six thousand rupees per day during which the failure continues.

The State Commissions have been giving numerous directions to the distribution companies year after year in the annual tariff orders, most of which have not been implemented. One example is providing of meters for supply to unmetered consumer categories which includes agriculture. Another example is energy audit to have realistic assessment of losses in distribution system. Though the Act provides that no licensee shall supply electricity after the expiry of two years except through installation of correct meter and energy audit, it has not been implemented in the States. The agriculture consumption is still estimated based on estimated hours of supply or by sample metering, giving scope for manipulations in computation of energy supplied and distribution losses. The service quality standards have been specified but their monitoring and enforcement, particularly on State owned utilities has not been satisfactory.

There are only a few instances of fine imposed by the ERCs for non-compliance of their orders and provision under section 146 has not so far been used. In any event, without effective power to enforce decisions this may be ineffective.

Timely disposal of cases

The financial stakes involved in the electricity matters are quite heavy and therefore timely disposal of cases is very important. The Act provides for disposal of tariff application by the ERC within a period of 120 days. It has also been provided that the Appellate Tribunal shall deal with the appeals as expeditiously as possible and endeavor shall be made to dispose of the appeal within a period of 180 days.

Establishment of Regulatory System has helped in disposal of cases much faster than possible in Courts. However, it has not been possible to dispose of cases within the timeframe as envisaged in the Act. While most of the cases are disposed of within a year, there are instances where cases have dragged on for more than two years. The main reasons for delay have been shortage of staff in the ERCs, delay in filling up the vacancies of members in the ERCs and the Appellate Tribunal and substantial increase in number of disputes due to increase in generation capacity in private sector and large number of developers setting up renewable generation capacity. The Central Government has notified setting up of circuit benches of the Tribunal at Chennai, Mumbai and Kolkata but the circuit benches have not been operational as it has not been found practical to operate circuit benches on a sustained basis with the available strength of two benches.

Impact on Power Sector

The impact of competition and enabling regulations for inter-State transfer of power has resulted in a huge capacity addition in the country during the last decade. The installed capacity at the end of the 10th Plan (FY2006-07) was 132 GW which has reached 277 GW at the end of October, 2015. Thus, what the country added in about six decades since independence has been added in less than a decade after enactment of the 2003 Act. There was a spurt in capacity addition in private sector. The capacity addition encouraged the international equipment manufacturers to set up manufacturing facilities in India in joint venture with Indian partners. Three large multinationals namely, Alstom, Mitsubishi and Toshiba set up steam generator/ turbine manufacturing facilities with supercritical technology having high efficiency in joint venture in India.

There has also been growth in renewable energy projects due to promotional measures like specifying Renewable Purchase Obligation, tradable Renewable Energy Certificates, feed-in tariff, banking, third party sale and open access with concessional wheeling/ transmission charges etc, introduced by ERCs. The renewable energy capacity today stands at around 36000 MW (13% of total installed capacity).

In the power transmission sector also there has been huge growth. In last decade the transmission infrastructure has almost doubled. The private sector has also participated in the development of transmission system either in JV mode with Power Grid Corporation or independently in projects awarded through tariff based competitive bidding. Strong transmission inter-connections have been established between the five Regional Grids operating in the country and high power highways have been created from large generation centers to the load centers. An all India power grid has now been in operation which is being strengthened every year.

The Central Commission has facilitated establishment of power market. Two Power Exchanges have also been established which provided facilities to generators, distribution licensees, consumers and traders to buy and sell power transparently. The price of power in day-ahead market transacted at the exchange has reduced considerably in last six years. The average market clearing price of FY 2008-09 was Rs 7.31 per kWh which has come down to Rs 3.51 per kWh, a reduction at a CAGR of 12%.

The Regulatory System can claim some credit for facilitating the above developments.

However, the progress in distribution sector which is vital in the electricity value chain, has not been encouraging. Despite the subsidy support from State Governments, the distribution sector faces today a financial distress on account of huge accumulated losses due to inefficiency of state owned distribution companies. The book loss of State discoms during 2013-14 was of the order of Rs. 64000 crore and the revenue gap was 73 paise per unit. Though, the national average of aggregate transmission and distribution losses of the country is reported to be around 22%, yet one has to relook at the fact that most of the distribution transformers and about 25% of the consumers are still unmetered. The losses have resulted in state owned discoms relying more on short term loans to fund their operations. The borrowings by State DISCOMs rose from Rs 1,58,003 crore in 2007-08 to Rs 5,45922 crore in 2013-14(CAGR 23%).The ERCs have, however, correctly decided the aggregate revenue requirement of discom at the normative loss level and the financial loss due to non-achievement of target loss level has been passed on the discom .

Though the energy and peak demand deficit of the country is reported to be around 2%, the reality is that a large number of consumer face power cut on regular basis due to breakdown or constraints in distribution system or the distribution companies resorting to load shedding to limit their power purchase cost due to financial problems even though power is available and the affected consumers have to resort to costly standby devices or procure power from short term market through open access to meet their demand on their own. Distribution has turned out to be a strange business where the more you sell, the more loss you incur.

There has been a very interesting case where power cuts were imposed in a State on industry by the discom. When the industry procured power through open access from power market, the discom imposed cross subsidy surcharge on them. The State Commission upheld the levy of surcharge. However, the Appellate Tribunal set aside the levy of surcharge stating that surcharge is a compensatory charge and in this case discom did not suffer any loss. This instance shows that the concerned discom preferred to impose power cuts on consumer than to procure power from short term market to fully meet its consumers' demand.

The ERCs have set up service quality indices for discoms but do not have any tools to monitor the actual performance. There is lot of scope for improving the services to the consumers through web based applications which is required to be encouraged by the ERCs.

Conclusion and Way Forward

The 2003 Act has provided a framework for setting up an independent regulatory system with wide regulatory functions and powers with adequate provisions for maintaining transparency. Though one of the objectives of the Act was to distance Government from regulatory functions, in practice this could not be achieved fully, particularly in the functioning of State ERCs. The Appellate Tribunal has acted from time to time to give directions to ERCs which has helped in strengthening the hands of the Commissions. Transparency has been maintained in data collection, collation and stakeholders' participation but some improvement is required in the orders and judgments passed with regard to analysis and discussion of underlying rationale of decision and in education of consumers to effectively contribute in the regulatory process. ERCs have framed MYT Regulations to maintain consistency but at times the predictability and consistency has been sacrificed to limit retail supply tariff even at cost of creating cash flow problems for the utilities. There is an urgent need for capacity building in ERCs and the Appellate Tribunal in view of complexity of issues and vast increase in workload.

Some suggestions are given below:

i) The selection committee to select members of the State

Commissions may be enlarged by including both, the Chairperson, CEA as well as Chairperson , CERC, instead of one of having them as existing now, along with an independent expert of repute to bring more credibility in selection process of the State Regulators.

ii) Central Government may consider selecting one of the IIMs to recommend an appropriate organizational structure for the regulatory commissions that may become standard model for the Commissions. This will ensure that the right people with proper understanding and aptitude are available who can help evolve the sector and address the concerns of all key stakeholders in a balanced and prudent manner.

iii) Appropriate Governments need to create regulatory fund and its devolution for operation of respective ERCs as provided for in the 2003 Act. This will provide financial independence to the ERCs and help them to effectively manage the training of staff and hire reputed consultants. All the ERCs can also pool their resources to establish a regulatory capacity building and research centre in collaboration with some University or IIT.

iv) There is an urgent need for the Appropriate Governments to consider augmentation of staff in ERCs and providing appropriate pay scales to attract talent. Similar action is required for the Appellate Tribunal. There is a need to create an additional (3rd) bench in the Tribunal to handle increase in volume of work over last few years.

At present there is no provision for supporting staff in the Appellate Tribunal from technical, commercial/financial, economics and law background to assist the benches. Provision of a small staff of four to six persons from the above field would help in expediting disposal of appeals.

v) The Central Government has a very ambitious plan for development of the electricity sector viz., 24*7 power supply to all, enhancement of renewable energy capacity to 175,000MW by 2022, smart metering, reduction of AT&C

losses to 15%, etc. ERCs have to play an important role in meeting these targets. Therefore, institutional strengthening and capacity building of ERCs has to be incorporated in the Central Government's program.

vi) The Supreme Court while interpreting the 2003 Act in PTC case, held that regulation framed by ERCs under the Act is a subordinate legislation and its validity cannot be challenged in the Appellate Tribunal and can be challenged only in High Court. The regulations are thus challenged in High Court which defeats the objective of formation of Appellate Tribunals as expert bodies to deal with the appeals in regulatory matters in a time bound manner. Regulators tend to specify all financial and operating norms and formula in the regulations after which the tariff determination is only a mechanical exercise. The Appellate Tribunal only has a limited role of interpretation of the Regulations. It may be necessary to amend the 2003 Act to provide power for examining the validity of the Regulations. Should that pose a legislative or judicial challenge, there is a need to evolve a more productive role for expertise available at the Tribunal to help High Court to decide such matters.

vii) There is a need for a proper planning for optimum power purchase by discoms from various conventional and renewable resources. There is also large scope in optimizing the cost of generation from the tied up resources by fuel swapping to minimize cost of fuel and diversion of available fuel from less efficient to more efficient plants. For example, a study conducted for optimization of cost of generation from thermal power plants in Delhi indicates that there is a scope of saving more than Rs 650 crore and reduction of power purchase cost of DISCOMs by 22paise/unit by diverting gas from less efficient gas based stations to more efficient station and closing down inefficient coal based and a gas based station which have already outlived their useful life. ERCs have to enforce optimum power procurement by discoms as it constitutes the major component of retail supply tariff and will benefit consumers immensely.

viii) There is a great scope for application of web based applications for various services provided by the distribution licensees viz , new connection, billing and payment, billing disputes, quality of supply, no current complaints etc, for transparency and quick redressal of the consumers' grievances without the need for the consumer visiting the office of the utility. ERCs have to insist for such services and provide necessary expenses for such services in the Annual Revenue Requirements of discoms.

ix) Establishment of monitoring mechanism for service performance data and making public the data on services, cost and efficiency of utilities along with data of other comparable utilities to empower the consumers to demand better services comparable to other efficient utilities. Once the performance indices of service quality of all the utilities are available in public domain it will result in public pressure on the non-performing utilities and denying of unreasonable expenditure by the Regulator for such utilities.

x) Amortization of regulatory assets in a time bound manner.

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ii) Handbook for Evaluating Infrastructure Regulatory Systems by Ashley Brown & others

iii) Website of Public Utility Research Centre

R.N. Nayak

Transmission Development in India

Background

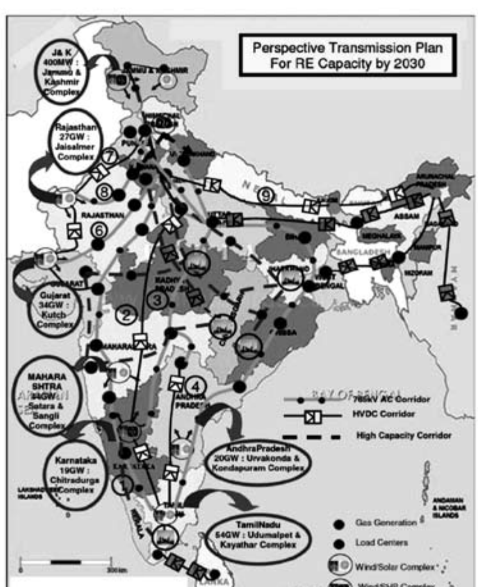
The Indian power sector is one of the largest in the world. Sources for power generation range from conventional sources like coal, lignite, natural gas, oil, hydro and nuclear power to other viable non-conventional sources like wind, solar and agriculture and domestic waste. Power generation resources either conventional or non-conventional are unevenly distributed across the country usually away from the major load centers. Transportation of natural resources are costlier, sometimes not feasible like Hydro resources, than transmitting power to widely spread load centers across the country. In these circumstances, transmission acts as an enabler to meet the energy demand from remotely located resources.

For the last couple of years, generation and transmission capacity has been added significantly. Present total installed capacity is about 282 GW. Peak and energy deficit has significantly come down to the order of 2 to 3 %. Adequate generation and transmission facilities are now available to meet the demand. Days are not far off when access to electricity will be available to all. Thus the Govt. of India is focusing now towards 24x7 power supply by 2019.

Clean Energy Development

To meet the upcoming electricity demand in a sustainable and environment friendly manner, India has been promoting Renewable energy (RE) for decades. In a move to augment clean energy at a rapid pace, the government has recently announced ambitious plans to add 175 GW of RE by 2022, that includes 100 GW of Solar, 60GW of Wind and remaining 15 GW through other forms of RE generation. Renewable energy development is being taken up on a big scale to meet the multiple objective of securing energy security and development of clean energy for sustainable development. This has more challenging after Climatic Change Conference with a Historic Agreement on 12th Dec’15 at Paris. Out of 100 GW Solar, 20 GW would be through Solar park, 40 GW through distributes Solar Generation and remaining 40 GW would be through rooftop solar generation. In the past one decade renewable penetration has increased multifold from merely 2.5 GW in 2005 to 38 GW in 2015. Renewable Generation is not uniformly spread across the country due to scarcity of land and also availability of RE resources. The nature of RE generation is very much different from conventional generation. It is highly intermittent / variable against the conventional coal / Hydro generation, which are quite stable in nature. RE generation is mainly distributed over a large geographical area, whereas conventional generation is mainly concentrated near pit head or Hydro potential rich areas. The potential of RE is location - specific i.e. concentrated in areas distant from consumers or the grid and located in selected few states. Another important characteristic of renewable generation that

Figure. 1: Green Energy Corridors



needs special attention is its low gestation period of the order of few months to a year as against 2 to 3 year gestation period for building EHV network. Large inter-connected grid facilitates integration of large scale renewable generation, to address variability and uncertainty associated it. In order to successfully integrate such type of large scale RE generation in the Grid, the existing transmission network is being further augmented. It is to be noted that renewable generations, being distributed in nature are also interconnected with grid at sub-transmission or distribution level. As mentioned above Ultra Mega Solar Parks are being developed in selected potential rich areas and bulk power from these locations would be evacuated through EHV transmission network. But to evacuate the distributed RE generation, sub-transmission network are also being strengthened / augmented. Evacuation system development for RE generation shall be required to be taken up much in advance to avoid any bottleneck in integration of renewable generation. For large scale rooftop solar generation integration, distribution network would also require to be modernized, augmented and made intelligent.

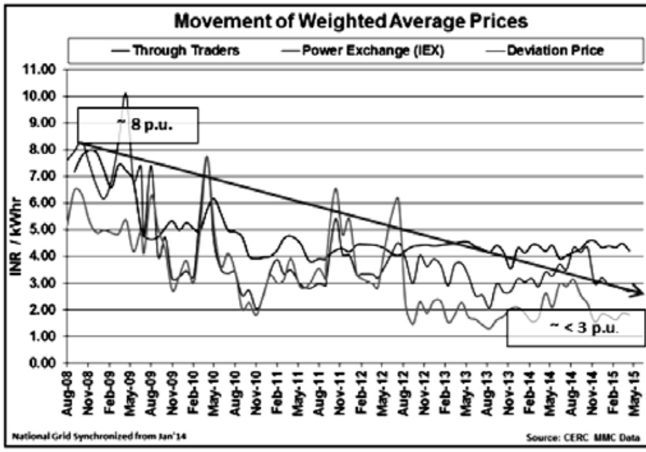
Renewable Integration

Presently in India, for integration of large scale renewable generation "Green Energy Corridors" are under implementation, that includes inter-state transmission system as well as intra-state transmission system. This also includes establishment of Renewable Energy Management Center as well as other State-of-the-Art monitoring and control mechanism including Synchrophasor measurement, dynamic compensation and Grid scale energy storage etc. One of the proposed improvements to the grid that will facilitate increased RE is the deployment of Smart Grids. There is no single technology or design, but this is a general term for the transformation of the power grid using digital communications and control to enable functionalities such as increased monitoring, resiliency, flexibility, efficiency, and intelligent.

Role of Transmission Network

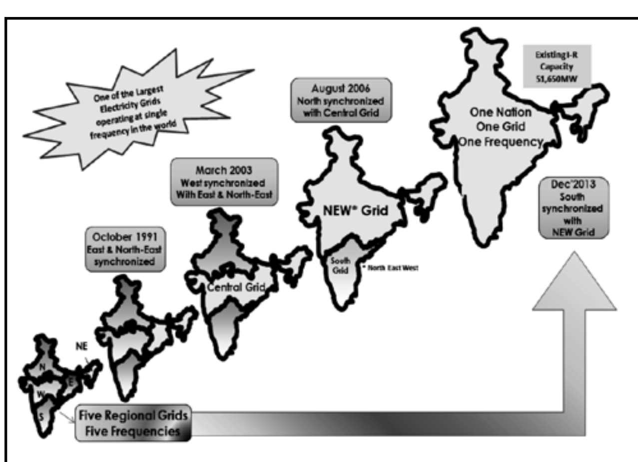
Towards meeting electricity demand of the country and also development of power system, Transmission is playing a central role.

Figure. 2: Trend in Cost of Electricity in Bulk Market



Today India has a transmission system comprising 23,789 circuit kilometer (ckm) of 765kV, 1,44,067 ckm of 400kV, and 1,55,666 ckm of 220kV lines. HVDC bipolar links comprises 12,938 ckm. and massive programme for enhancement of transmission capacity addition about Rs 2,00,000 Crs are under implementation Such a large interconnected 3,36,560 ckm long robust transmission network has facilitated seamless flow of power across the length and breadth of

Figure. 3: Evolution of National Grid



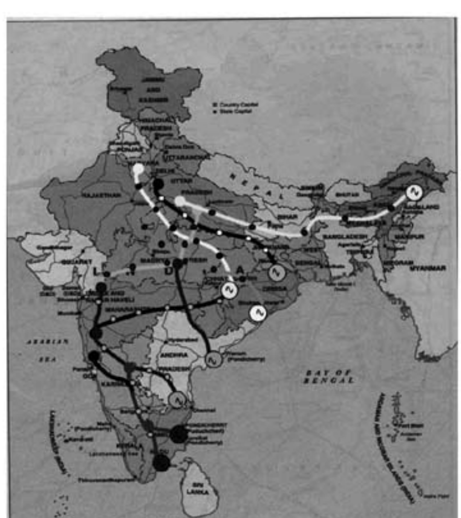
country and helped in establishment of vibrant electricity market, bringing efficiency in the overall sector resulting in decreasing cost of electricity in the bulk electricity market from more than Rs. 8 per unit to less than Rs. 3 per unit.

In fact, the spot market price of all regions except southern region was Rs 2.45 per unit and in the south highest average price was Rs 3.10 per unit in Dec'15 which is 20% lower than Nov'15 . Further, for the first time the spot market price on 29th Dec'15 was single price i.e. Rs 2.30 throughout the country, a great achievement for Power sector. It can be seen that stable and reliable transmission infrastructure of the country has brought competition in the sector, providing electricity at affordable price and also bringing efficiency into the sector.

Transmission System Development in India

Major portion of the network is covered by transmission utilities owned by Central and state govt. The Central Transmission Utility (CTU) viz. POWERGRID is responsible for planning and coordinating the Inter State Transmission system (ISTS) while the State Transmission Utilities (STUs) are responsible for intra state

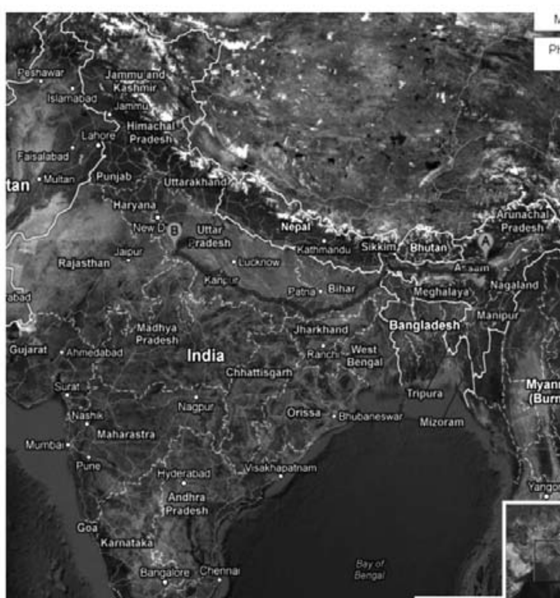
Figure. 4: High Capacity Corridors



transmission system. Private sector participation in the transmission system is gradually increasing since 2011, even Govt. owned utilities are required to compete for building lines as per the policy.

