REVIEW OF INDIA'S CIVIL NUCLEAR ENERGY PROGRAMME: POST FUKUSHIMA DISASTER

As Japan grappled with the nuclear crises at its plant at Fukushima, the third major accident after 1979 three mile accident in United States and 1986 Chernobyl accident of Russia, the fear of similar occurrence prompted people of Jaitapur at Maharashtra to protest against the decision of the France's Areva and the Nuclear Power Corporation of India Ltd (NPCIL) to build a nuclear plant there. Similar sentiments against the nuclear power generation were expressed across the world prompting the world leaders including our PM to announce special stress tests to and review safety standards to reassure the viability of safe power generation. Germany even shut down seven reactors and has announced closing of all 17 nuclear power plants by 2022. This indicated a decisive shift in Germany's energy policy to renewable power sources for energy supply and reduce CO_2 emissions by 40%.

In response to Fukushima disaster, China has put on hold its plan of building 77 reactors. In US there was protest at Vermont demanding shutting down of the plant of the same design of the vintage of Fukushima. Till recently, bowing to the public sentiments after Three Mile nuclear disaster in 1979, United States did not construct a new nuclear power plant for nearly three decades. There is a question in every ones mind that if a highly developed nation as Japan which is so well prepared for disasters, can end up in such an apparent nuclear mess as in Fukushima, what hope do a less developed countries (in Asia and Africa) have in preventing and managing such disasters at their nuclear facilities? The disaster at Japan's Fukushima-Daiichi nuclear power plant poses a valuable learning opportunity for India as we consider further expanding our nuclear energy sector.

India's Energy Policy

Energy policy of India is predominantly controlled by the Government of India's, Ministry of Power, Ministry of Coal and Ministry of New Renewable Energy and administered locally by Public Sector Undertakings (PSUs). Power is in the Concurrent List and the primary responsibility at the consumer end is with the States. Distribution today is the weakest link in the Power Sector. In India bulk transmission has increased from 3708 ckm in 1950 to more than 265,000 ckm today. The entire country has been divided into five regions for transmission systems, namely Northern Region, North Eastern Region, Eastern Region, Southern Region and Western Region. The interconnected transmission system within each region is also called the regional grid. Any strategy to reform the power sector has to focus first on the distribution sector in order to ensure cash flows and make the sector viable. The Energy Policy is largely focused on developing alternative sources of energy, particularly nuclear, solar and wind energy to bridge burgeoning energy deficit. About 70% of India's energy generation capacity is from fossil fuels, with coal accounting for 40% of India's total energy consumption followed by crude oil and natural gas at 24% and 6% respectively.

India is largely dependent on fossil fuel imports. The dependence on energy imports is expected to exceed 53% of the country's total energy consumption. As on now 35.5% of the population still live without access to electricity. The growth of electricity generation has been hindered by shortage of coal/gas/nuclear fuel, poor hydrology etc. Though we have large coal deposit, but due to its poor quality (low calorific value and high ash content) the coal is imported. Its demand is further expected to rise due to increase in demand by the steel and the power sectors which are expanding capacity. Most of India's coal imports come from Indonesia and Australia. India's coal requirement in 2011-12 is likely to be 135 million tonnes.

Given India's growing energy demands and limited domestic fossil fuel reserves, the country has ambitious plans to expand its renewable and nuclear power industries. India has the world's fifth largest wind power market and plans to add about 20GW of solar power capacity by 2022. India also envisages increasing the contribution of nuclear power to overall electricity generation capacity from 2.75% to 9% within 25 years. The country has five nuclear reactors under construction (third highest in the world) and plans to construct 18 additional nuclear reactors (second highest in the world) by 2025.

Power Generation Scenario.

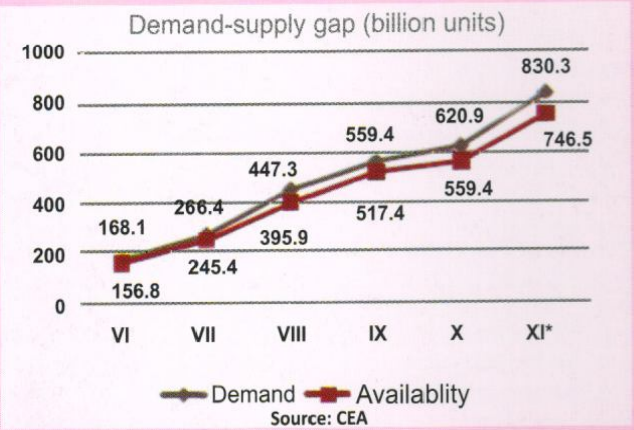
India has the fifth largest electricity generation in the world. The installed capacity for power generation has tripled over the last 20 years and is slated to be 173,626.40 (As on 31-3-11). More than 2/3 of the generation is at the state and the central sector. The breakdown is given below:-