The development of the electricity grid in India occurred on a regional basis till last decade of the twentieth century. Subsequently, considering the skewed nature of natural resources and demand, the network planning shifted to have a pan India focus. Starting from five regional grids in early nineties we have today one national grid comprising more than 53,150 MW inter-regional capacity. This is one of the largest interconnected grids in the world.

Figure. 5: HVDC Link between NER & NR



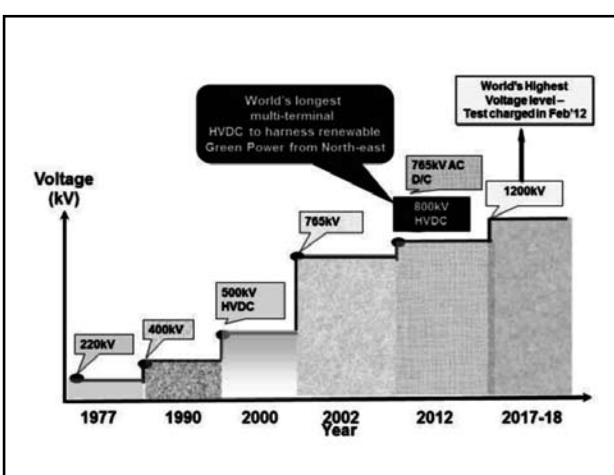
To meet bulk power evacuation requirement of various Independent Power Producers (IPPs) mainly coming up in resource rich and coastal States such as Chhattisgarh, Odisha, Madhya Pradesh, Sikkim, Jharkhand, Tamil Nadu and Andhra Pradesh 11 nos. of High Capacity Power Transmission Corridors (HCPTCs) are being implemented in a phased manner matching with generation projects.

As mentioned above, the Indian power system has been unique characteristic of having mix of AC and DC transmission system. Prior to phase wise synchronization of regional grids, HVDC Back-to-Back stations were used to transfer power between regional grids. As India has a skewed distribution of natural resources like coal, gas and hydro required for electrical power generation including the upcoming wind and solar. This mandated building up of high capacity HVDC lines and EHVAC lines which helped to transfer power from surplus to deficit areas as transfer of bulk electrical power is cheaper than transporting natural resources. High capacity EHVAC and HVDC links between regional grids are under operation and there is a phase wise strengthening of transmission system in the Indian Grid at EHV level is undergoing.

Technology

Major Challenge in the development of transmission system is availability of Right of Way (Row) for lines and acquisition of land for substation construction. In this direction, latest technologies viz., EHVAC transmission, HVDC system, GIS substations, FACT devices etc. are being adopted on a large scale. In the Technology front, India has emerged as pioneer and is a leader in the world with the commissioning of 1800 km UHV HVDC 800 kV from Biswanath

Figure. 6: Technology Adoption



Chariali in North Eastern region to Agra in Northern Region and successful indigenous development 1200 kV UHV AC system which is under field trial since 2 to 3 years.

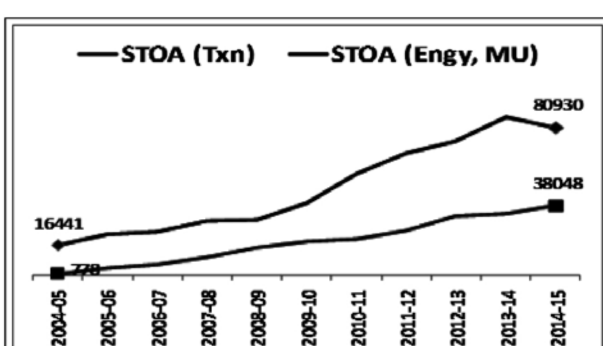
FACTS devices are installed in important AC transmission lines to increase the power transfer capacity. The hybrid mix of AC and DC transmission system in India has given the system operator to exercise a better control over the grid and flexibility in operation during any exigency in grid. The HVDC Back-to-Back and Long Distance HVDC interconnection along with AC tie lines between the regional grid help to control on the AC tie line flows.

The interconnection of grid has enabled in harnessing the diversity available in the vast country covering 3.2 million square kilometers. State of Art Five regional control centers known as Regional Load Despatch Centers (RLDCs) coordinate the operation of each region under the overall supervision and control of National load Dispatch Center(NLDC). The State Load Despatch Centers coordinate operations within the state. The Indian Electricity Grid code (IEGC) governs the integrated operation of the Grid.

Market Development

To bring efficiency in the power sector through market mechanism, the first significant step was the implementation frequency linked imbalance pricing. It facilitated the implementation of open access at the inter-state transmission level as envisaged in the Electricity Act 2003. Since its implementation in FY 2004-05, more than 80

Figure. 7: Growing Power Market



billion units of electricity have been transacted through about 38000 transactions benefitting both the end consumer as well as supplier.

The next step was the introduction of Power Exchange (PX) as a platform for Day Ahead Market (DAM). At present two power exchanges are in operation since June 2008 / November 2008. There is no doubt in the fact that interconnected national grid has resulted large benefits to the country.

Further, the next step of reform in the electricity market was the introduction of Point of Connection (PoC) Tariff mechanism on the fundamental principle of Quantum, Distance and Direction for sharing of the interstate transmission charges and losses in 2011. All these reforms have resulted into establishment of vibrant electricity market in the country that has encouraged private players participation in all elements of the power supply value chain.

The robust transmission network of the country has not only shown its resilience during normal operation period but also during extreme emergencies like super cyclone Hudhud, Philian, earth quakes, floods etc. Through the adaptation of advanced technology and best operation practices the bulk transmission network at the inter-state level is maintained consistantly with more than 99% system availability.

However, there are issues in providing access of electricity to all and ensuring 24X7 power supplies. To mitigate these issues, matching development is required in the sub-transmission and distribution sector. Recently Govt. of India have come out with a much needed Ujwal Discom Assurance Yojana (UDAY) with an objective to improve the operational and financial efficiency of the State Discoms. This shall go long way to ensure financial and operational turnaround of Discoms resulting 24X7 reliable power supply and large scale Renewable penetration.

Conclusion & Way Forward

The present Indian Power Grid has evolved from small isolated systems in the 1960s to regional grid in 1980s and finally to a single large interconnected synchronous National grid in early 21st century with an installed capacity of about 282 GW. The size and complexity of Indian Power Grid is increasing rapidly due to the factors like demand growth, increasing system size, long distance power haulage and integration of renewable energy resources etc. With the increasing competition in Electricity market and large seasonal load variations, the grid is expected to operate closer to their limits and in such a scenario it is foremost essential to further strengthen the network and regularly upgrade it with latest technological development. To reap full benefit of national grid, other important steps that need to be taken includes stable frequency band, implementation of primary and secondary control, development of parallel/ redundant transmission corridors, establishment of ancillary services and Grid Discipline etc. Therefore, it can be seen that transmission is playing a pivotal role in development of Indian power system through seamless flow of power from source to load and also amongst consumers bringing efficiency and affordability into the sector.

Sudhir Vadehra

Power Capacity Addition in India

Performance and Challenges

Generation Capacity is the prime indicator of power development and the prime mover for infrastructure growth in the country. Generation Capacity has improved during last Plan period, from average of 20,000 MW/ Plan to about 55,000 MW during XIth Plan period. The improved trend is likely to continue during the current Plan period, where it is likely around 1,00,000 MW i.e growth of over 80% over previous Plan period, which was a benchmark.

The Sector wise trend of performance in capacity addition during previous Plan period indicates major contribution from Private Sector, which added about 23,000 MW capacity during XIth Plan out of about 55,000 MW overall addition i.e. 42% of the overall.

Major fuel base however remains thermal (i.e conventional fuel of Coal / lignite/ gas), which contributed 48,540 MW of the overall 54,964 MW (i.e. 88%) during XIth Plan period.

The comparative Plan wise capacity addition over last few Plan periods is captured below : (all figs. in MW)

Plan **Sector/Type**	**VIIIth**	**IXth**	**Xth**	**XIth**
		Central		
Thermal	6,252	3,084	6,590	12,790
Hydro	1,465	540	4,495	1,550
Nuclear	440	880	1,180	880
	8,157	**4,504**	**12,265**	**15,220**
		State		
Thermal	6,040.50	5,538	3,553.64	14,030.40
Hydro	794.70	3,912	2,691	2,702
	6,835.2	**9,450**	**6,244.64**	**16,732.4**

Private				
Thermal	1,262.4	4,975	1,970.60	21,719.50
Hydro	168	86	700	1,292
	1,430.4	**5,061**	**2,670.6**	**23,011.5**
Overall				
Thermal	13,554.9	13,592	12,114.24	48,540
Hydro	2,427.9	4,538	7,886	5,544
Nuclear	440	880	1,180	880
	16,422.8 MW	**19,010 MW**	**21,180.24 MW**	**54,964 MW**

Source: CEA

During the current XIIth Plan, targets for Capacity addition were based on actual capacity achieved during XIth Plan and Demand forecast of 18th EPS, which had forecast an energy requirement of 1,355 BU and a peak demand of about 2,00,000 MW .

The following is the year wise Demand forecast for XIIth and XIIIth Plans as per 18th EPS.

Year	Electrical Energy Requirement (MU)	Peak Electrical Load (MW)
2012-13	98,4743	1,39,682
2013-14	10,65,571	1,52,329
2014-15	11,53,606	1,66,260
2015-16	12,48,081	1,81,988
2016-17	13,54,874	1,99,540
2017-18	14,50,982	2,14,093
2018-19	15,52,008	2,29,465
2019-20	16,60,783	2,46,068
2020-21	17,78,109	2,64,041
2021-22	19,04,861	2,83,470

Source: CEA

As observed, the peak load by the year end 2021-22 is projected for 2,83,470 MW. Consequently the tentative capacity addition required during XIIIth Plan works to following : -

Source	Hydro	Thermal	Coal	Nuclear	Total
	12,000	566,400	56,400	18,000	86,400

The contribution to capacity addition from renewable sources in the country is 38,283.59 MW , as following:-

Source	**Capacity (MW)**
Solar	4,684.74
Wind	24,759.32
Bio-Power	4,677.63
Small Hydro	4,161.90
Total	**38,283.59**

Source: CEA

MNRE is targeting cumulative capacity addition of 1,75,000 MW by 2022

Following is the status at present of Capacity addition in Thermal, Hydro and Nuclear:

		(MW)
	Plan Target	**Actual to date**
Central	26,182	14,051.60
State	15,530	15,241
Private	46,825	44,283
	88,537	**73,575.6**

		(MW)
	Plan Target	**Actual to date**
Thermal	72,340	68,884.60
Hydro	10,897	3,691
Nuclear	5,300	1,000
	88,537	**73,575.6**

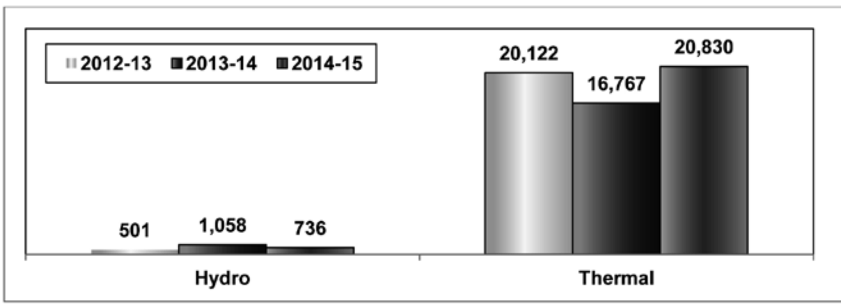
Source: CEA

Thus against 88,537 MW targeted during the Plan, 73,575.60 MW is already achieved. Cumulative capacity addition by end of current year is likely around 80,000 MW

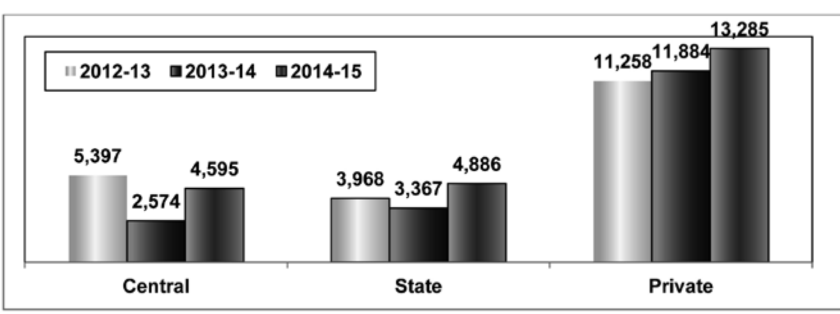
The yearly Capacity addition trend of 20,000 MW is likely to continue in the last year of the Plan period as well. It is likely that 1,00,000 MW benchmark for the Plan period may get breached.

The following trend in capacity addition during last three years focuses on areas of attention:

FUEL WISE TREND IN CAPACITY ADDITION (TH + HYD) (figs. in MW)



SECTOR WISE TREND IN CAPACITY ADDITION (TH + HYD) (figs. in MW)



QUARTER WISE TRENDS IN THERMAL & HYDRO CAPACITY DURING LAST THREE YEARS

(figs. in MW)

	Q1	Q2	Q3	Q4	
2012-13	5,266	2,370	2,218	10,768.8	∑ = 20,622.80
2013-14	2,512	2,286	3,930	9,097.01	∑ = 17,825.10
2014-15	4,229.97	4,748.67	1,631.97	10,955.90	∑ = 21,556.31

Source: CEA

- No clear trend emerges during first three quarters except that focus is put by the Developers / Utilities only during the last quarter i.e. in Jan – March to commission the resp. units, either to achieve the target (in case of Central and State sectors) and in case of private utilities it is to meet their commercial targets and / or conditionalities, though in certain cases they need to be pursued to meet the deadline.
- In all three years the fourth quarter has contributed to 50% of yearly achievement – which is though not a healthy / desirable trend.

The capacity addition over years has improved from about 14,000 MW/ yr at beginning of the XIIth Plan to around 20,000 MW/ yr. The capacity addition of 22,522 MW during last year is a new benchmark, which may be difficult to be breached considering that "Fresh starts" during recent years have not been commensurately maintained. Thus the basket of projects under construction is getting depleted. We may breach 1,00,000 MW capacity addition mark during current Plan period but unless "Fresh starts" are immediately focussed upon, the performance during the following Plan period will be found wanting.

There are many commercial and technical constraints being faced by the Developers which have resulted large operationable capacity remaining unutilized, because of which even the "resourceful Developers" are hesitant to add capacity and relatively smaller Developers left to face uncertainties.

The concern of unutilized generating capacity is being addressed by focussing on transmission corridors and strengthening sub transmission/ distribution network but it may not result immediate turnaround, while concern of outstandings with the State Utilities remains a major irritant. A broad exercise on falling productivity of generation capacity is as below :

In the comparative performance column above, the time lag of 6 months in Installed capacity during the period w.r.t. the Generation performance is with consideration that capacity commissioned is to achieve COD within 6 months, as per norms of CERC. Though the comparison does not reflect the true picture as earlier installed capacity would already be operational but being a comparative study, it moderates such inconsistencies to an extent.

Comparative Performance				Deliverables	
Installed Capacity at end of period (GW)	Generation during the month (BU)	Productivity indices		Energy Shortage	Peak shortage
		Value (BU/ GW)	Variance		
03/2012 199.877	*09/2012* 73.077	0.365			
09/2012 207.876	*03/2013* 79.928	0.384	*04/2013 – 03/2014*	*04/2013 – 03/2014*	*04/2013 – 03/2014*
03/2013 223.343	*09/2013* 82.508	0.369	(-) 4.68%	Improved from (-) 8.7% to (-) 4.2%	Improved from (-)9.0% to (-) 4.5%
09/2013 228.721	*03/2014* 83.865	0.366			
			04/2013 – 03/2014	*04/2014 – 03/2015*	*04/2014 – 03/2015*
03/2014 243.028	*09/2014* 85.81	0.353	(-) 7.65%	Improved from (-) 4.2% to (-) 3.6%	Deteriorated from (-)4.5% to (-) 4.7%
09/2014 254.049	*03/2015* 86.10	0.338			

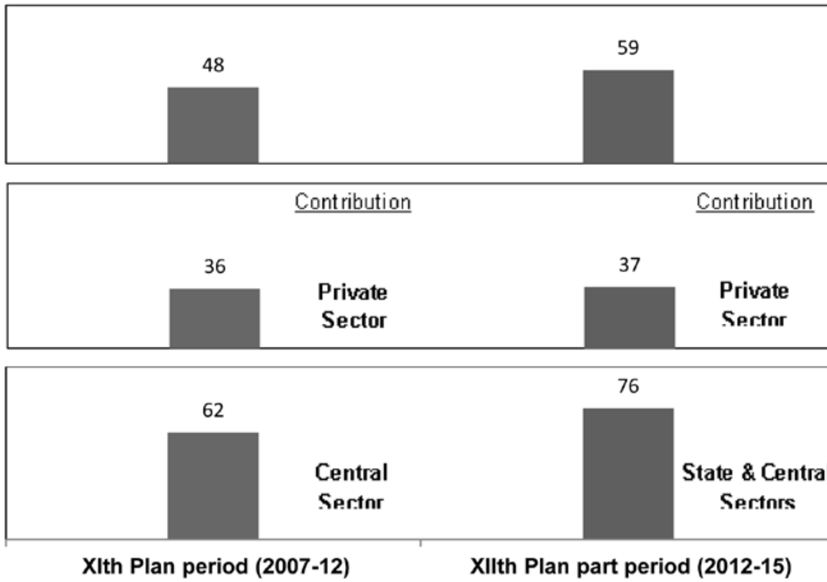
Source: CEA

\# **An analysis by the author indicates improvement in "Deliverables" i.e. reduced Shortages but the deteriorating "Productivity Indices" during last three years from 0.365 to 0.338 indicates increase in unutilized capacity (also confirmed by falling PLF during the last three years from around 78% to 63%)**.

The analysis was conducted to determine if the improving capacity addition has also resulted improved "Project management" in power projects under construction, but unfortunately it has not been the case.

The comparative results are rather unexpected, as they indicate the average execution period from Main Plant equipment award to commissioning has increased from "48 months during XIth Plan" to "59 months during the first three years of the XIIth Plan". Further while the minimum execution period has remained alike at "36 / 37 months" (all in private sector), the maximum execution period has increased from "62 months during XIth Plan" to "76 months during XIIth Plan".

Execution period from Main Plant equipment award to Commissioning (mths)



Source: CEA

There are varied reasons for the scenario that emerges – one being that all projects/ units commissioned during the first three years in current Plan period are delayed and mostly are the subsequent units (award placed for 2 or 4 units together), thus the gap of about 3 to 9 months gets added to the execution period – but here too the gap between subsequent units has increased from earlier 3 mths to even 9 to 12 months in certain cases.

Second problem is of bunching of contracts with major Balance of Plant equipment agencies, as a result they resort to levelling of their limited resources, consequently causing interface fronts release issues at project site.

The performance of Private sector could still have been better if their issues pertaining power congestion, PPA issues etc. were addressed but nevertheless some of the Developers are equally to be blamed as without conducting due diligence, construction was taken up and issues addressed as they were encountered. No internal techno economic commercial appraisal seems to have been done by the Developers.

Focus at beginning of the XIth Plan was on fixing the target matching with the capacity requirement (even if ambitious) and taking all administrative measures to ensure it's realisation. The focus thus was on building and augmenting manufacturing capacity of power plant equipment to match the enhanced capacity addition targets. The manufacturing capacity of BHEL, the sole Main plant supplier during that period was limited to around 6 – 7,000 MW / year in thermal. It was persuaded to enhance its capacity and in addition other new players were also encouraged to set up manufacturing capacity in the country. The following is the manufacturing capacity of indigenous manufacturers :

(i). Boiler (36,200 MW)

BHEL - 20,000 MW/ L&T-MHI – 4,000 MW / Thermax – Babcock & Wilcox – 3,000 MW / BGR- Hitachi – 3,000 MW / Doosan Power System – 2,200 MW

(ii). Turbine/ Generator (35,000 MW)

BHEL - 20,000 MW/ L&T-MHI – 4,000 MW / Alstom – Bharat Forge – 5,000 MW / Toshiba – JSW – 3,000 MW / BGR- Hitachi – 3,000 MW

Source: CEA

In addition, other measures like developing new vendors for Balance of Plant equipment, easing qualifying requirements for Balance of Plant suppliers, development of Ultra Mega Projects, holding international conferences on key inputs for power sector were also undertaken to ensure the capacity addition targets were realised.

The resultant of the Efforts was capacity addition of about 55,000 MW during 11th Plan period, which was a benchmark.

However due to lack of focus on 'Fresh starts' primarily for impediments being faced in operating the units, the scenario of unutilized available manufacturing capacity in the country depicts an alarming trend as it is not only the main manufacturers but there subsidiaries as well which run the risk of getting out of business.

The unutilized capacity gap is a major cause of concern when seen in the light that these Manufacturers were pursued by Government to set up Shop here and there is no institutional effort at national level even till date to utilize the available capacity within the country for manufacturing Spares for projects built by Chinese or other international suppliers.

While individual Developers are making efforts to reduce their dependence on Chinese manufacturers for Spares and other O&M requirements but even after more than five years of a good Chinese make capacity in place, we get constrained in ensuring the same because neither there was any prerequisite of technology transfer, nor any precondition of building in-house capacity for Spares and other O&M requirement for their equipment, enforced at time of award.

Similar concern is of Balance of Plant equipment where we have now built adequate capacity for major auxiliaries. The concern here too is alike for the equipment purchased primarily of Chinese make, as they remain reluctant to share or part with the requisite technology/ knowledge / information.

Following is the consequent impact on electrical equipment industry:

(i). Under utilized available Capacity

Due to earlier focus on capacity addition, the domestic electrical equipment manufacturing industry made investments in doubling and, in some cases, even tripling its production capacity.

However, this built-up capacity stands under-utilised (to extent of about 30%) due to economic slowdown and surge in imports of electrical equipment in recent years. This is significantly impacting the commercial viability of the domestic electrical equipment industry and impacting the manufacturers.

(ii). Non availability of Critical Inputs / Raw Material in the country

There are several critical inputs / raw material used in the manufacture of electrical equipment which are not available in-house, thus have to be imported.

CRGO is a prime example. CRGO is a critical raw material for large generators / transformers, manufactured by 14 companies (no Indian manufacturer) in the world, and is totally imported. No manufacturer/ investor seems to have come forwarded to establish CRGO manufacturing facility in the country.

(iii). Commercial only focus in procurement

There is slow pace of absorption of new technology by domestic manufacturers of electrical equipment, and also user industries, along with insignificant investment in research & development (R&D). The current buying practices in government undertakings also do not encourage innovations and R&D.

As a result, main focus of the manufacturers of electrical equipment is on cutting costs and not on innovative technologies. It is thus more on piecemeal short-term tactical measures rather than evolving any strategic action plan for their growth and development.

(iv). Education and employability mismatch

There is major concern of getting skilled and employable technically competent deployable manpower.

With focus now on "Make in India" it is needed to explore possibilities for utilizing the available capacity and correcting the anomaly with possible solutions for effectively utilizing the available indigenous capacity :

(i) Encourage and facilitate through concessions for competitive bidding outside the country.

(ii) Facilitate and encourage in house capacity for orders within the country without sacrificing the international competition and parameters for concern of quality, speed and state of art technology (as our own Manufacturers are no less competitive and enabled)

(iii) Utilizing the available capacity for manufacturing spares and other O&M requirements of foreign manufacturers through reverse engineering, wherever constrained due to lack of technical knowhow.

(iv) Focus on R&M for old plants where the indigenous capacity can be used (irrespective of make of the equipment).

(v) Continue to maintain focus on fresh capacity addition by monitoring fresh starts for sustainable capacity growth in the XIIIth Plan period.

The following thoughts for consideration to address impediments in Capacity addition: -

(1). Decentralized and participative approach in target setting will help in involvement, commitment and accountability of respective State Governments in target setting including private sector projects being set up in resp. states.

(2). Need to link allocation of Central resources to resp. States with their performance in Capacity addition and Generation for which they are to be made accountable and responsible – Thus an integrated State wise give and take approach.

(3). Technical support / Single window facilitation at State level -

It may in turn create need for technical advisory bodies / sub offices of CEA in the States – all these bodies may be under CEA at Delhi but supporting resp. State Governments as CEA is supporting Ministry of Power at Centre. – Appropriate administrative structure and exchange systems may be put in place. Funding may be by State Governments for the structures created in resp. States.

(4). Tapping the hydro potential - need to focus on hydro projects languishing with private players. Private participation is a success story in Thermal, while the same is not true in Hydro.

True that project clearances need to be expedited but if due diligence is not properly done, it will be suicidal for the Developers as uncertainties and inadequate data in hydrology and geology will further delay project execution. Thus focus is to be more on facilitation during execution in Hydro.

(5). Need for more frequent and value based exchanges with the Project financing agencies. The inputs / projections with FIs on project implementation in certain cases are not in tune with the realistic situation. Further there is no dispute resolution mechanism for issues between FIs and Developers, which can ensure avoidable concerns getting timely addressed. A Dispute resolution forum/ institutionalized mechanism maybe considered for private sector projects in power.

Rupendra Bhatnagar, Somenath Byabortta

Business Models and Technological Aspects of Smart Grid

Introduction

Smart grid brings transformation to the electricity industry towards less centralized and more consumer oriented operation. The journey towards a smarter grid changes the business model of the industry and its relationship with all the stakeholders involving utilities, regulators, service providers, technology vendors and consumers. Throughout the world, smart grids are still under evolution. Though many of the constituents of a smart grid exist today, it has not been fully packaged in one integrated solution.

A smart grid vision can be fulfilled through enablement of technology and changing business processes and an end-to-end requirements of grid operation. Adoption of innovative operational and information technologies play a pivotal role in the development of smart grid. With system reliability and fault-resilient grid being the critical objective of smart grid adoption, building a robust electrical network supported by strong measurement, operational and control framework are of prime importance to fulfil smart grid vision. This necessitates utility wide adoption of operational technology that can measure and send system and asset information in real / near real time basis and based on these accumulated information, it should either be able to assess and send back control signal back to the system or asset or take appropriate measure based on real time assessment of the system.

Movement towards smart grid also has a profound impact on the way business is being performed. Some critical business drivers for the smart grid include:

- Focus on real time monitoring of grid operation, automation and information management to achieve increased reliability and safety operation of grid with improved quality of supply

- To mitigate the environmental issues, control emission of greenhouse gases and greater penetration to renewable resources
- To include consumers as the active participants of the energy value chain as consumers are the key factors in achieving Utility's goal for effective peak load management by taking part in the demand response programme.

The inclusion of renewable energy sources from the end user side implies a pivotal change: electricity consumers are also able to produce electricity now, hence turning them into "prosumers" with a different role in the whole power grid system.

All these changing business scenarios and technology aspects has opened up new business opportunities. Intelligent and innovative technology can be the key to help build and nurture the customer and utility relationship with a promise for emerging new business models for the benefits of all the stakeholders in the smart grid regime.

Smart Grid Technology: Trends and breakthrough innovation

Successful adoption of smart grid calls for implementation and adoption of combination of electrical, operational and information technology. Plug-in hybrid or electrical cars and associated vehicle-to-grid technology, improved technology to store large scale energy, the technology towards virtual power plant for clustering of distributed generation are critical components for smart grid journey. However, for the limited scope of discussion, we restrict to the operational and information technology aspect and its impact on the overall solution architecture.

Wide scale implementation of sensor technology across the critical network components along with implementation of SCADA and DMS for data acquisition and control purpose and Integrated GIS based Outage Management system are some of the initiatives that fall into the operational technology domain of power utilities.

Fast and accurate real time monitoring of the grid is a fundamental requirement of the smart grid, and Phasor Measurement Units (PMU) are being deployed in the power grid to achieve this feature. We have also seen the introduction of a wide area measurement system (WAMS) with advanced measurement feature to help utility in understanding and managing the complex behavior presented by integrated power systems. WAMS is designed to improve the situational awareness of the network operator for safe and reliable grid operation. With the introduction of PMU based wide area measurement system utilities are going to have the self-healing capability of the electrical grid fulfilling another objectives of smart grid roadmap.

These devices and controls are inter-connected through a utility-wide and two-way data communications network connecting customers, distributed resources and field devices with the enterprise systems and applications which demand an integrated and cohesive approach between IT and OT world. Also, for effective smart grid deployment, the large amount of data generated by these devices and systems is to be captured, stored and analyzed for decision making purpose. This poses a strong challenge to ICT infrastructure and need effective and innovative IT architecture and solution to execute this. Proper dissemination of data with event detection, predictive, forecasting and modelling capability are some of the requirements that need to be fulfilled in the solution architecture to meet the objectives of smart grid.

Information Technology also plays a critical role in smart grid development. All around the globe the smart grid deployment is focused on foundational technologies like Automated Metering Infrastructure (AMI) with bi-directional communication facilities. One of the important IT components associated with this is to store, manage and analyze the interval meter readings and energy information generated by smart meters and use this for CIS and billing application. Integration with metering head-end and development of Meter data acquisition system (MDAS) along with an appropriate meter data management system (MDM) to store and manage high volume consumption data, estimation and forecasting of demand based on historical trend and weather information, capture metering event and performing energy accounting and thereby identifying the loss at different asset and voltage level across the distribution network are some critical functions where IT application is being used effectively. IT has helped in development of customer-side applications enabled by smart meters which assist consumers to understand and control their energy usage.

Among other Information Technology applications some of the key applications include Enterprise Resource Planning for managing HR, Finance and Materials resources, Enterprise Asset Management application for supply chain, maintenance and asset and work management, Energy Portfolio management for energy planning and portfolio optimization, Demand Response Management for DR management and Virtual power plants, Geographic Information system for mapping of distributed assets on GIS and use of mobility solution for Asset and workforce management and management of field crews and work scheduling purpose. Apart from applications, the smart grid deployment demands other aspects of Information technology including data governance, inter-operability and security aspect. To support and manage exponential growth of data, IT should provide cost-effective and secure infrastructure for enterprise scalability, performance and reliability point of view. Under smart grid paradigm, IT has to ensure flexible and agile response to new business requirements and to deliver informed business decisions by providing visibility, control and analytics to the enterprise through a digitally connected energy network that forces participants to synchronize and collaborate to deliver stable, affordable, clean and reliable electrical energy.

Consideration of a suitable technology architecture for smart grid is based on breakthrough technology innovation which gives rise to the possibility of development of a digital energy network, built on following technology trends:

- **Hyper connectivity:** Connectivity drives the smart grid principle where every consumer and asset are interconnected to form a collaborative digital network of consumers, suppliers, assets, information and workforce

- **Real time computing:** The technological maturity to provide a real time in-memory computing platform creates infinite business opportunities and made the real time analytics possible on terabytes of data generated from different elements of the connected grid.
- **Cloud based computing:** Adoption of smart grid promises to deliver new business processes. Cloud based collaboration platform enables utilities to launch new business practices in quick time.
- **Cyber Security:** The digitally connected network gives rise to security threat and sabotage. Technology to prevent such threat and cyber security is critical for safe and reliable operation.

In the transformation journey towards smart grid, future business models for utilities should capitalize on the Digital energy network through a systematic approach to identify and capture business opportunities.

Smart Grid Business and operational change

Adoption of the Smart Grid enhances every facet of the electric delivery system including generation, transmission, distribution and consumption. It encourages consumers to modify patterns of electricity usage, including the timing and level of the electricity demand. It will increase the possibility of the distributed generation, bringing generation closer to the load center. It will empower consumers to become active participants in their energy choices to a degree never before possible and it will offer a two-way visibility and control of energy usage. It is clear that the traditional energy value chain under the smart grid regime is transforming at breakneck speed and has its effect on the way the business is being done. Some of the critical business and operational changes towards this are mentioned below:

Supply-side coordination: Distributed generation of volatile renewable energy requires a sophisticated digital supply side coordination that collects, analyzes, and distributes information in real time to the market participants for the sake of better decision making.

Transmission: Significant investments need to be done to adapt the transmission network from the as-is thermal plant locations to the new renewables plant locations. Simulation to predict load patterns, financial and technical modeling, and real-time control optimizes grid utilization and avoids building oversized transmission assets

Smart and efficient distribution: Intermittent and decentralized power production requires the ability to predict and handle power in-feed with bi-directional power flow. Evaluation of energy data helps to predict grid loads and anticipate bottlenecks that strain the grid. This allows for the optimization of grid investments. Real-time processing of load data enables the integration with demand/supply balancing services to optimize grid utilization. Similar to power plant operations, new capabilities in predictive maintenance and self-healing concepts help to further reduce operational costs.

Asset operations and maintenance: Smart asset operations and maintenance are key drivers for cost efficient, compliant, and reliable grid operation and power generation, in particular in highly distributed environments under smart grid regime. Predictive analytics based on sensor data enable advanced asset management requirement of smart grid operation.

Meter Data Operation: Meter data is not just needed for billing purposes – it is analyzed in real time to forecast and balance load, optimize demand response, monitor and improve energy efficiency and reliability, and optimize energy portfolio profitability.

Storage and flexibility services: Sensors and meters attached to power consumption or generation devices and the industrial consumers' overall operations plan deliver input to calculate and offer demand increase/reduction capacity. This capacity can be managed automatically and is sold to grid operators who need to stabilize their grid.

Customer Service: Digital information about consumer behavior, preferences, and needs creates a new world of opportunities. Regardless of the business model, Utilities need a digital, 360-degree view of the consumer and the market. Innovative service offerings and processes can have a game-changing impact on customer relationships and the top and bottom line. All service processes will be digitally connected to the workforce, suppliers, customers, and assets for more efficiency and customer value.

Demand Response: The objective of Demand Response (DR) program is to shift the load of the consumers from the peak demand period to the off-peak period, thereby reducing the critical peak demand and flattening the load curve. It helps utilities to save the cost of building additional generation capacity to meet the peak demand.

Energy efficiency program: It allows the consumers to use less energy with the use of energy efficient items and components. It also encourages and incentivizes consumers to give up critical energy use in the peak period. Real time access of information of the digitally connected grid can cut energy consumption to a great extent.

Some of these new elements like demand response and distributed generation and storage allow for optimization of system performance and asset utilization. Information on energy consumption patterns, consumer demographic and behavioral information, and access to personal connections/networks for marketing purposes, are the foundation for new revenue sources. In the traditional electricity value chain, the one-way flow of electricity and information puts electricity utilities in the position of power and control over consumers. However, smart grid deployment could create major changes in the consumer-electricity supplier relationship. The consumers are having more control over electricity usage and the opportunity to trade with the utilities.

Emerging business models

The flow and volume of information itself, along with new services it enables, are strong contributors to the new values and business opportunities generated under the deployment of smart grid. In the initial period, there will be a little financial or operational value delivered from the data generated by consumers because it is limited in scope and frequency. However, the quantity, frequency and quality of data generated by consumers and its usefulness to energy providers and third parties are set to grow exponentially as smart grid infrastructure is being deployed.

The inclusion of renewable energy sources from the end user side implies that electricity consumers are also able to produce electricity now, hence turning them into "prosumers" with a different role in the entire power grid ecosystem. A "prosumer" can generate electricity with renewable distributed generation technology, can store energy during off-peak hours in electric car batteries and other storage equipment and can also take part in the grid system through smart meter and other consumer-end energy control devices. A household residential customer, a housing complex, a commercial establishment or a plant, office or similar entities that can send energy back to the power grid can also be termed as a "prosumer". In the operation of a smart grid, a "prosumer" plays a critical role as an active market participant and influences the demand-supply balance of the electricity grid. Ideally a "prosumer"should respond to the market signal in the smart grid ecosystem (like price signals sent by distribution system operator and so on).

Furthermore, the electricity services that is currently been occupied by distribution system operators (DSO) and power producers will be expanded and restructured and new players will enter the emerging new market. These varied market forces will create a paradigm shift in the industry that challenges the viability of traditional business models. For example, coordinated smart charging of electric vehicle batteries mitigate the intermittency challenges of wind power and both can synergize to form an operational model. Similarly, clean energy technologies, including roof top solar, distributed storage, energy conversion, and conservation offer sustainable solutions when combined with real-time markets enabled by the requisite information infrastructure.

Based on the above discussion it is evident that there are strong indications of emerging business models evolving around the following four business categories:

Digitally connected "prosumers"

The emergence of "prosumers" and increasing environmental and energy awareness broaden the scope of customer interactions and increase addressable consumer spend. From Utilities point of view, the socio-demographic information and behavioral pattern of the consumers including their preferences, lifestyle, location and consumption pattern obtained from the smart meters and consumer-end devices create new business potential to serve and interact with the consumers. New investment coming from the consumers under energy efficiency and demand side management program and investment in renewable generation like roof top solar etc. open up new business opportunities in terms of provision of new infrastructure and services. There will also be new business avenues and engagement model to connect with the consumers who are having e-mobility (electric cars) as an option.

Demand/supply balancing services

The steady growth of the renewable energy poses a serious challenge for the grid managers. The availability of solar and wind energy greatly depends on the weather conditions and largely variable in nature. The integration of large amount of renewable energy of intermittent nature is a serious technical challenge for smooth operation and balancing of grid. This also generates business opportunities around demand/supply balancing services. The business model around balancing services requires real-time processing and forecasting of generation and consumption data to assess the demand and supply position. Different options for balancing services include storing of cheap energy and releasing expensive energy, or by influencing the demand side to shift consumption and save energy. The service should also consider different storage technologies such as batteries, pumped-hydro, flywheel, compressed air etc.

Energy generation excellence

New opportunities in the power generation business is visible with increased portfolio in green energy across industry. It is also supplemented by increased carbon price in certain countries by making fossil fuels more expensive and encouraging private investment in renewables. This clearly open up competition in the market and top performers will focus on efficient operation of large-scale power generation plants to outperform small-scale commercial and private producers, Utilities are also engaged in building large-scale solar and wind farms to help meet the renewable mandates. To ensure profitable operation generators integrate and process real time sensors, weather and market data for daily operation. Predictive analytics will be a key enabler to maximize the use of centralized and de-centralized assets in this sector.

Smart and efficient distribution

The shift towards decentralized operation through wide spread growth of distributed generation still needs robust and resilient distribution grid to deliver electricity. Profitability of distribution utility depends on achieving excellence in grid building, operations, and maintenance activity. The ability to predict and handle intermittent and decentralized power along with bi-directional power flow is the key for optimized operation of the distribution entities. In the rapidly changing scenario, distribution operation needs to be smart and efficient in evaluating energy data to predict and forecast grid loads and anticipate bottlenecks. Real- time processing of load data enables the integration with demand/supply balancing services to optimize grid utilization. New capabilities in predictive maintenance and self-healing concepts help to further reduce operational costs.

Conclusion

Deployment of the smart grid technology is accelerating at a rapid pace. Along with the deployment of smart grid infrastructure, the electricity production and delivery ecosystem is fast changing with new participants entering into the marketplace. Development of smart grid will create opportunities for both traditional energy infrastructure vendors while opening up market to the new players. To capture the business opportunity, smart grid players must build a profound understanding of where the value is in the evolving grid system and they must also develop a compelling business model to pursue this value. A sustainable business model aligns with the utility goal by reducing operating expenses while also reducing risk in operation. Real time information generated from the digital energy network and inclusion of consumers in the energy value chain are two critical factors to drive the future business. In coming years, the smart grid market will grow rapidly and this growth will occur across the value chain, from customer side applications to grid wise automation upgrades. Smart grid promises to create a much more dynamic electricity market with the combination of cutting-edge technologies and the new role taken by the market participants.