Sector	MW	%age
State Sector	82,432 .58	47.49
Central Sector	54,412 .63	31.34
Private Sector	36,761.40	21.17
Total	173,626.40	

Source: CEA

Energy Demand vis-a-vis Supply

India's energy requirement during the year 2009 2010 was estimated at 830,300 million units (MU), while its energy availability was 746,493 MU. An energy shortage of 10.1 per cent was recorded in 2009-2010, as compared to 11 per cent in 2008-09: The country is expected to witness electricity shortage by 10% and its peak shortage by 12.9% for the current fiscal as well.



Source: CEA

As per the planning commission, to deliver sustained growth rate of 8% through 2031-32 and to meet the lifeline energy needs of all citizens by 2031-32, power generation capacity must increase to nearly 8,00,000 MW from the current capacity of around 1,73,626 MW. Nuclear power meets mere 2.75% of the total power requirement with major dependence still on fossil fuels. Thermal power accounts for 64.9 per cent of the power produced in India (112824 MW), followed by hydro-electric power (37567 MW).

		MW	%
Total Thermal		112824.48	64.98
	Coal	93,918.38	54.09
	Gas	17,705.35	10.20
	Oil	1,199.75	0.69
Hydro		37,567.40	21.64
Renewable (solar/wind)		18,454.52	10.63
Nuclear		4,780.00	2.75
Total		1, 73,626.40	100.00

India's per capita consumption of power stood at 612 kWh which still far lower than the developed world. The most important question to ask is - do we have other options of power generation to meet our growth trajectory which for next decade is predicted to be in the region of 8-9%. Choosing a wrong option could result in success or failure of our national vision to be a developed nation with poverty fully eradicated.

Thermal Power

At present, the thermal source nearly meets 65% of the power requirement of India and one of the main sources of environment pollution. Though India is the one of the largest producer of coal but, the coal has low calorific value with high ash content. Hence, good quality thermal coal is imported mainly from Indonesia and Australia. This year, we are expected to import 100 millon tonne of coal. The thermal projects are cost effective and have short gestation period, however, there are serious environment concerns. The main emissions from coal combustion at thermal power plants are carbon dioxide (CO), nitrogen oxides (NO), sulfur oxides (SO), chlorofluorocarbons (CFCs), and air- borne inorganic particles such as fly ash, soot, and other trace gas species. Carbon dioxide, methane, and chlorofluorocarbons are greenhouse gases. These emissions are considered to be responsible for heating up the atmosphere and producing a harmful global environment. Now, India after voluntarily accepting to cut down the carbon emission by 20-25% at Copenhagen climate meet is committed to explore other sources of energy to meet its energy requirement. In view of the worldwide awareness of climate change it would be difficult to pursue fossil fuel route to meet our power needs other than when integrated with effective carbon capture technologies.

Hydro Power

Our country is endowed with enormous economically exploitable and viable hydro potential assessed to be about 84,404 MW at 60% load factor (1,48,700 MW installed capacity). In addition, 6781.81 MW in terms of installed capacity from small, mini and micro hydel schemes have been assessed. However, only 15% of the hydroelectric potential has been harnessed so far and 7% is under various stages of development. Thus, 78% of the potential remains untapped. Central Electricity Authority (CEA) has accorded sanction projects for another 13,032MW under the central and state sector and another nine projects for generation of 2796 MW power under the private sector. Hydro power is a renewable economic, non-polluting and environmentally benign source of energy. It offers the best choice for meeting the peak demand, besides, the generation cost is not only inflation free but reduces with time. For example per unit generation cost of electricity at Bhakra is mere 20 paisa per unit. The project also supplies drinking and irrigation water to Punjab, Haryana and Rajasthan. Hydroelectric projects have long useful life extending over 50 years and help in conserving scarce fossil fuels. They also help in opening of avenues for development of remote and backward areas. An average of 2GW per year growth in capacity that has taken place between 2000-2009. With this estimate India could have 90 GW of hydroelectric capacity by 2032.