Yogesh Daruka, Subhrajit Datta Ray

Hydropower in India*

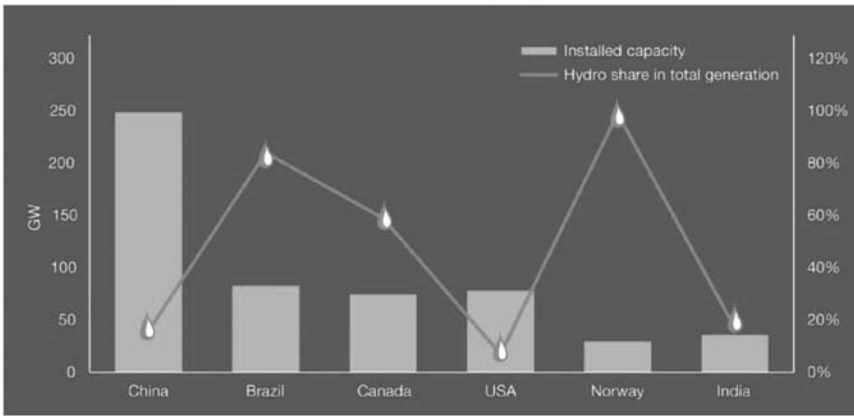
Key Enablers for a Better Tomorrow

Introduction

Propelled by sustained economic growth and rise in income levels, India is poised to face significant increase in energy demand in the next few decades which also translates into higher demand for electricity. The gap in the electricity demand-supply situation is highlighted by the fact that the country experienced a peak deficit of 5.2% and energy deficit of 4.2% in FY 13-141, with the surplus western and eastern regions unable to compensate for the severely deficit northern, southern and north-eastern regions. Considering an energy elasticity of 0.82, India is projected to require around 7% annual growth in electricity supply to sustain a GDP growth of around 8.5% p.a. over the next few years. This requires tapping all potential sources to address the deficit and meet the demand growth for accelerating economic development while taking into account considerations of long-term sustainability, environmental and social aspects. Climate change and other negative effects of using fossil fuels for power generation along with growing concerns over energy security are driving the expansion of hydropower around the world. Though reservoir based hydropower projects have come under criticism due to CO_2 and methane emissions beyond acceptable limits, most hydro-rich countries have followed an integrated full life-cycle approach for the assessment of the benefits and impacts to ensure sustainability.

*The IC Centre for Governance express its thanks to the Federation of the Indian Chambers of Commerce and Industry (FICCI) and Price Waterhouse Coopers (PwC) for their concurrence to publish this article.

Installed hydropower generation capacity and share in total generation



(Source: World Energy Council, CEA)

India is endowed with rich hydropower potential to the tune of 148 GW (which would be able to meet a demand of 84 GW at 60% load factor) which makes it one of the most important potential sources to meet the energy security needs of the country.

1 CEA, Load Generation Balance Report, 2014-15

2 Planning Commission, government of India

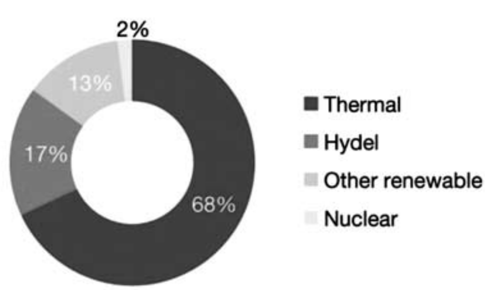
Critical role of hydropower in sustainable development and promoting economic growth

The current development profile and trends in generation capacity addition in India have resulted in the following aspects:

- **Skewed development pattern between different generation technologies:** The current portfolio of installed capacity of 233 GW is dominated by thermal power with around 68% share. Hydro, with an installed capacity of 36 GW, has a share of around 17% coming down from around 46% in 1966. Adequate diversity in generation asset base has not been maintained with growth in hydro assets not being concomitant with growth in the thermal asset base. This also impacts the long-term least cost development pattern with overt reliance on 25-year thermal plants visà- vis more than 40-year hydro assets.

- **Inadequate peaking and quick response capability:** While regional grids have been integrated and frequency regimes have been streamlined due to Availability Based Tariff (ABT) regime, the country faces lack of assets capable of meeting peaking deficits and with quick response characteristics. Peak shaver hydro assets will prove beneficial in meeting the current and projected energy and peak shortage in the Indian power market.
- **Sustainable low carbon development:** While India is considering a low carbon strategy and actively considering focusing on Energy Efficient Renovation & Modernization (EE R&M) to sweat existing assets, the low carbon strategy can be fostered further with a higher thrust on green capacity additions via hydropower development. These factors necessitate renewed emphasis on 'responsible hydropower development' to promote economic growth. Hydro's critical role in sustainable development and energy security for the country is based on the elements of sustainability, availability and affordability.

India's generation mix



Estimated levelised cost of electricity (LCOE) for plants to be commissioned in 2019

Plant type Total system LCOE (USD/ MWh)

Conventional coal fired 95.6

Conventional combine cycle gas fired 66.3

Integrated coal-gasification combined cycle (IGCC) 115.9

Nuclear 96.1

Wind 80.3

Wind - Offshore 204.1

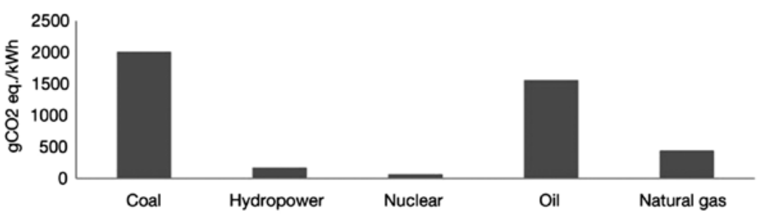
Solar - PV 130

Solar thermal 243.1

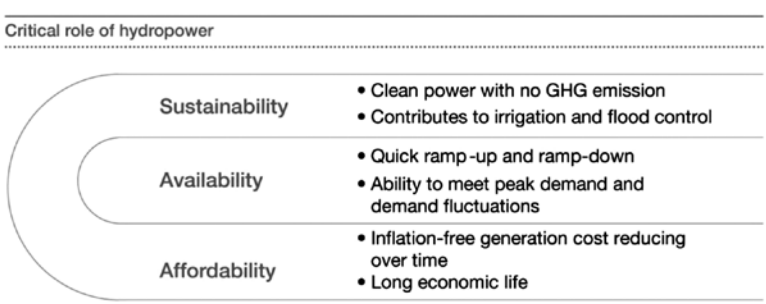
Hydropower 84.5

Source: US Energy Information Administration

gCO2 equivalent emission



Source: IJSTR, Vol 2, Issue 12, Dec'13



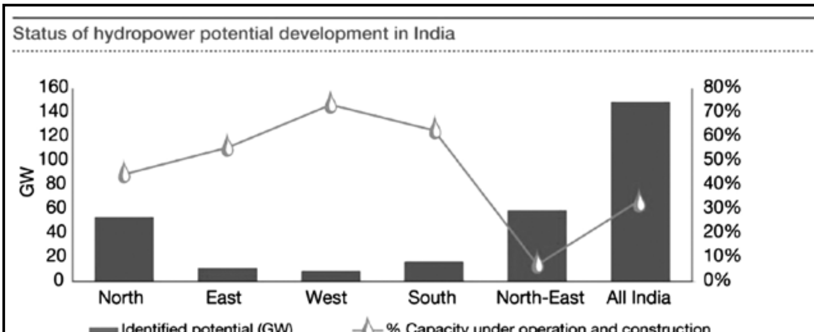
Evolution of the hydropower sector in India

Untapped potential

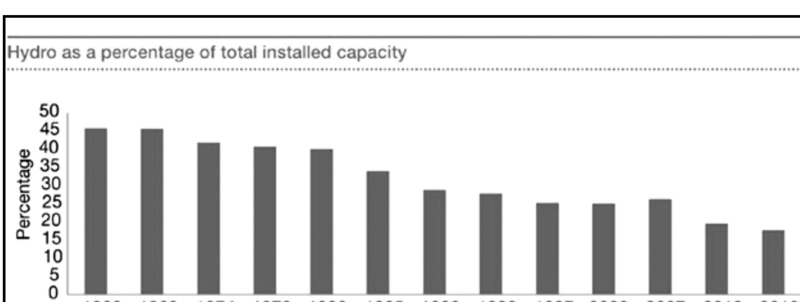
India is endowed with significant hydroelectric potential and ranks fifth in the world in terms of usable potential. As per the latest available data, India has around 36 GW of installed hydropower capacity whereas an additional 13 GW is under construction. This puts the total capacity which is yet to be tapped at around 67% of the potential. Countries such as Canada and Brazil had harnessed around 69 and 48% of the economically feasible potential back in 2009.

From a regional perspective, over 93% of the total potential in the north eastern region is yet to be tapped, primarily in parts of the Brahmaputra river basin. The scenario is in sharp contrast to the southern and the western regions where more than 65% of the potential has already been harnessed.

The government of India has, over the years, taken a number of initiatives to prioritise hydropower development and to attract investments in the sector. Key measures include the preparation of a shelf of well investigated projects, which could substantially reduce risk perceptions, streamlining clearance procedures, the provisions of



(Source: CEA)



(Source: CEA)

Electricity Act, 2003	National Electricity Policy, 2005	National Tariff Policy, 2006	National R&R Policy, 2007	Mega Power Projects Policy, 2008	Hydro Power Policy, 2008	Land Acquisition Act, 2014
Changed the industry structure and laid the foundation for open access, which suits hydropower projects that are naturally best suited to meet peak power requirements in the country.	Emphasised on full development of feasible hydropower potential. Issues of long-term financing, centre and state participation, etc. were addressed.	Differential rates for peak and non-peak power and uniform guidelines for SERC. Aimed to bring greater transparency in the power sector.	Emphasises a need for a more transparent and participative rehabilitation and resettlement process in improvement in the quality of life of PAPs.	Hydropower projects with capacity over 500 MW are given mega power project status. Such projects get several benefits including a 10-year tax holiday, no customs duty on import of equipment, etc.	Emphasised the development of hydropower capacity and increasing private sector participation.	Replaced archaic act of 1894. Greater clarity in acquisition and R&R policies.

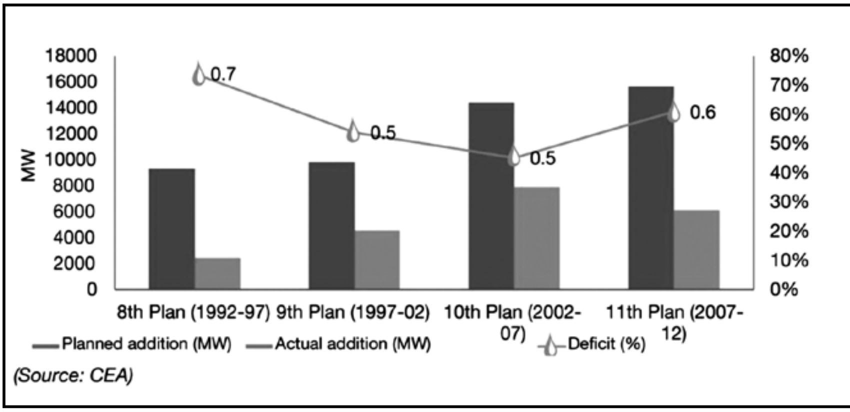
open access and trading as per the Electricity Act 2003, etc. However, issues in implementation of such policy initiatives and regulations still plague the sector resulting in the declining share of hydropower in India's energy mix since 1966.

Recent trends

The government of India has increased financial allocation, along with other non-financial support, to prioritise hydropower development and increase capacity addition. Accordingly, in the 11th Five Year Plan, the target for hydropower capacity addition was placed at 16.5 GW, which was almost half of the total installed capacity then. However, the achievement, at around 5400 MW, was well short of the target. The same trend of achievement falling short of target by far can be observed in the previous plan periods too.

Various factors such as environmental concerns, R&R issues, land acquisition problems, long clearance and approval procedures, capability of developers, etc. have contributed to the slow pace of hydropower development in the past. These issues have been compounded as hydropower development has largely remained under the ambit of state governments (water being a state-specific subject) with varying policies (e.g. upfront premium, royalty power, land acquisition policy, etc.) adopted by the states.

Target vs achieved capacity addition (Source: CEA)



Major slippage reasons for 10th Plan projects

Major reasons for slippage Hydro capacity

slipped (MW)

Geological surprises 510

Natural calamity 450

Delay in award of works 823

Delay in MoEF clearance 400

Delay in clearance/investment decision/funds tie-up constraints/ delay in financial closure

1400

Delay in preparation of DPR and sign of MoU between HP & SJVNL 400

CR & R issues 400

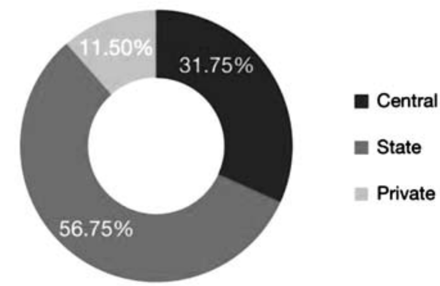
Court cases 675

Total 5058*

* This does not include 3009 MW dropped from 10th Plan

Source: Working Committee on Power for 11th Plan

Percentage contribution in hydro capacity addition from 1992-2012

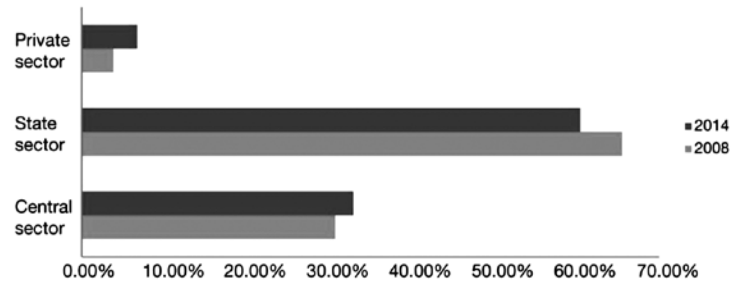


(Source: CEA)

To accelerate growth in the hydropower sector and to bridge the gap between the actual and planned capacity addition, the private sector is being seen as an important stakeholder. The hydropower sector was opened up for private sector participation in 1991. Subsequently over the years, to facilitate projects through PPP/ JV mode, some states have nominated a state nodal agency with an option of equity investment by the state government. However, from 1991 to 2012, the private sector has contributed to about 11.5% of the hydropower capacity addition. So far only about 2700 MW has been commissioned through the private route, which constitutes less than 7% of the total installed hydropower capacity.

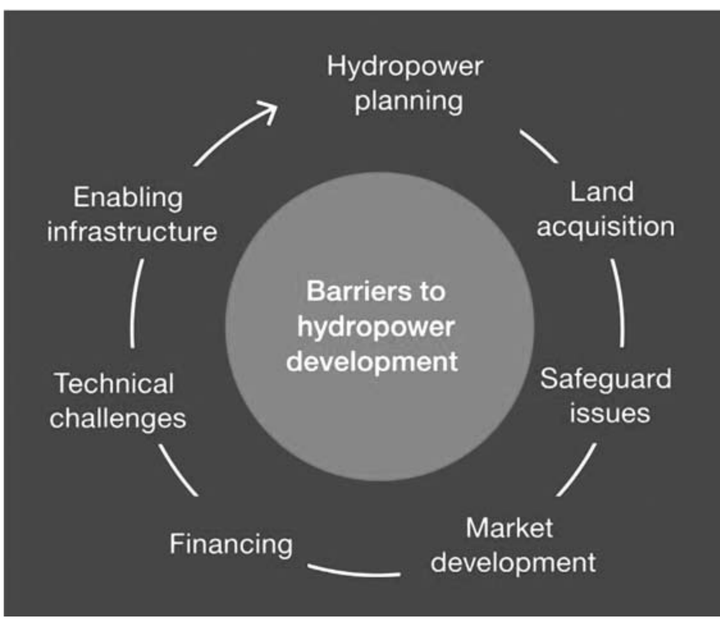
Though private participation in the hydropower sector has gained momentum in the recent past, it still faces impediments in the execution of projects across various stages of the project implementation cycle. The central and state governments need to create an enabling investment climate for increasing private participation by addressing issues related to safeguards, land acquisition, evacuation, law and order problems, technical challenges and non-appreciation of the risks involved in project development.

Share of central, state and private sector in hydropower capacity in 2008 and 2014



(Source: CEA)

Current issues and challenges



Hydropower planning

Planning for hydropower development in India has generally been oriented toward individual projects. However, this approach has several limitations for sustainable development of an entire river basin.

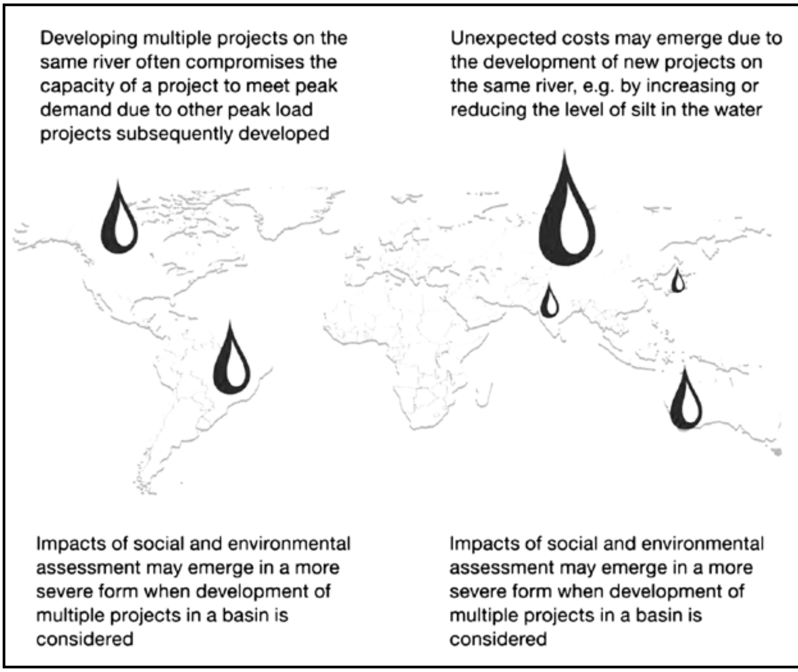
Inter-state disputes are another aspect which hinders integrated river basin development for hydropower projects. A large number of hydropower projects with common river systems between adjoining states are held up due to a lack of inter-state agreements and disputes on water-sharing. The Sutlej-Beas dispute between Punjab and Haryana and the Mullaperiyar dam conflict between Kerala and Tamil Nadu are well-reported examples of water-sharing disputes between states. The conflicts in Assam and Arunachal Pradesh on division and utilisation patterns of the Brahmaputra are also emerging.

Land acquisition

Land availability and acquisition are among the core structural issues that impact almost all infrastructure sectors. Problems arising in the acquisition of land for hydropower projects are causing suspension and delay in construction activities.

Till recently, under the 120-year-old prevailing Act, land acquisition for public purpose had been beset by several issues surrounding processes, procedures and compensation, as the term 'public purpose' was never clearly defined. The new law, which came into effect from January 2014, attempts to address the social inequities in the existing framework of land acquisition. However, there are still serious issues which need to be addressed to remove constraints in infrastructure development. The government had already identified the following issues and is working towards finding an optimum solution between addressing the land-loser's concerns and the developer's perspectives:

- Consent of 50% landowners in PPP projects even if the ownership vests with the government
- Compensation amount for acquisition in rural areas and urban regions
- The Social Impact Assessment (SIA) processes which, instead of addressing issues related to responsible development and benefit sharing, cause delays
- Legal definitions which increase complexity and cost for developers without adequately benefitting the affected population



Safeguard issues

Construction and operation of hydropower dams can significantly affect natural river systems as well as fish and wildlife populations. Furthermore, hydropower projects involve submergence causing the displacement of project area people. The rehabilitation of project affected people is also a major issue which is more pronounced in the case of storage-based hydropower projects, as was evident during the development of the Tehri dam. The project met with mass protests and public outcry on the issue of safety, environment and rehabilitation, resulting in unusual delays (e.g. the Tehri dam was commissioned more than 25 years after R&R was started).

Hydropower projects often require forest areas for their implementation and compensatory afforestation on non-forest lands. Progress of many projects has been affected on account of delay and non-clearance on environment and forest aspects.

These factors have resulted in negative public perception about hydropower projects resulting in sustained opposition to project construction in many cases often resulting in time and cost over-runs.

Market development

The power market development in India is still at a nascent stage. Though section 63 of the Electricity Act makes competitive bidding mandatory for all power procurement, hydropower projects are exempted under a sunset clause which expires by end 2015 (as per the June 2011 amendment to the Tariff Policy 2006). The deferment for hydro power is based on the recommendation of a Power Ministry taskforce, which cited high risks and uncertainties inherent to these projects as among the reasons why it is difficult for hydro projects to compete with thermal generation on long-term basis.

Furthermore, the current market structure does not allow hydropower developers to realise the potential benefit of meeting peak demand as the tariffs for both peak load and off-peak load are undifferentiated.

Though the Enquiry Committee constituted after the two major grid failures in the country on 30 and 31 July 2012 opined that "a review of UI mechanism should be carried out in view of its impact on recent grid disturbances. Frequency control through UI may be phased out in a timebound manner and generation reserves and ancillary services may be used for frequency control", an appropriate regulatory mechanism for implementation is yet to be set in place.

Rehabilitation of Project Affected People (PAP)

Deforestation

Protection of flora, fauna, forests, and Wildlife

Disaster potential in the event of earthquakes, reservoir induced seismicity, surplusing of reservoirs, etc.

Financing

Hydropower projects are capital-intensive and financing them, by finding an optimum balance between bankability and affordability, is often a challenge. Although the operating cost of hydro projects are minimal and the project life longer than thermal, there are multiple other factors that make hydropower difficult to finance.

Additionally, hydropower development needs long tenure debt (20 years or more) availability which is limited in Indian capital markets. The constrained financial situation of the distribution sector which is the end user of the power generated also often poses counterparty risks for developers and lenders. Furthermore, the technical challenges in hydropower development often results in time and cost overrun, posing additional risks for financiers.

High capital costs

- Capital cost of hydro projects ranges between 60 mn to 80 mn INR/ MW compared to 30 mn to 50 mn INR/ MW for thermal plants.
- Hydro projects require higher upfront costs to address greater complexities in design, engineering, environmental and social impact mitigation, etc.

Long construction period

- Most hydroprojects takes at least five to six years to construct which increases the interest during construction.
- Delay in cash inflows increase uncertainty and risks, resulting in higher risk premium on financing charges.

Hydropower plays an important role in all mature power markets. For example, hydro is the cheapest power source in the Nordic market. A low level in hydro reservoirs will mean producers use more expensive sources which will result in higher production costs. In the same manner, production costs will fall with more water in the reservoirs. Hence, Nordic power prices are highly dependent on both rainfall levels and access to nuclear power and the price of other sources, establishing the critical role of hydropower in power markets.

(Source: http://www.nordpoolspot.com)

Technical challenges

Techno economic viability of hydropower projects depends on the geology, topography, hydrology and accessibility of the project site. Even if extensive investigations using state-ofthe- art investigation and construction techniques are adopted, an element of uncertainty remains in the sub-surface geology. Geological surprises during actual construction cannot be ruled out. This unpredictable geology is more pronounced in the young fold Himalayas where most of the Indian hydropower potential resides. Such technical challenges add to construction risks.

During the 11th Plan capacity addition, multiple projects such as Tapovan Vishnugad (520 MW) in Uttarakhand, and Parbati St. II (800 MW) and Rampur (412 MW) in Himachal Pradesh have been delayed due to adverse technical challenges.

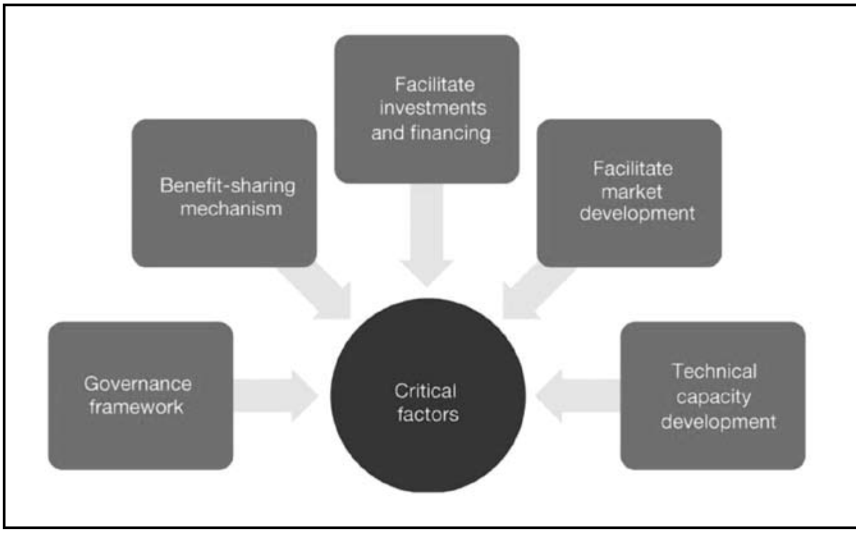
Enabling infrastructure

A number of hydropower projects are located in remote sites in states which do not have adequate demand for electricity. This creates the requirement for developing enabling infrastructure for power evacuation. The 'chicken neck' presents geographical constraints in developing requisite transmission infrastructure for hydropower evacuation from the north east.

There are certain other challenges for the coordinated development of the transmission network, e.g. identifying beneficiaries well in advance, developing excess evacuation capacity keeping in mind the future development of projects (especially where there are Right of Way (RoW) issues). Furthermore, the Plant Load Factor (PLF) for hydropower projects is typically less than 50%, as a result of which significant transmission capacity is under-utilised. All these result in higher transmission costs.

Hydropower projects also require the development of associated infrastructure such as roads and bridges in the area. Inclusion of the cost of development of such associated infrastructure increases the cost of power generated affecting project viability and sustainability. Lack of infrastructure such as schools, hospitals and difficult access to sites often become blocks to moving skilled manpower to difficult project sites.

The associated transmission system for evacuation of Kameng (600 MW) power is estimated at Rs 11,000 million, about 50% of the cost of the generation project.



Governance framework

Strengthening of governance in the natural resource sector is a key determinant for sustainable and inclusive growth. Thus, a nation needs to have an overarching policy framework, specific sector strategies, and clear and transparent processes for accelerating hydropower development. Standardised processes and efficient inter agency governmental coordination reduces unpredictability to create a better climate for potential investors.

Roadmap for accelerating responsible hydropower development

Action plan

Key enablers

Efficient coordination for implementation of policy goals and targets

Action plan

Ministries, departments and state governments need to work together collaboratively and efficiently, in a coordinated manner, to achieve policy goals and capacity addition targets. Alignment of processes, structures and institutional framework is necessary to achieve this.

For example, the National Solar Mission with a clearly articulated goal of 20 GW by 2020 helped get commitment from all stakeholders and ensured efficient inter departmental coordination for achievement of the well laid down goal.

Planning for integrated river basin development

- The government of India needs to ensure that inter-state agreements for water sharing must be in place to avoid disputes. A National River Authority of India may be constituted to improve river management, address inter-state disputes and for integrated river basin development.
- A basin wide hydrological simulation model needs to be developed under the guidance of Central Electricity Authority (CEA)/Central Water Commission (CWC) to understand the effects of one project on another in a cascade. This will reduce project risks, encourage planning and operation on a broader scale, and allow planners and developers to understand how changes to one project might affect others in the system.
- An appropriate planning forum needs to be constituted to bring all stakeholders (developers, state governments, etc.) together to discuss infrastructure needs and reach a consensus on how to proceed. Greater coordination in developing infrastructure such as access roads, transmission lines, etc. can help lower overall costs by allowing developers to pool costs. It will also reduce environmental impact.

Using mathematical modelling, a case study shows that optimising the operation of two adjacent projects on the Alaknanda as a cascade (rather than the planned individual operation) will be likely to increase annual energy output by 230 gWh, currently valued at around 15 million USD.

Project allocation procedures

Allocation of hydro sites to developers needs to be done in a fair and transparent manner, keeping in mind the optimal development of the river basin. Specifically, the state government needs to ensure project allocation on inter-state rivers in line with the CEA's/CWC's optimal development plan of the river basin.

- A comprehensive cost-benefit analysis between different project allocation models (e.g. MoU vs competitive bidding) needs to be carried out on a case-to-case basis based on project specific issues. Further, the project allocation model needs to give due weightage to the financial capacity, technical capacity as well as credibility of developers.

Institutional framework

The current institutional framework and organisation of concerned institutions for hydropower development at the state level needs to be reviewed.

The objective will be to ensure that the government plays a key role in planning, procuring and regulating the assets created. Also, whenever necessary, based on project-specific circumstances, the government needs to fully or partially own the asset and play a role in project development. Private players, however, should also be provided requisite freedom to develop, finance, build and operate the assets.

Benefit-sharing framework

Mitigation of social and environmental risks also plays a critical role in the development of hydropower projects. Since the benefits and negative effects of natural resource development are often unevenly distributed, benefit-sharing mechanisms and mitigation measures are crucial for sustainability and stability in development. Benefit-sharing is a commitment by the government and the developer to share the monetary and nonmonetary returns with stakeholders. An appropriate benefit-sharing mechanism ensures social stability and also aligns a country's national strategy with the local needs.

Focus on responsible development

Social and environmental impact assessments need to be given due importance, instead of treating them as mere legal formalities.

The process needs to be participatory and transparent.

The overarching principle for socially and environmentally responsible hydropower development needs to be that the project affected population be the first beneficiary of the project.

Public private people participation

Involvement of project affected persons (PAPs), and joint consultation processes between developer, government and PAPs need to be carried out to smoothen out differences and get legal and social consent. Such involvement and joint consultation processes are necessary to address immediate problems and legitimise decisions.

- Project developers need to be mandated to open technical training centres in the neighbourhood of the project. This will help developers gain public acceptance and get skilled labour while local residents get employment opportunities. Similarly, developers can open clinics and health centres, schools, etc. for local residents with minor impact on project cost.

Benefit-sharing with PAPs

A structured mechanism needs to be developed for balancing benefits from hydropower projects and transferring economic rents from projects to the government which should ultimately be passed on to affected stakeholders.

The mechanism should find an optimal balance, to the consensus and benefit of all stakeholder, between modalities:

- Revenue sharing
- Local development funds
- Ownership structure
- Taxation levels
- Preferential electricity rates, etc.

Facilitating investments and financing

In order to attract investments for capital-intensive hydropower projects, it is necessary to address the concerns of developers, consumers as well as PAPs. To broaden investment avenues, the government needs to facilitate optimum risk allocation and often, on a casespecific basis, better upside to developers. Furthermore, the PPP framework needs to be designed considering key factors needed to develop commercial hydropower projects such as capital, capability and credibility.

Streamlining clearance processes

Appropriate institutional mechanisms need to be set up by each state with a clear mandate to speed up clearances and eliminate duplicity of clearances. Specific timelines to award all statutory and non-statutory clearances to a project at both central and state levels need to be fixed, along with accountability for delays. Specific timelines for the concessionaire to initiate, execute and commission the project must also be decided.

State governments may set up 'investment boards' to facilitate private investments across multiple infrastructure sectors including hydropower. These boards will be expected to address issues related to interdepartmental coordination and avoidable delays in according approvals and clearances.

Streamlining land acquisition process and modalities

Consultation between central and state governments needs to be taken up to bring in required changes in the new land acquisition law in order to enable speedier project implementation by addressing the issues and concerns of developers while ensuring that the rights and interests of the land-losers are protected.

Evacuation infrastructure

- Dedicated transmission infrastructure may be created for evacuation of power from the north east. For example, Green Energy corridor for the evacuation of renewable energy projects from states such as Rajasthan and Tamil Nadu is being constructed.
- Building pooling sub-stations in locations having large concentration of hydro resources is an efficient option which help developers reduce the project cost on account of last

mile connectivity

- For evacuation of energy from the plant bus-bar to the Central Transmission Utility (CTU)/ State Transmission Utility (STU) interface, multiple options can be evaluated, based on the specific circumstances of the project:

Options

Cost entirely borne by the developer but recovered through generation revenue

Developer and concerned utility shares the cost in a specified ratio

Cost entirely borne by the utility but recovered / socialised through revenue

Financing through a 'hydropower development fund'

Underlying risks/issues

- Increase in project cost
- Regulatory risk for developers – approval on total investment, connectivity with CTU/STU network
- Increase in project cost
- Basis for arriving at an acceptable ratio
- Regulatory risk on account of approval on investment
- Impact on the overall transmission tariff
- Regulatory risk on account of approval on investment
- Availability of funds, as part of the cost needs to be refinanced through interest-free loan or concessional debt support from such fund

Other associated infrastructure

Other associated infrastructure needs to be developed to facilitate project implementation in a costeffective manner. Since development of such associated infrastructure spurs economic activities, the state government must partially bear the costs of development. The state governments must effectively channelize local development funds, upfront premium, etc., received from developers to invest in such associated infrastructure.

Fiscal incentives

Favourable tax treatment, especially at the early stage of projects, reduces project cost and helps projects secure cheaper financing. This is also important for projects that have predominant local supply, as cascading taxes only lead to higher tariffs. In addition, the government may offer tax credits (as in the US) or tax holiday (as in Laos) to facilitate investments. Thus the government of India needs to continue with tax holidays and the exemption of import tariffs for projects greater than 500 MW capacity.

Innovative financial products

- Capital markets need to be deepened to help provide long-term debt financing for the capital-intensive nature and high gestation periods of hydropower projects. Initiatives such as India Infrastructure Finance Company Ltd. (IIFCL) for infrastructure lending have been taken. The government of India needs to also encourage suitable innovative products. E.g. tax-exempt bonds focussed on the hydropower sector
- Given the large-scale requirements of infrastructure and hydropower development, many more initiatives are required to channelise long tenure funding (from pension funds, banks, etc.) to these sectors. The government of India may create a special hydropower financing scheme (e.g. the Accelerated Generation and Supply Programme to state utilities) providing loans to power utilities at a subsidised rate of interest.
- Multi-lateral institutions and green funds have, in recent times, shown some appetite to fund both public and private sector hydropower investments and can be a good source for investors if a sound business case and risk mitigation mechanism can be demonstrated.

Facilitate market development

Policies targetted at market development play a crucial role in channelizing investments and private sector participation in hydropower development like any other sector. The private sector recognises the enormous potential of the hydropower sector in India. Yet, more substantive and enabling changes by the government in the policy and regulatory framework are needed to expedite the initiative.

Development models and ownership structures

A unified framework needs to be adopted with instruments standardising the fiscal and revenue-sharing policies for the selection of technically and financially qualified private developers with sound corporate governance practices.

Minimisation or optimum allocation of risks and associated costs between all stakeholders involved is one of the critical success factors for all successful infrastructure projects across the world. Thus, the options for ownership structures need to take into account risk allocations and ensure that the risk burden does not get shifted heavily towards any of the major stakeholders involved, i.e. the government, the developer, the off-taker, or the project affected population.

Hydropower purchase obligations

The government needs to consider making it mandatory for power distribution utilities to purchase a fixed amount of hydropower. Such hydropower purchase obligations or HPOs provide assurance to developers by guaranteeing the purchase of electricity and make projects much more bankable.

Such a move will, however, require amendments in the Electricity Act 2003 and subsequent changes in the National Tariff Policy.

Differential tariff structure

Tariff comparison needs to be done on the basis of the quality of energy supplied, reflected by the position hydropower occupies in the load duration curve. Currently the tariffs for both peak and off-peak loads are the same. Regulators need to differentiate between them and set differential tariffs which benefit hydropower developers.

Most hydro plants are intended to operate in the medium to upper range of the load curve while thermal plants operate near the base load. This makes it misleading to compare generation costs between the two as the value of peak generation is significantly higher than the base load generation.

Developing market for ancillary services

A robust commercial mechanism based on an enabling regulatory framework need to be developed to encourage ancillary services support across the national grid. This will help maintain power quality, reliability and security of the grid. Hydropower operators will play a key role in providing such ancillary services given their black start characteristics.

Technical capacity development

Hydropower development involves significant challenges on account of terrain and geology. The solution to such challenges requires capacity-building of the agencies involved as well as the introduction of modern techniques and technologies. The capacity-building initiative will need to appreciate the technical challenges specific to hydropower and equip the concerned institutions with tools, training and systems to help address them.

State-of-the-art investigation and construction techniques

- Detailed geological and seismic mapping of specific potential areas needs to be carried out involving the Geological Survey of India. Similarly reliable hydrological data mapping needs to be done involving the National Hydrological Institute.
- Hydrological yield estimation can be vastly improved through the coordinated collection of hydrological and meteorological data and dissemination of that data to developers. Similarly, centrally conducted studies can estimate the effects of climate change, an important aspect that individual developers are likely to ignore.

- An upstream storage facility in each river basin can, by regulating overall flow, reduce silt loads downstream as well as lead to greater energy output.
- Flood forecasting and warning system will be useful to ensure that all downstream power projects and local towns and villages receive adequate warning in the event of a flood or upstream dam break. Developing such a system is beyond the capacity of any individual developer and needs to be coordinated by state and central agencies.

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Mahadeva Srinivasan

Low Energy Nuclear Reactions (LENR)

Emerging Clean and Compact Source of Nuclear Energy

Introduction

Any reference to "Nuclear Energy", generally brings to mind visions of uranium fission nuclear power plants and perhaps futuristic thermonuclear fusion reactors. Indeed, fission based nuclear power forms the basis of the Three Stage Nuclear Power program of India.

In this article we discuss a drastically new route to nuclear energy based on "Low Energy Nuclear Reactions" or LENR for short, which is not mentioned in any textbook of physics so far, in spite of the fact that the basic concept of LENR has been around for over a quarter century. This class of nuclear reactions occur when certain metals such as palladium, titanium, nickel, lithium etc. are impregnated with normal hydrogen or its heavier isotope known as deuterium, and appropriately "triggered" to initiate the onset of nuclear reactions. In such metal-hydrogen or metal-deuterium systems, two types of nuclear reactions are possible: If a nuclear reaction occurs between a pair of deuterons embedded within the solid metallic lattice, it is characterized as a "fusion" reaction. If however a nuclear reaction occurs between a proton (nucleus of the hydrogen atom) or deuteron on the one hand and a nucleus of the "host metal" atom such as Pd or Ni etc., then we refer such reactions as "transmutation reactions".

According to physics text books such nuclear reactions cannot and should not happen at normal or "room" temperatures because of the so called "Coulomb barrier", the electrostatic repulsion between the positively charged nuclear particles involved. The protons (or deuterons) would have to have high kinetic energies to be able to overcome the Coulomb repulsion and succeed in colliding with the target nucleus before any type of nuclear reaction can take place. As there is no obvious mechanism to explain the occurrence of nuclear reactions inside a crystal lattice, the purists vehemently dismissed all claims of "cold nuclear reactions" as unacceptable! But, in science one has to trust confirmed experimental evidences and be prepared to re-examine the long held theories. It is a commonly held concept that chemical energies being orders of magnitude smaller than nuclear binding forces, the chemical environment cannot have any influence on the nuclear processes occurring within the solid lattice. Clearly this long held "belief" is being challenged by the new experimental findings in the LENR field over the last couple of decades, suggesting that we are witnessing a new phenomenon, indeed a paradigm shift in Nuclear Science.

Origins of LENR:

The origin of the Cold Fusion story goes back to 1989 when two chemistry professors, Martin Fleischmann and Stanley Pons of the University of Utah, announced that they had accidentally stumbled upon evidence for the occurrence of nuclear fusion reactions between a pair of deuterons (d) while conducting a simple electrolysis experiment in a "test tube" wherein a Pd rod was used as cathode submerged in an electrolytic solution of lithium deuteroxide (LiOD). They claimed to have observed sporadic episodes of enormous heat release that they said could only be explained on the basis of nuclear fusion reactions occurring between deuterons entrenched inside the Pd rod [1]. Thus was born the phenomenon which came to be known as "Cold Fusion" and which was announced at a press conference convened at Salt Lake City on March 23rd 1989. This "historic" press conference however unleashed one of the most intense controversies in Physics! Interestingly researchers at the Bhabha Atomic Research Centre (BARC) did carry out very creditable research on this topic in the early 1990s and were amongst the first groups in the world to have confirmed [2,3] the nuclear nature of the "cold fusion" phenomenon; but unfortunately research in this field was shut down in BARC in the mid-90s under global peer pressure.

The field has however been kept alive by about 500 dedicated researchers worldwide with 19 "International Conferences on Cold

Fusion" (ICCF series) having been held to date, with the latest, ICCF 19 [4], having been convened at Padua in Italy during April 2015. This author has attended most of the above conferences apart from personally conducting ICCF 16 [5] at Chennai in February 2011. Most recently he had the privilege to co-guest edit a special section on LENR in the prestigious journal "Current Science" [6] published by the Indian Academy of Sciences. The online version of this issue is available at reference [7].

It must however be conceded that even two decades after the Fleischman-Pons announcement and the painstaking research of a number of experimental teams, no group had succeeded in coming up with a device that showed "excess heat" production at kW levels, to attract the attention of industry.

Enter Andrea Rossi: The Emergence of the Ni-H Reactor and Resurgence of LENR:

We now fast forward to the year 2010 when we first learnt through a news item which appeared in the World Intellectual Property Organization's newsletter that a patent application [8] had been filed by an Italian-American engineer-inventor by the name of Andrea Rossi claiming that he had invented a table top Nickel-Hydrogen fusion reactor producing kW levels of power. To be honest even those of us who had been following the progress of LENR field closely for over two decades, found it very difficult to believe Rossi's patent disclosures at first. We too initially dismissed the news lightly as yet another "tall claim"!

It was only on 14th January 2011 when Rossi demonstrated a 10 kWth Ni-H reactor at the University of Bologna in the presence of 50 scientists and engineers that the world woke up to the reality of a breakthrough having occurred in the field. Rossi followed this with a demo of a 1 MWth reactor in October 2011, again at the University of Bologna. The 1 MWth water cooled reactor was composed of over a 100 of the basic 10 kWth modules connected in a series-parallel fashion. Rossi named his invention as Energy Catalyzer or "E-cat" for short. Interested readers may Google on "E-cat" or "Andrea Rossi" or "Ni-H Reactor" or even LENR to know more. A book published in 2014 titled "An Impossible Invention" by science journalist Mats Lewan [9] of the Swedish technology watch-dog newspaper NyTeknik gives a fascinating account of the personal story behind Rossi's E-cat invention.

Dozens of websites have since cropped up to follow the rapid progress of the LENR field in general and the E-cat in particular. The website www.e-catworld.com for example gives a comprehensive overview of these developments under headings such as "What is LENR ?", "What is the E-cat ?, "Why I believe in the E-cat?", "Third Party E-cat Tests", "LENR History (Timeline)", "LENR Organizations" and even an "LENR Knowledge base". This site also gives daily updates on the latest news pertaining to the LENR field.

Brief Description of the Basic E-Cat Module:

Rossi's basic E-cat module comprises of a sealed stainless steel reactor tube a few millimetres in diameter inside which a gram of nickel powder is filled along with hydrogen gas under pressure. The fuel also contains a small quantity of a "proprietary catalyst" powder, the nature of which has not been revealed by Rossi. The reactor tube is heated to a temperature of 450 C (Curie temperature) by means of electrical heating resistors and is surrounded by a cooling coil through which water as coolant flows to remove the generated heat. The 10 kWth device was demonstrated on 14th January 2011. The device was covered in aluminium foil to prevent onlookers from learning too many details about his invention. The reactor generated several kilowatts of power, although the power input used for heating the fuel powder initially was only about 400 watts.

Rossi demonstrated the 1 MWth reactor in October 2011. This reactor is made up of over 100 of the basic 10 kWth modules and is housed inside a standard shipping container for convenience of shipping to a customer. An upgraded version of his 1 MWth reactor is currently undergoing a 400 day endurance test at the premises of Rossi's first customer, generating low temperature steam. It is learnt that this reactor is owned by Rossi's company (Leanardo Corporation) while the generated steam is reportedly "sold" to the customer for use as industrial process heat. As already mentioned the "e-catworld.com" site has a section titled "Rossi's 1 MW plant updates" which gives very informative daily bulletins on the performance of this plant. One of the important bits of information we learn from this is that he has often operated the device under "self-sustaining conditions" for short durations. Rossi appears to have already obtained the requisite safety and commercial licensing certificates, and subject to the 400 day test concluding "satisfactorily" in February 2016, he has indicated [10] that necessary steps for manufacturing and marketing of the 1 MWth industrial version would be set in motion in March 2016. The mass produced version of "E-cat the new fire", is expected to be more compact, occupying a volume of just 4 m3 .

Industrial Heat LLC

In 2012 Andrea Rossi sold the rights of his technology to a financier by the name of Thomas Darden, CEO of Chirokee Investment Partners who in turn has set up a new company called Industrial Heat LLC to commercialize E-cat technology. A press release [11] issued by Industrial Heat in January 2014 states:

"Industrial Heat, LLC announced today that it has acquired the rights to Andrea Rossi's Italian low energy nuclear reaction (LENR) technology, the Energy Catalyzer (E-Cat). A primary goal of the company is to make the technology widely available, because of its potential impact on air pollution and carbon dioxide emissions from burning fossil fuels and biomass. "The world needs a new, clean and efficient energy source. Such a technology would raise the standard of living in developing countries and reduce the environmental impact of producing energy," said JT Vaughn speaking on behalf of Industrial Heat (IH). Mr. Vaughn confirmed IH acquired the intellectual property and licensing rights to Rossi's LENR device after an independent committee of European scientists conducted two multi-day tests at Rossi's facilities in Italy.

IH has set up a new 20,000 sq.ft testing laboratory in Cary, North Carolina for testing Metal Hydride reactor prototypes and also carrying out independent studies relating to applications of E-Cat technology. It is significant that a UK based fund management company called "Woodford Funds" has recently invested heavily in Industrial Heat LLC after carrying out a two and half year long "due diligence exercise", indicating the growing confidence in the commercial prospects of LENR [12].

Birth of the "Hot Cat":

In 2013 Rossi came up with an advanced high temperature version of his E-Cat which he called the "Hot Cat". An improved version of the Hot Cat module fabricated by Industrial Heat LLC was handed over to a group of seven professors (five from Sweden and two from Italy) to carry out an "Independent third party" test in early 2014. It is noteworthy that this test which was conducted in an Industrial Laboratory in the city of Lugano in Switzerland was financed by Elforsk, the R & D wing of the Swedish Electricity Generation Companies. The results of this 32 day performance test conducted on the Hot Cat module during Feb-March 2014 was released in October 2014 and deposited in the Cornell University archives [13].

The Hot Cat deployed in this test was basically a 2 cm dia x 20 cm long alumina cylinder with V shaped ridges cut on the outer surface to facilitate convective cooling [13]. The fuel, about a gram in weight, and made of Ni powder admixed with 10% by weight of Lithium Aluminum Hydride (LiAlH4), was inserted into the alumina reactor tube which was then sealed off by means of end plugs. To trigger the onset of the nuclear reactions the temperature of the reactor tube was slowly raised by powering the solenoidal electrical heating coil wound around it. The input heating power fed into the system was in the range of 800 to 900 watts. As there was no provision for cooling the reactor other than through radiation and convection to the ambient air, the temperature of the alumina tube rose to red hot conditions, estimated to be in the 1200 to 1300 degrees C. The power dissipated from the reactor under steady state conditions was measured using a pair of infra-red cameras which had been appropriately calibrated. Full details of the experimental procedure adopted and the pyrometric measurements carried out are documented in the Luagno Test Report [13]. The output to input power ratio defined as the Coefficient of Performance (COP) was in the range of 2.5 to 3.5 during the test run. Incidentally it turned out that LiAlH4 was the secret additive that Rossi did not divulge earlier but it appears to have been inadvertently revealed by the professors who wrote the final Lugano test report. The primary role of this "hydrogen storage compound" is to release hydrogen gas into the reactor tube when heated, although it now appears that the Li in LiAlH4 may also be involved in the nuclear processes.

Throughout the duration of the test an expert specialized in radiation monitoring measurements who had kept a careful vigil looking out for emission of neutrons or other harmful radiations from the reactor tube, has certified in the final test report that there was no detectable radiation emission. Also the spent fuel did not show any remnant radioactivity after the run. These measurements confirm once again the "clean" nature of the LENR phenomenon in general and the E-Cat in particular as has been repeatedly stressed in this article.

On completion of the 32 day test run, the spent fuel powder was extracted and subjected to detailed chemical and mass spectrometric analysis. A significant finding [13] of the Lugano test, besides confirmation of excess power generation, was the observation that the isotopic composition of the nickel and lithium contained in the fuel mixture had substantially changed from their initial natural isotopic distributions. In addition, many new elements not present in the virgin fuel mixture are also reported to have been detected. These results indicate that the excess power production in Rossi's Ni-H E-Cat reactor is attributable to nuclear transmutation reactions between the protons from hydrogen and the nuclei of Ni and Li. (There are indeed some speculations that the observed preferential depletion of Li7 in comparison to Li6 could be attributed to formation of Li8 which then could have emitted a beta particle and split to yield two atoms of neutral He4)

As already mentioned the occurrence of nuclear transmutation reactions in a variety of LENR devices has been observed by many researchers in other laboratories also. Readers who wish to know more about LENR transmutation reactions may like to peruse our review paper [14] on the topic .

Replication Attempts of the Hot cat:

The availability of the Lugano test report in the public domain in October 2014 has triggered a series of attempts by researchers in different parts of the world to try and replicate the Hot Cat excess heat and transmutation results. The revelation that Rossi's "secret sauce" was in fact LiAlH4, has served as an incentive to embark on replication attempts. Andre Parkhamov of Russia was the first to report that he had succeeded in replicating the basic findings of the Lugano report in Jan. 2015 [15]. A group from the Chinese Institute of Atomic Energy in Beijing has published results of a 96 hour long replication test carried out in May 2015 [16]. Since then a second group from Moscow [17] has also reported success in replicating the Hot Cat-Parkhamov results and most recently a team from Kazakhstan [18] has announced observing excess heat in a similar Ni-H system.

Other Companies on the Commercial LENR Path:

Besides Andrea Rossi there are other companies who are pursuing development of commercial LENR based power sources. Among these the foremost is Berkley based Brillouin Energy Corporation (BEC) [19] founded by Dr. Robert Godes. Although BEC, like Rossi, also uses nickel as catalyst along with very small amounts of hydrogen gas, Godes claims his proprietary "Controlled Electron Capture Reaction" (CECR) process results in generation of He4 as the end product following a three step fusion process involving protons (hydrogen nuclei), rather than transmutation reactions. The Hydrogen Hot Tube (HHT) boiler system developed by Brillouin is "designed to operate at temperatures of between 500°C to 700°C and is ideally suited to meeting industry's demands for clean, cheap modular heat at the point of demand". At an event held on 2nd Nov 2015 at Capitol Hill, Washington DC, BEC showcased their modules to representatives of the US Congress. BEC however does not plan to get involved in any manufacture or marketing of products but rather their business model is based on licensing their Intellectual Property (IP).

Sensing the steady movement toward commercialization of

LENR based technologies, a pair of forward looking researchers/ engineers has set up an "LENR Industrial Association" [20] to help advance the field and have sought membership of the "United States Energy Association". "LENRIA is a new not-for-profit organization to advocate both scientific study and, especially, commercial advancement of the field. There shall be various member services to dues-paying individuals and companies. The Association has been set up in the U.S. However it shall serve the global community of involved and interested persons and organizations."

Need for Basic Research

The problem with LENR however is that the exact theoretical basis underlying these nuclear reactions has still not been fully understood. As already noted LENR defies text book nuclear physics. It is paradoxical and indeed even embarrassing that a new technology is poised to enter the market while the science behind the invention is still a mystery. This is where basic research in this field in academic institutions is very vital. Internationally, at least three dedicated research centres have cropped up, two in the USA and one in Japan.

Thanks to a generous donation by billionaire Sidney Kimmel, "The Sidney Kimmel Institute of Nuclear Renaissance" (SKINR) [21] was established in 2012 at the University of Missouri to get to the bottom of the science behind LENR. In January 2015 the Texas Tech University (TTU) at Lubbock, Texas announced the setting up of the "Center for Emerging Energy Sciences" (CEES) [22] to unearth the physics behind the "Anomalous Heat Effect". Prof. Robert Duncan, presently Vice President for Research at TTU who has emerged as a key player in the US, pushing for support for LENR studies, was instrumental for the establishment of both SKINR and CEES.

On 30th March 2015, Clean Planet Inc. and Tohoku University announced the launching of the "Clean Energy [LENR] Research Lab" [23]. This Center will carry out R & D on energy generation and nuclear waste decontamination based on LENR. This is the first official research center created for Condensed Matter Nuclear Science and its applications in Japan. The Japanese government has provided part financial support for this Center. The main scientist behind this effort is Prof. Yasuhiro Iwamura, formerly of Mitsubishi Heavy Industries Labs.

Both Mitsubishi and Toyota Industries have been carrying out LENR research for the past two decades. In fact even today the International Society for Condensed Matter Nuclear Science (ISCMNS) [24] awards a "Toyoda Medal" for the best research paper in this field, using a donation given by the family of the late Minoru Toyoda, founder Chairman of Toyota Corporation. We have just learnt that Nissan too has recently entered the LENR fray.

Not many are aware that the US Government's "National Aeronautics and Space Administration" (NASA) is seriously looking into the feasibility of deploying LENR based power packs for powering space missions [25]. Most recently the well-known European Aircraft manufacturer, Airbus Industries has revealed their strong interest in LENR. In fact during Oct. 15th-16th, 2015 Airbus hosted [26] the "11th International Workshop on Anomalies in Hydrogen Loaded Metals" at their premises in Toulouse in France. Research in LENR is being pursued in a large number of academic institutions and private corporations all over the world. A comprehensive compilation of these centers is available in Ref. [27]. This list however does not include some of the well-known "deep pockets" of Silicon Valley in the USA who are very quietly and confidentially carrying out exploratory experimental investigations of LENR configurations, keeping an eye on potential commercial payoffs.

Revival of Research on LENR in India:

No discussion of the origin and progress of the field of LENR would be complete without a reference to the very unfortunate role played by the committee appointed by the US Department of Energy [28] in 1989 to investigate the validity of the cold fusion claims of Fleischmann & Pons. The hasty and erroneous conclusion they arrived at, namely that there was no evidence to substantiate the claims of the two Utah professors, dealt a premature "death blow" to the field of cold fusion/LENR the world over, including

India. Mankind has lost much precious time in bringing to fruition a potentially clean and inexpensive source of Energy due to the short sightedness of the US DOE.

It is in this backdrop that the publication of a special section on LENR by the Journal "Current Science" brought out by the Indian Academy of Sciences in its Feb 25th 2015 issue, carrying over 30 peer reviewed papers, needs to be viewed. The publication of this issue, along with the renewed global interest in LENR following the advent of the Rossi reactor has certainly helped create a favourable climate for revival of LENR research in the country. Thanks to the initiative of the Minister for Power, Mr. Piyush Goyal in November 2014, a high level Advisory Group under the stewardship of former Chairman of AEC Dr. Anil Kakodkar was formed to help revive LENR research in India. This group held its 1st meeting at the National Institute of Advanced Studies (NIAS) Bengaluru on 8th April 2015 with funding provided by the Ministry of New and Renewable Energy (MNRE). Following this meeting, research in this field is in the process of being revived in at least half a dozen academic Institutions and laboratories in India. A core group comprising distinguished scientists such as Dr. Srikumar Banerjee, former Chairman, AEC, Dr. Baldev Raj, presently Director of NIAS and others is spearheading this revival effort. The goal of the Indian effort is not only to try and obtain independent confirmation of the heat generation in Ni-H systems as reported by many experimental groups who have claimed successfully replicating the Hot Cat, but also to carry out basic studies in the LENR field.

Prognosis in the Indian context:

Decentralized "off-grid" power is ideal for rural India. The advantages and benefits of captive locally sourced power have already been appreciated in the context of solar/renewable energy technologies. LENR based power packs would have all the advantages of solar and nuclear power on the one hand without their respective disadvantages, namely there is no need for vast tracts of land nor availability of sunshine/wind as in the case of solar/wind energy and no radioactive waste and radiation hazards as in present fission nuclear power. The small size and simple technology makes LENR ideally suited for Indian Industry to quickly absorb the technology and to innovate improvements. One such 100 kWe LENR generator located in the outskirts of each village and powering a local micro-grid can work wonders, not only to light up LED lamps in every village home, but also to help produce clean drinking water for the community. One can perhaps even envision tractors being powered by a LENR source in the not too distant future. (One company in Switzerland is already designing LENR-powered cars – see www.lenr-cars.com.)

The success of LENR obviously depends entirely on mass production. Taking the example of the 1 MWth plant being tested by Rossi's company right now (see www.e-cat.com), in principle it can be coupled to an electricity generator through a Stirling Engine or micro-turbine to generate 300 kWe of electricity. A single factory producing 40,000 such 300 kWe LENR gensets per annum has the potential of adding the equivalent of one Kudankulam type 1000 MWe nuclear station capacity every month! It may be pointed out that there are already many automobile factories in India which are producing similar numbers of cars/trucks annually. Of course the 1 MWth plant under development presently is only the "Model T Ford" of the LENR era. We have a long way to go from prototype to factory-finished product, but these are all challenges which the mature Indian Industry can handle.

In this writer's assessment, LENR technology could well make its first debut in the country through the private sector route during 2016/17. Informal exploratory discussions with a few multibillion dollar Indian MNCs have indicated industry's readiness to evaluate the potential of this emerging technology, provided a foreign player who has this technology with patent protection comes up with an attractive proposal. Given the great emphasis that the present government in Delhi is placing on reduction of greenhouse gas emissions and the "Make in India" campaign, we have every reason to expect government support and encouragement for tie ups of Indian industries with foreign players who are willing to make LENR technology available to us.

The technology involved in LENR power sources is clearly very simple. In its current version the basic 10 kWth module involves only a 20 cm long tube with a few grams of Ni nano powder along with some additives. There is nothing in it that is complicated or expensive. Indian scientists are fully capable of mastering the technology in a period of a few years. In principle a public-private initiative should be able to come up with a prototype based on the information already available in the public domain.

However, one problem that is likely to arise with indigenously developed technology could be intellectual property issues, unless the indigenous model is so radically new and original that it cannot be challenged in a court of law for patent infringement. The indigenous developer would have to protect his invention through international patents, considering that patent wars in the LENR field have already begun in Europe. Thus it appears that the first entry of LENR into India will most likely be through tie ups between a foreign player who possesses the requisite patent protected technology and an Indian MNC which has the expertise and experience in manufacture and marketing.

For the future however there is plenty of scope for innovation and invention of new configurations. The LENR reactor of the year 2025 will most certainly look very different from Rossi's present version of the Hot Cat or Brillouin's HHT boiler. Under these conditions the question arises as to what is the role of the various stake holder agencies in India? As of today the private sector is unwilling to get involved in LENR research saying basic research is not their job. In this context the recent recommendations of the "NITI Aayog Panel on Innovation" [29] that the private sector must be encouraged to fund R&D through tax breaks etc. is a most welcome step. So far no government lab has jumped into the LENR fray in earnest. Ideally CSIR should have taken a leading role is spearheading research in this field as eventually the technology is to be adopted by Indian Industry. The academic community in India is good at carrying out basic studies and publishing papers but have very little track record in coming up with prototypes ready for manufacture and marketing. The ideal situation would perhaps be to incubate a collaboration between Industry and IITs/Universities.

In this context the recent news report [30] that the Japanese government has adopted precisely such an approach to fund LENR research is noteworthy. Their effort is to be coordinated through the New Energy and Industrial Technology Development Organization (NEDO) as a leading initiative of Eco-energy innovation. The nano-metal hydrogen energy NEDO-MHE project commenced on 26th Oct 2015 and comprises of six institutions - two companies: Technova and Nissan; and Four Universities: Tohoku, Kyushu, Nagoya and Kobe.

It is hoped that this article would help initiate a healthy debate in the country on how to "Make LENR happen in India" since India needs this potentially game changing and disruptive clean energy technology as early as possible, if the government's commitment to the international community that India will cut carbon emissions substantially before 2030 is to be honoured.

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Krishna Vishwanath, Krishan Kumar Chopra

Gas Hydrate Exploration in India

A Futuristic Energy Resource

What are gas Hydrates?

Gas, mainly methane, enclosed in a lattice of ice is Gas Hydrate. Theoretically, 1 meter cube of gas hydrate can generate on an average of 164 meter cube of gas and 0.8 meter cubic of water. Methane Hydrate is environment dependent and requires a host of conditions to form and be stable. Disturbing these conditions will cause it to dissociate into water and methane gas. A key area of basic hydrate research is the precise description of these conditions so that the potential for occurrence of hydrates in various localities can be adequately predicted and the response of that hydrate to intentional, unintentional, and/or natural changes in conditions can be assessed.

In naturally occurring methane hydrate the fundamental controls on hydrate formation and stability are (1) adequate supplies of water and methane (2) suitable temperatures and pressures and (3) geochemical conditions.

Global Scenario - Gas hydrate field projects

A brief review of the international activities for exploration and exploitation of gas hydrates shows that India could play a lead role in this area.

Exploration

Gas Hydrate exploration is still at the Research and Development Stage throughout the world. Various International Projects are at different stages of progress. Some of these are listed as follows:

- USA: USDOE's "Methane Hydrate Research and Development Program"

- Japan: "National R&D Program for Methane Hydrate Resources in Japan" - Ministry of International Trade and Industry (the current Ministry of Economy, Trade, and Industry – METI), with the Japan National Oil Corporation (the current Japan Oil, Gas and Metals Corporation)
- India: "National Gas Hydrate Program" - Ministry of Petroleum and Natural Gas, with the Directorate General of Hydrocarbons (DGH), ONGC, GAIL, OIL, IOC, GSI, NIO, NIOT & NGRI
- Canada: "New Canadian Gas Hydrate Research Program" – Natural Resources Canada, Earth Sciences Sector (Geological Survey of Canada)
- China: "China National Gas Hydrate Program" – the China Geological Survey through the Guangzhou Marine Geologic Survey of China
- Korea: "Gas Hydrate R&D Organization" – Ministry of Science and Technology (MOST), with Korea Institute of Geoscience and Mineral Resources (KIGAM) and Korea National Oil Corporation (KNOC)
- Other programs: Russia, Germany, Taiwan, Great Britain, France, Norway, Mexico, Chile, Columbia, Brazil, New Zeland

Production

Producing methane from gas hydrate has been a topic of research globally. It is known that gas hydrate is stable under specific temperature and pressure regimes. Destabilization of the conditions that keep gas hydrate stable would result in the dissociation of methane. Some of the noteworthy achievements on the international scenario, particularly with reference to the exploitation of methane from gas hydrates are as follows:

The First Production Testing - Mallik was carried out in 2002 and the main process used for liberating methane from gas hydrate was the thermal method under a collaborative research in which JOGMEC, GSC, DOE, USGS, ONGC participated. Dubbed the "hot water circulation method" – a type of heating method – was selected for producing methane gas from methane hydrate. In this method, hot water heated up to 80° C was fed into test wells to heat methane hydrate layers existing approximately 1,100 m below ground so that methane hydrate can be dissociated. The temperature of hot water was estimated to be around 50° C when it came near the methane hydrate layers.

The Second Production Testing - Mallik: (MH21) was carried out the at the Mallik site in the Mackenzie Delta in Northeast Territories of Canada, where they tested the hot water circulation method in 2002.

This testing was conducted twice, once in 2007 and again in 2008. The tests conducted in 2007 and 2008 are called the First Winter Test and the Second Winter Test.

In the First Winter Test in 2007, methane gas was collected from methane hydrate being dissociated with the depressurization method. However, since methane hydrate layers are unconsolidated sediments, sand was also collected (sand production) along with methane gas and water, and the sand stalled the pump. As a result, the test had to stop 12.5 hours after it began. Although the test was terminated within a very short time, it was the first time in the world that methane gas had ever been successfully collected from methane hydrate layers using the depressurization method.

A second attempt was made in 2008 after developing measures to prevent sand production (sanding), MH21 reattempted the depressurization method-based production test. This was called the Second Winter Test in 2008. In this test, MH21 achieved continuous production over approximately 5.5 days. The amount of methane gas produced during the test period was approximately 13,000 m^3, much larger than the approximately 470 m^3 in the previous. This demonstrated that the depressurization method is more effective for producing methane hydrate.

In December 2011 Iġnik Sikumi field trial in the Prudoe Bay area of North Slope Alaska was initiated by a consortium of Conoco Phillips, Japan Oil, Gas, and Metals National Corporation (JOGMEC) and the US Department of Energy (USDOE) completed the first field program designed to investigate the potential for CO2-CH4 exchange in naturally occurring methane hydrate reservoir. The test was designed as a 'huff and puff' style where one single well was used first for injection then followed with production. The target for the test was a 10 m sand zone estimated to contain 70-80% hydrate saturation. For 13 days, between February 15 and February 28, 2012 over 5600 m3 of a CO2 mixture (77mol% N2, 23 mol% CO2) were injected in the hydrate-bearing interval. Injectivity was maintained over this period. Following injection, flow back commenced over a 30 day period. The well Ignik Sikumi#1 produced for approximately 30 days and the production rates achieved was as high as 1,75,000 scf/d and a total of about 8,37,000 scf of methane was produced over the period.

M/s JOGMEC, Japan, conducted the first ever marine test from the 06th March 2013 to the 12th March 2013. The intention of the production trial was to achieve continuous production for 2-weeks. However, the production testing was closed due to the following reasons:

i. Trouble from hydraulic pump
ii. Increasing sand excretion
iii. Inclement weather forecast
iv. Signs of hydrate dissociation at the monitoring well about 20m apart.

The Nankai trough produced a cumulative gas of about 1,20,000 cu,mts with a mean daily production of 20,000 cu.mts per day.

Brief History of Gas Hydrate Exploration in India:

In 1995 an expert committee identified that to augment research for newer energy sources; the potential areas for gas hydrate could be studied. In 1997, Ministry of Petroleum & Natural Gas (MoPNG) initiated the study for gas hydrates in India under Gas Authority of India Limited. Geoscientific data was studied for Bottom Simulating Reflector (BSR) and Gas Hydrate Stability Zone (GHSZ) and large areas of Indian Offshore were considered prospective for gas hydrates.

In 2000, the National Gas Hydrate Programme (NGHP) was formulated by the Ministry of Petroleum & Natural Gas (MoPNG). The NGHP is managed by two committees, a Steering Committee and a Technical Committee. The Steering Committee consists of Secretary, P&NG as Chairman and concerned Joint Secretary as Convener with DG, DGH as the Technical Coordinator. Also included in the Steering Committee are Heads of National E & P companies, namely ONGC, GAIL, OIL, IOC , representatives of Department of Ocean Development (National Institutes such as NIO & NGRI), GSI, representative from the Ministry of Environment, Forests & Climate change (MOEFCC), Secretary, Oil Industry Development Board (OIDB). Members of the Technical Committee include Scientists from these organizations and other organisations as felt necessary.

Under the Technical Coordination of DGH, NGHP undertook detailed studies on the presence of BSR on the Indian coasts. The NGHP Expedition-01 was launched in 2006 which established the presence of gas hydrates.

On collating the results of NGHP Exp-01 and it was concluded that for the Indian NGHP to progress further in the field of gas hydrates, it was necessary to identify areas having a high probability of sand deposition within the GHSZ. This was primarily because gas hydrates associated with arenaceous or sandy sediments formed the focus of research for the extraction of methane from gas hydrates. Gas hydrates in association with Shaly or argillaceous sediments have not been targeted for production research by geoscientists because of the uncertainty of the continuity of massive gas hydrate or layered gas hydrate deposits within shale. Besides, producing methane from massive deposits within shale could trigger unwarranted environmental hazards such as subsidence, debris flow etc. Thus, for the Indian NGHP it became imperative that a search be made for gas hydrate deposits associated with sand depositional systems within the gas hydrate stability zone as the gas hydrates discovered during the NGHP Expedition-01 were mostly associated with shale sediments.

With this objective the NGHP Exp-02 was launched in March 2015. The drilling of 42 wells at 25 sites and the collection of a large number of cores and subsurface information culminated in July 2015. Based on the initial results it can be mentioned that large tracts of sand depositional systems have been identified in the Krishna Godavari Basins which have a high potential of gas hydrate. The acquired data is now under detailed study.

The NGHP further plans to carry out pilot production testing (NGHP Exp-03) at one of the sites identified during NGHP Exp-02.

NGHP Expedition-01

NGHP Expedition 01 was designed to study the gas hydrate occurrences both spatially and temporally off the Indian Peninsula and along the Andaman convergent margin with special emphasis on understanding the geologic and geochemical controls on the occurrence of gas hydrate in these two diverse settings. The primary goal of NGHP Expedition 01 was to conduct scientific ocean drilling/coring, logging, and analytical activities to assess the geologic occurrence, regional context, and characteristics of gas hydrate deposits along the continental margins of India in order to meet the long term goal of exploiting gas hydrates as a potential energy resource in a cost-effective and safe manner. During NGHP Expedition 01, dedicated gas hydrate coring, drilling, and downhole logging operations were conducted from 28 April, 2006 to the 19 August, 2006.

On behalf of NGHP & the Ministry of Petroleum & Natural Gas, ONGC established a National Gas hydrate Core Repository at IEOT, ONGC Panvel, Navi Mumbai in 2006 for preservation of samples to be collected during the NGHP Expeditions under controlled conditions. More than 2800 m of hydrate/non hydrate cores collected from NGHP Expedition-01 are preserved at this National gas hydrate core repository.

Based on analysis of geological and geophysical data, the Expedition was planned to visit ten sites in four areas: the Kerala-Konkan Basin in the Arabian Sea – western continental shelf of

India; the petroliferous Krishna-Godavari Basin and Mahanadi Basin in the Bay of Bengal – eastern continental shelf of India; and the previously unexplored Andaman Islands. The goals of the cruise were to conduct scientific drilling, well logging, coring, and shipboard scientific analyses of recovered samples from each site to provide further insight into:

- the distribution and nature of gas hydrate in marine sediments
- the geologic controls on the formation and occurrence of gas hydrate in nature
- the processes that transport gas from source to reservoir
- the effect of gas hydrate on the physical properties of the host sediments
- the microbiology and geochemistry of gas hydrate formation and dissociation
- the calibration of geophysical and other predictive tools to the observed presence and concentration of gas hydrates.

a) Scientific Findings and Impact

The NGHP Expedition 01 Initial Reports, released at the conference in New Delhi, includes a series of integrated site chapters (Sites 1-21) describing the operational history and scientific data collected during the expedition. The Initial Reports volume also includes a companion publication that contains all downhole log data collected during the expedition.

The NGHP Expedition 01 science team utilized extensive on-board lab facilities to examine and prepare preliminary reports on the physical properties, geochemistry, and sedimentology of all the data collected prior to the end of the expedition. The following are some key scientific highlights of the expedition to date:

- Discovered gas hydrate in numerous complex geologic settings and collected an unprecedented number of gas hydrate and non-gas hydrate bearing cores.
- Most of the recovered gas hydrate was characterized as

fracture-filling material in clay dominated sediments.

- Gas hydrate was found occurring in "combination reservoirs" consisting of horizontal or sub-horizontal coarse grained permeable sediments and apparent vertical to sub-vertical fractures that provide the conduits for gas migration.
- Most of the gas hydrate occurrences discovered during this expedition appears to contain mostly methane which was generated by microbial processes. However, there is also evidence of a thermal origin for a portion of the gas within the hydrates of the Mahanadi Basin and the Andaman offshore area.
- Gas hydrate in the Krishna-Godavari Basin appears to be closely associated with large scale structural features, in which the flux of gas through local fracture systems, generated by the regional stress regime, controls the occurrence and distribution of gas hydrate.

The following are the lessons learnt from the Expedition

1. Presence of BSR is not conclusive for the presence of gas hydrates and vice versa;
2. Most of the gas hydrate occurrences have been associated with fine to very fine sediments; and,
3. Gas hydrate occurrences are recorded in very shallow depths below sea bed in unconsolidated sediments.

b) Actions taken after NGHP Exp-01

In 2008 the First International Conference on Gas Hydrates was organized by DGH in New Delhi. The results of the Expedition-01 which culminated in the form of technical papers were deliberated upon. The major outcome of the Conference was that:

i. Indian gas hydrates were found to be associated with predominantly argillaceous/shale sediments (in the Krishna Godavari and Mahanadi Basins) while gas hydrates were associated with the volcanic sediments in the Andaman deep water basins.

ii. It was necessary to identify sand bearing depocentres within the gas hydrate stability zone.

In 2009 studies were initiated by NGHP to identify sites which would ideally have:

i) Sand dominated gas hydrate occurrence

ii) Reasonably compacted sediments

iii) Occurrence of free gas below the gas hydrate stability zone

During 2010 – 2015 several technical meetings of Indian Scientists and International experts on gas hydrates led to the extension of the area of study for gas hydrate in KG & Mahanadi deepwater basins.

NGHP Expedition-02:

The objective of the NGHP Exp-02 was to identify sand bearing depositional systems with the gas hydrate stability zone on the east coast of India within the Krishna Godavari and Mahanadi deepwater Basins. The objective of NGHP Exp-03 is to carry out pilot production testing at a suitable site identified during the NGHP Exp-02.

NGHP Expedition 02 consisted of LWD (Logging While Drilling) /MWD(measurement While Drilling), Conventional Coring/Pressure Coring, Wireline logging, Vertical Seismic Profiling (VSP) and Modular Dynamic Testing (MDT) operations in KG & Mahanadi Offshore areas NGHP-02 commenced on 3rd March 2015 and has been completed on 28th July 2015. During NGHP R&D Expedition 02, total of 42 gas hydrate wells have been completed in 147 days against the original target of 40 wells in 150 days The completed 42 gas hydrate wells consist of 25 wells for LWD/MWD operations and the 17 wells for continuous coring/pressure coring/ wireline logging/VSP/MDT operations.

Scientists from NGHP (ONGC, DGH, OIL, GAIL, IOC, NIO, NGRI & GSI) and international agencies (USGS, USDOE, JAMSTEC, JOGMEC, AIST, GEOTEK) were involved in carrying out the onboard studies on gas hydrates/cores/formation fluid during NGHP-02

Scientific Findings and Impact

The initial results of NGHP-02 are very encouraging and producible gas hydrates have been discovered in KG deep offshore areas in sand reservoirs.

NGHP-02 has discovered significant gas-hydrate-bearing sand reservoir system in the KG Area at Site NGHP-02-08 and NGHP-02-09 channel-levee prospects.

The above outcome of the expedition has fulfilled the objectives of discovering gas hydrates in sand facies and the identification of sites for pilot production for testing in NGHP Expedition 03 is becoming a reality.

Future Plans for Gas Hydrate Exploration in India:

Keeping in view the objectives of the NGHP Expeditions, activities on the following lines are planned under NGHP:

- Determine the geologic controls on the formation and occurrence of gas hydrate in nature;
- Investigate gas transport mechanisms, and migration pathways from source to reservoir
- Examine the effect of gas hydrate on the physical properties of the host sediments and understand the environmental implications of producing gas hydrates;
- Investigate the microbiology and geochemistry of gas hydrate formation and dissociation; and,
- Analyse the highly saturated gas hydrate occurrences in sand reservoirs that could be the target of a future production test study.

The Expedition-03 which aims at carrying out pilot production testing will be carried out after a thorough study of the data collected in the two earlier of expeditions, planning and designing a suitable production testing method, understanding of environmental impacts of attempting a pilot production testing.

Conclusion

The challenges faced for commercial exploitation of gas from Gas hydrates are more or less similar all over the world. Extracting methane from gas hydrate in marine environments is relatively a new path. Japan has taken a lead in this direction. From the progress being made by the Indian NGHP steps are under way to mitigate anticipated challenges in the Indian context. The NGHP expeditions are an appropriate line of research investigation which could help the country forward by harnessing this yet elusive resource.

Avinash Chandra

The Indian Shale Gas Scenario

What is shale gas and why it has become so significant in the world?

Geologist regarded shales as: 'Source Rocks' for oil and gas due to their richness in organic content, its thermal maturity and hydrocarbon generation potential. Shales also act as 'Cap Rocks' for sealing or trapping the hydrocarbons in a subsurface structure due to their impermeable nature and compactness.

Methane gas is generated in shales under subsurface condition due to higher temperature and pressure of overburden rocks by transformation of organic matter by bacterial (biogenic) and geo-chemical (thermogenic) processes. This generated gas gets stored by multiple mechanisms as free gas in micropores and as sorbed gas on the internal surfaces of organic matter. Thus, Shale Gas is a combination of sorbed gas and micropore gas. When shales are rich in higher hydrocarbons i.e. Ethane, Butane, Pentane etc they also yield crude oil by a similar process resulting in the formation and production of shale oil.

Due to pioneering work done by a number of private oil and gas companies in USA it became possible to produce natural gas and crude oil from shales. One of the main person was George Mitchell who started Mitchell Energy and invested $250 million in the Barnett Shales from 1981- 1997 and could not recoup its costs. The breakthrough came in 1997 when Mitchell Energy utilized slickwater fracking. Eventually, Barnett became the most productive source of shale gas in USA during 2002 -2010 (In 2013, it produced 4.56 billion cubic feet per day). Currently it is on third position. Globally shale oil production is expected to reach 14 mill. Bbls per day by 2035. This amounts to 12% of world's total oil supply. However, new trend suggests it could possibly be as high as 23 mill. Bbls per day by 2035 i.e. about 20% of world's total oil supply.

Global Shale Gas Resources-EIA Assessment

Country	Gas in Place (GIIP) tcf	Recoverable Resource tcf
China	4746	1275
USA	3856	1161
Argentina	3244	802
Algeria	3419	707
Canada	2413	573
Mexico	2233	545
Australia	2046	437
S Africa	1559	390
Russia	1921	285
Brazil	1279	245
India	584	96 (R.Est. 2013-120 tcf)
Pakistan	586	105

Characteristics of Shale Gas or Unconventional Gas Formations which may require market driven prices for encouraging production

Conventional Gas is found in sedimentary rocks which have reasonable porosity and permeability. The associated conventional gas is always found floating above the oil in subsurface formations, whereas, non associated conventional gas is found on its own (without oil). In contrast the nonconventional gas like tight gas and shale gas fall on one flank of the triangle and Coal Bed Methane and Gas Hydrates are on the other flank of the triangle. The common theme is that unconventional gases like shale gas are produced from formations which have decreasing permeability, decreasing reservoir quality but require increasing technological effort to produce it.

Generally, shales have low porosity of 2-6%, TOC over 3-4%, low recovery factor (8-12% typically), ultra-low permeability between 0.1 to 1000mD. Large developments are required to get economies of scale. Mainly dependent on Fracture permeability (Natural or Induced), which requires multiple fracking (5-20 fracks per well).

Drilling strategy is prime criteria –importance of horizontal well patterns. Typical use of 3-4 Mn Gallons water/well and typical use of proppant 1000-3000 metric tones per well. Generally Shale gas wells in the same basin could be 1000 m deeper than the conventional wells, use multi-well pad to have lesser footprint on ground due to limited land availability in India and produced water requires expensive treatment before disposal. Such factors increase the cost of shale gas wells 1.5 -2.5 times more than conventional oil & gas wells.

Therefore, to encourage production of shale gas market driven gas price may have to be offered.

Characteristics of Major Shale Producing Plays in USA

Currently the largest producer of Shale oil and Shale gas is USA. Very soon the LNG exports from USA would capture the world market. GAIL in India and many other organizations around the world have signed major contracts for LNG imports from USA. Moreover, USA has already reduced its import of crude oil by over 50 % due to its shale oil production. Within a few years, USA will be exporter of crude oil instead of the largest importer of crude oil mainly due to shale oil and shale gas production. Characteristics of Major Shale basins of USA are given below:-

	Eagleford	Woodford	Haynesville	Bakken	Marcellus
Depth (ft)	5,000-13,000	6,000-14,000	10,000-13,500	4,000-11,000	4,000-8,000
Thickness (ft)	50-200	100-220	60-300	10-60	50 - 250
TOC (Total organic carbon)	2-9%	3-10%	2-5%	10-15%	3-10%
Ro (Maturity of the Shale)	1-1.14	.75-3.0	1-1.2	0.45-0.60	.8 - 3.0+
Hydrocarbon Type	Oil - Gas	Oil-Gas	Gas	Oil	Gas

Indian Shale Gas Resources

Different organizations have provided different estimates from time to time. Ministry of Petroleum and Natural Gas and DGH requested EIA, USA to provide estimates of Shale gas in India. In their first report only 6.1 tcf resources were shown in 3 basins.

Subsequently in 2011, ARI working on behalf of EIA, USA studied 4 basins and estimated 63 tcf of risked recoverable reserve. The then Secretary Petroleum in 2012 asked Dr. Avinash Chandra to give his tentative estimates based on earlier data studied by him as the former Director General of DGH. He gave tentative estimate of atleast 133 tcf of recoverable resource in 5 basins (Cambay Basin 45 tcf, KG Basin 49 tcf, Cavery Basin 9 tcf, Assam-Arakan Basin 10 tcf , Gondwana i.e Damodar Valley Basin 20 tcf , Vindhyan -not known due to limited data).

Some other organizations also prepared reports. NGRI, India estimated resources of 527 tcf and recoverable resource of 260 tcf. IHS-CERA Report gives resources of 744 tcf and recoverable as 211 tcf. Schlumberger while working for ONGC in Damodar Valley basin drilled pilot wells and established 48 tcf (GIIP) and estimated resource for whole India between 600-2000 tcf. At the lower end McKinsey report suggests recoverable as 100 tcf.

Potential Shale Gas Basins of India

1. Cambay Basin
2. Gondwana Basin
3. Assam-Arakan Basin
4. Krishna-Godavari Basin
5. Cauvery Basin
6. Vindhyan Basin
7. Bengal Basin
8. Rajasthan Basin

Characteristics of Indian Shale Formations & Prognosticated Resources

Basin Parameters	Cambay	Krishna Godavari	Cauvery	Assam-Arakan	Gondwana (Damodar valley)	Vindhyan
TOC (%)	1.5-4.0	1.4-5.3	0.31-4.76	0.64-1.00	4.0-10.0	0.40-6.04
VRo(%)	0.75-1.20	0.9-1.3	0.65-1.20	0.57-1.94	0.40-1.20	No Data
Thickness(M)	500-1200	300-1500	300-750	400-1000	500-1000	>350
Kerogen Type	II & III	II & III	II & III	II & III	III	II&III
Gas Concentartion Bcf/sq mile **	231	156	143	120	123	No Data
Depth (M)	1200-2000	>2000	2000-3000	>2500	>2000	>1800
Prognosticated Resources(Tcf)	217	280	80	55	85	Not estimated

Issues & Challenges in Shale Gas Production

India has sedimentary basins with proven, mature source rocks which is indicative of significant shale gas potential in the country.

Based on preliminary data analysis and geologic assumptions significant shale gas resource potential of around 717 tcf is estimated with possible recoverable component of 120 -140 tcf.

Several reasons listed earlier add to the cost of shale gas production due to which these wells are 1.5-2.5 times more expensive. There is shortage of sufficient land in India and for producing shale gas in economic quantities 200-600 wells are required. There is drastic shortage of fresh water in the country which may permit drilling of wells only in a very limited part of the country. Fear of pollution of ground water by produced water may create difficulties in getting environmental clearances. Above all if market driven prices are not provided then large development and production of shale gas may be difficult.

New Shale Gas Policy of Government of India and ONGC Plan

Government has recently announced a new policy guideline allowing ONGC and OIL to take up shale gas exploration in their Nomination Blocks.

No special treatment will be given to shale gas and oil production from these blocks.

As per the policy guidelines ONGC will have to take up 50 blocks for shale gas and oil exploration in phase-1

The Phase-1 will be of three years and ONGC has to carry out Geological and Geophysical studies followed by drilling of assessment wells where extensive coring will have to be carried out.

Vijay Kumar Sinha

Meeting the Challenges of Mine Fire in Jharia Coalfield

Introduction

The history of coal mining in Jharia Coalfield dates back to 1894 when coal bearing areas were owned by Zamindars (Raja of Jharia, Katrasgarh and Nawagarh) who granted mining leases to individuals/ companies for payment of "Salami" and royalty. As such coal mining in JCF during the early days was more or less confined to the outcrop regions. The lease holds were very small and fragmented and soon unscientific mining started by erstwhile mine operators which led to a number of fires and subsidence cases endangering a large area. The first case of fire was revealed at Bhowrah Colliery in 1916. Over the years the mine fire in the coalfield have spread in area and numbers, though mitigation measures have been taken from time to time but its dynamic nature pose a serious constraint in abatement measures. Apart from sterilizing the vast coal reserve especially prime coking coal, fire affects normal coal production and pollutes the environment. Some of the openly blazing fires not only cause serious environmental threat through emission of steam, smoke and noxious gases but also pose a serious health hazard to inhabitants. They bring forth irreplaceable damage to land and scarce water resources. And above all, it endangers surface structures and human lives with potentiality to cause disaster. As such the problem of mine fire in Jharia Coalfield needs to be urgently addressed in right perspective. The problem of fire and subsidence together with high population density and unabated growth of human settlements and townships has made the exploitation of coal in the coalfield one of the most difficult.

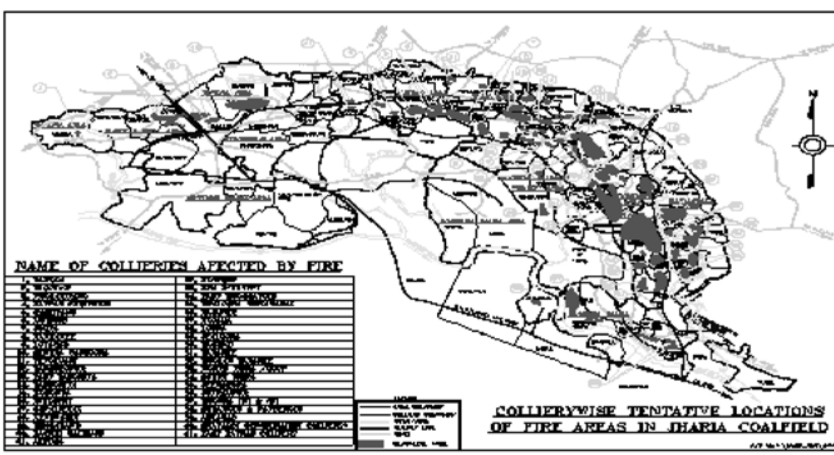
While scanning through the various studies and recommendations and subsequent mitigation measures taken for delimiting and liquidating fire in the past, it has been observed that there has been remarkable achievement. The ten active fires have been totally extinguished while nine others have been made dormant thereby substantially reducing the surface area affected by fire. The present measures under Jharia Master Plan approved in August, 2009 envisage dealing with fires under various proven technologies. Presently, 67 fires have been identified affecting 41 mines, for which 45 fire projects are envisaged in the Jharia Master Plan at a cost estimate of INR 2311 cr.. Some of the fires are being liquidated by excavation method with remarkable success. However, due to presence of large number of seams in close proximity and aggravated by thickly populated human settlement poses a serious challenge for fire management. Now that fire abatement measures have been identified and established, it is high time that people living in unsafe areas are re-located and coalfield is made free from any menace of fire.

Jharia coalfield

The Jharia Coalfield, formed along Damodar valley covering an area of 453 Km^2, is the major source of coking coal and the only source of prime coking coal used for metallurgical industry in the country. From the very beginning of the coal mining history, it was supposed to be most attractive and profitable area for mining as it has one of the highest concentration of thick coal seams in the world at relatively shallow depths. With 14.8% of the India's proved reserve, it contributes to only about 5% of the total production of the country. This is on account of highly complex geology with associated risks of fire, water and inflammable gases.

Jharia Coalfield, an "outlier" of Permo-carboniferous sediments in an Archaean country is one of the major coalfields of the Damodar Valley coal belt occurring roughly in an E-W alignment. It is sickle shaped on plan and occurs in the form of a basin with its axis bending broadly in East-West direction and plunging towards west. The southern flank is truncated by a boundary fault. The non-coal bearing Talchir formations (45 Km^2) are mainly exposed along the northern and North-western boundaries of the basin. Overlying the Talchir formations are the Barakar formations, covering an area of 218 Km² which are exposed in the northern, eastern and south-eastern part of the coalfield area and contain over 40 coal seams, some of which are exclusive store-house of Prime Coking Coal in India. The Barakar formation is successively overlain by Barren Measures (136 Km ²) which is devoid of workable coal seam. This is mainly exposed in central part of the coalfield. The barren measures are overlain by the coal bearing Raniganj formation (54 Km ²). These are exposed in the South-Western part of the coalfield and contains 12 workable coal seams.

Figure 1: Jharia Coalfield showing 67 fire spots affecting 41 Collieries



Causes of mine fire in Jharia coalfield

The analysis of causes of Jharia mine fire reveals that they may have two origins:

- **Endogenous origin** fires are due to nature of coal which undergoes spontaneous heating even under ambient conditions. The most of the fires in Jharia Coalfield belongs to this group. The occurrence of fire due to spontaneous heating is attributable to following contributory causes on account of unhealthy mining practices of the erstwhile mine operators:
  - Exploitation of superior grade coal occurring at shallow depths without filling cracks and often leaving pillars exposed to upper atmosphere

- o Crushing of Pillars due to undersized pillars or over extraction or splitting
- o Non-superimposition of workings in contiguous seams/thick seam developed in multi-sections
- o Plenty of coal left in mined out areas due to inappropriate mining methods with poor percentage of extraction or in case of selective mining
- o Undersized pillars, unstowed goaf, unsystematic mining and inadequate support system leading to instability and fracture of strata causing air breathing to mine workings
- o High ventilating pressure of fan causing leakages from goaves and often between intake and return lying in close proximity
- o High prone-ness to spontaneous heating of some of the coal seams
- o Presence of cracks in opencast benches and loose coal left in toe of the benches

➢ **Exogenous origin** fires are open fire caused by contact with external source of fire or hot spots and include:

- o Bantulsi fires near outcrops finding way to mines in dry seasons
- o Illicit distillation of liquor in abandoned mine entries/workings
- o Hot ash or heated debris of mine refuse coming in contact with coal bed

Impact of Mine Fires

The fires in Jharia have been causing huge losses by sterilizing high quality coal and damaging and endangering to land, surface structures, human lives and eco-system in the following ways:

a. Direct loss of prime coking coal due to burning

b. Blocking of coal reserve in the same seam and underlying seams

c. Environnemental pollution causing:
   - Air pollution by continuous discharge of poisonous gases like CO, NOx, SOx, unburnt hydrocarbons
   - Water pollution as high salinity becomes unsuitable for agriculture
   - Land damage caused by subsidence and cracking apart from lowering of water table, high temperature of soil etc.

   Mitigation Measures have been taken to maintain the pollution level within permissible limits. Ecological restoration with three-tier plantation is being done all over the coalfield at mined out areas

d. Creating difficult geo-mining conditions and vitiating normal production
e. Risk of inflow of Carbon Monoxide to working area from adjacent mine
f. Fire damp/coal dust explosion if fire comes in contact with concentration of inflammable gas in explosive limits
g. Danger to surface structures:
   - Railway line like Dhanbad Patherdih line (dismantled), Gomoh Adra line,
   - Roads like NH32, Jharia Sindri Road, Jharia Kenduadih Road etc
   - Jores like Kari, Chatkari, Ekra
   - Towns and human settlements such as Kerkend, Jharia,

   Action are underway to protect the surface structures.

Challenges of Dealing with Fire

The fires in Jharia are in advanced stage as adequate abatement measures were apparently not taken in the past. The presence of multi-seam and multi-section workings with multiple openings have intensified the fire and also led to its spread at fast rate engulfing a large area and quite a large number of seams. Further, the complexity of the mine conditions has aggravated the situation in some cases and led to fires occurring at unexpected places and times, traveling in direction and speed difficult to ascertain. Some of the challenges which have to be met for combating Jharia fire are:

- Due to high population density, re-location of large number of families living in endangered area becomes difficult which preclude the fire abatement measures
- Multiple seams in close proximity and predominance of thick seam (>3.5 m) at shallow depths have caused easy travel of fire from one seam to another at fast pace through developed galleries, connections through partings, depillared areas and even weak mine barriers.
- Multiple openings of seams through inclines near outcrops facilitate air entries which further aggravates the fire once they are attacked by excavation
- Operation of HEMM becomes risky due to complexity of fire and instability of ground
- Due to insufficient space, operation of HEMM for excavation of fire becomes difficult or even sometimes not feasible at all
- Coal left in goaf areas provide the fuel for the fire to sustain and expand
- Mining induced subsidence, cracks and fractures causing unstable strata pose serious problem to persons and machineries engaged in fire combating measures
- High proneness to spontaneous heating of coal seams especially IX seam and above
- Top soil layer is so thin that it is unable to form impervious layer for air and as such insufficient for surface sealing at fire affected areas
- Drilling and blasting in hot strata is difficult to carry out. While drilling, there is risk of entry of air which may flare up the fire
- The sandstone is predominant in superincumbent strata which when broken are highly porous to pass air and as such surface blanketing sometimes gives a false notion that air breathing has been contained

- Old workings either have no mine plans/ records or have unreliable plans

Measures taken prior to Nationalization

Prior to the nationalization of coal mines in Jharia Coalfield, while there were a large number of mine operators with small holdings, the problem of mine fire did not attract the attention. The erstwhile mine operators used to exploit on 'more hole more coal' precept without taking care to safety and conservation. However, with the enactment of Coal Mines (Conservation and development) Act, 1952, Coal Board was formed who took interest in dealing with fire singly or jointly with mine owners. The methods which were applied for dealing with fire included digging out, trench cutting, surface blanketing with sand, sand flushing in fire area. The attempts do not appear to have yielded the desired results as many fires which had started earlier is still raging.

Measures taken after Nationalization

After the nationalization of coal mines in 1972 and 1973, serious thoughts were given for conservation of prime coking coal in JCF, the only source in the country. A Master Plan of Reconstruction of Jharia Coal Field was drawn up where fire was one of the major problems to be dealt in JCF before starting large opencast blocks as envisaged in the Master Plan of JCF Reconstruction.

During 1976-1988, 22 fire projects to deal with the fires were sanctioned by BCCL and were implemented by application of best available technology, such as surface sealing, digging, trenching, inert gas infusion and sand-bentonite mixture flushing etc. These fire projects covered the then 59 fires out of the 70 fires existing at the time of nationalization. Between1998-2001, another eight schemes for dealing with fire and subsidence problems were sanctioned by Govt. of India under S&T grant (EMSC/RCFS) for a capital investment of Rs. 39.85 Crores. Out of these, six schemes have been completed and two are under implementation.

Over 22 million cubic metre of blanketing work has been carried out, and more than 50 million tons of sand stowed below ground. Approximately 3 million cubic meter of nitrogen gas has been flushed below the ground to control fires. A sum of Rs. 76.00 Cores approximately has been incurred in the fire fighting, measures against the fire projects till March 1997. The implementation of these schemes, though could not extinguish all the fires completely, has achieved the following:

- Liquidated 10 fires completely
- Controlled majority of the fires from total devastation. However, slow fire activities continue.
- Reduced total surface area affected by fire to 8.90 km² from 17.32 km²
- Reduced the blockage of coal from 1864 MT to 1453 MT.

Jharia Mine Fire Control Technical Assistance Project

Due to the fact that the problem of fire is very vital and technical in nature and also due to various other serious issues like environmental pollution, rehabilitation and acute financial constraints, the company approached the World Bank through Ministry of coal, Govt. of India for Jharia Mine fire Technical Assistance to conduct an exhaustive study of the technology of dealing with fire and environment in Jharia coal field. World Bank provided a loan of 12 million US$ and International Consultant GAI/MET-CHEM was engaged for fire dealing problems from 1994 to 1996.

Utilizing the Remote Sensing data of NRSA for Fires of JCF and colliery details, GAI/MET-CHEM undertook extensive drilling and temperature /gas monitoring along with field investigations for making inventory of boundaries and critical parameters of fires with possible spread and rate of spread of fires vertically and horizontally, potential danger to surface structures arising from spread and rate of propagation of fires. They also evaluated cost for the most suitable method of remedial actions.

The main observations /recommendation of GAI/MET-CHEM (1996) as per reports on "Jharia Mine Fire Control Technical Assistance Project" are as under:

i) Surface fire affected area has been reduced from 17.32 km^2 to 8.90 km^2.

ii) Dhanbad - Patherdih rail line (2.8 km stretch) is endangered by fire and requires immediate grout stabilization or preferably relocation of the same.

iii) Adra-Gomoh rail line requires protection near Phularitand.

iv) Ekra, Kari and Chatkari jores are endangered due to fires and require immediate protection at several places.

v) Jharia and Kirkend towns and many other built up areas are endangered due to fires and require immediate isolation from fires.

vi) Total extinguishment of fires immediately is not achievable but further advance of these fires can be controlled by application of the recommended fire abatement measures / control measures.

The recommended fire abatement measures are the more improved use of one or combination of the following existing control measures:-

- Excavation
- Isolation by trenching
- Grout barrier and stabilization
- Blanketing / surface sealing
- Blind flushing

Present strategies under the Master Plan

'Master Plan for dealing with fire, subsidence and rehabilitation in the leasehold of BCCL' prepared by CMPDIL (2008), is a comprehensive document which includes identification of fire areas, selection of technologies to deal with fire, prioritization of implementation and assessment of tentative fund requirement.

To deal with all the existing 67 fires spread over 41 mines, 45 fire projects have been proposed to be implemented in two phases each of five years duration at a capital outlay of Rs. 2311 Crore. Out of 67 fires, nine fires are in dormant states which require only maintenance.

Fire Abatement Measures

Fire abatement measures consist of three fold strategies as given below:

- Delineation of sub-surface fires by aerial or air borne thermal scanner/ thermal infra-red survey periodically and fire dynamics studies by scientific methods
- Delimiting the fire area
- Extinguishment of fire

It is necessary that the fire which cannot be extinguished immediately shall be demarcated and not allowed to spread. The first two strategies are intermediate or ad hoc measures and each fire must be finally dealt to extinguish it completely.

A fire can take place in a mine only when all the three basic ingredients namely Fuel, Oxygen and Source of heat are present at one time. The underlying principle for fire control is based on taking away at least one ingredient. Out of the various control measures currently available based on the above principle, the recommended measures are the more improved use of one or combination of following measures:

1. Excavation of fire material and filling with cohesive soil
2. Filling of opencast high wall, shafts, inclines and other subsided areas.
3. Isolation by trenching and backfilling with soil
4. Construction of grout barrier and isolation against rail, road and jores
5. Surface sealing and blanketing
6. Blind flushing with sand / fly ash / grout mixture
7. Cooling by water curtain / infiltration pond
8. Cooling, quenching and removal
9. Seam sealing, tunnel plug and underground stopping.

Excavation, surface blanketing, flooding and flushing are the potentially viable methods available for extinguishing the fire but the excavation method is the only sure option to completely extinguish the fire with certainty. However this method together with trench cutting is fraught with constraints as given below:

- o Collapse of sides and face
- o Risk of Carbon monoxide poisoning
- o High temperature causing difficulty in operation of persons and machineries
- o Low efficiency of machines
- o Poor visibility of operators, supervisors etc
- o Difficulty in drilling and blasting in heated strata
- o Difficulty in handling, transport and disposal of hot debris
- o Requirement of large quantity of water for quenching

All the above methods of fire control have been tried in Jharia Coalfield depending on the nature of fire and site and mine specific conditions. Presently methodology followed by BCCL is digging out the fire affected coal seams by excavation of overburden using heavy earth moving machinery. The exposed coal which constitutes fire affected part are excavated and dispatched after quenching the hot masses by water. This method has come out with remarkable success especially in liquidating most of the mine fires at Block-II, Ena, Rajapur, Shatabdi, Dhanbad Patherdih Railway line etc. As a result, ground surface manifestations of burning condition reflected by thermal infra-red survey studied and reported by National Remote Sensing Centre (NRSC), Hyderabad has reduced from 8.9 Km^2 to 2.118 Km^2.

Now that technology for dealing with Jharia fire has been established, only hindrance is the large population living over endangered area who need to be re-located before taking up excavation for liquidation of fires. However, the dealing with fire requires careful study of the extent, direction of propagation and dynamics of fire, mine-specific parameters, formulation of time-bound action plan, trained and well-equipped organization and management for successful implementation. A quick and timely action in dealing with fire is necessary for desired results.

Conclusion

Jharia Coalfield, the only storehouse of prime coking coal in the country has a high resource potential to provide coking coal, non-coking coal and CBM. The exploitation of coal is hampered by presence of 67 numbers of fires, 595 unstable sites endangered due to subsidence and thick human settlements over the entire coalfield including endangered sites. The scenario of Jharia fire is complex due to presence of multi-seam and multi-section workings at shallow depths. The complexity of the geo-mining parameters and other conditions has led to fires occurring at unexpected places and times, traveling in direction and speed difficult to ascertain. By taking pro-active measures, a number of fires are being liquidated by firming up the technology by excavation. But the challenges have to be met by taking fire abatement measures for which quite sizable population has to be re-located for which detailed blueprint and adequate fund has been provided under approved Jharia Master Plan. The strategies for combating Jharia fires call for a common will and pro-active approach on the part of all stakeholders for fast implementation of the Jharia Master Plan without delay. The liquidation of Jharia fire will not only unlock vast reserve of good quality coal but also improve the environmental condition of the place.

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