Constraints. It must be appreciated that large hydro projects require enormous financial inputs, besides detailed environment impact assessment and elaborate rehabilitation measures due to submergence, which must be acceptable to the local populace and must contribute to raise their standard of living. The constraints which have

affected hydro development are technical (difficult investigation, inadequacies in tunnelling methods), financial (deficiencies in providing long term financing), tariff related issues and managerial weaknesses (poor contract management). The hydro projects are also affected by geological surprises (especially in the Himalayan region where underground tunnelling is required), inaccessibility of the area, problems due to delay in land acquisition, and resettlement of project affected families, law & order problem in militant infested areas etc are some of the problems of the hydro projects. For example, the Gobind Sagar reservoir behind the Bhakra dam is spread over 168.35 sq. km. Apart from these difficulties, mobilising men and machinery at remote and inaccessible locations where such projects are generally located is also problematic. However, such challenges also provide the opportunity to develop the project area and raise the standard of living of local populace. Northern India is dotted with an extensive network of canals. In fact, such projects are instrumental in controlled and channelized releases of water through downstream canals that can meet the drinking power requirement of Indian cities. So despite there being large untapped source of energy in the North and North-eastern region of our country, it is not possible to exploit due to the domestic and International ramifications.

Renewable Energy Sources

Renewable energy provides 18 percent of total electricity generation worldwide and with time to come the capacities would further build up and add on the capacities and contribute to the power bank. Renewable energy involves generation of the energy through natural phenomena such as sunlight, wind, tides, plant growth, and geothermal heat. Awareness about Renewable energy sources is growing rapidly. Climate Change concerns, coupled with high oil prices, and increasing government support, incentives and commercialization are driving increasing renewable energy sources. Renewable power generators are spread across many countries. For example wind power alone already provides a significant share of electricity in some 14 percent in the U.S. state of Iowa, 40 percent in the northern German state of Schleswig-Holstein, and 20 percent in Denmark. In fact, some countries get most of their power from renewable, including Iceland and Paraguay (100 percent), Norway (98 percent), Brazil (86 percent), Austria (62 percent), New Zealand (65 percent), and Sweden (54 percent).

India's Renewable energy strategy leans heavily on the Solar and wind energy. Renewable energy producers in India are enthused by the National Action Plan on climate change (NAPCC) has set the target of boosting the India's share of renewable energy in the energy mix to 15%. Not only it will help India in lowering the carbon emissions by 2.5% which is tenth of the 20-25% reduction which India has volunteered at the international summit in the climate change in Copenhagen. Renewable energy sector is set to grow. Presently, India is the third most favoured destination globally for investments in the renewable energy sector and will also be a major source of new entrants into the sector, behind the US and China.

Solar Power. India has abundant solar resources, as it receives about 3000 hours of sunshine every year, equivalent to over 5,000 trillion kWh. Today the contribution of Solar power with an installed capacity of 9.84 MW, is a fraction (< 0.1 percent). It is estimated that solar power is expected to meet 5-7% of the India's total requirement by 2021-22 and it can save over 30% of the India's total coal imports. The initial cost for setting up the project is very high. Once the plant is set up, its cost comes down.

There is no extra cost, except managing the mirrors. It (solar plant) can go on as long as the sun shines. Of course, we have got to make arrangements when the weather is cloudy. To overcome this constraint, Hybrid plants (hybrid wind-solar generating system) can be considered. There is a serious problem of extending the power line to the un-electrified 80000 villages in India. A solar power plant is a good option for electrification in areas that are located away from the grid line or where other sources are neither available nor can be harnessed in a techno economically viable manner. Solar power generation has lagged behind other sources like wind, small hydropower, biomass etc. The Indian Solar Loan Programme, supported by the United Nations Environment Programme has won the prestigious Energy Globe World award for sustainability for helping to establish a consumer financing programme for solar home power systems. Over the span of three years more than 16,000 solar home systems have been financed through 2,000 bank branches, particularly in rural areas of South India where the electricity does not yet extend.

Wind Power. The development of wind power in India began in the 1990s, and has significantly increased in the last few years. A combination of domestic policy support for wind power and the rise of Suzlon (a leading global wind turbine manufacturer) have led India to become the country with the fifth largest installed wind power capacity in the world. It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2012. Wind power accounts for 6% of India's total installed power capacity, and it generates 1.6% of the country's power.

Constraints. The regulatory framework to promote renewable energy resource is yet to take concrete shape to promote renewable energy. Besides, the other problem is that electricity from sources such as wind power and solar power is variable or intermittent. Latter is expensive and unaffordable and can not become the major source for till there're is breakthrough technology to harvest solar energy

at lower the cost. The estimated unit cost of generation of electricity from Solar Photovoltaic and Solar thermal route is in the range of Rs. 12 -20 per kWh and Rs. 10 -15 per kWh respectively in India. With present level of technology, solar electricity produced through the photovoltaic conversion route is 4-5 times costlier than the electricity obtained from conventional fossil fuels. Some of the materials (like Cadmium) used for producing Solar PV cells are hazardous and other raw materials like plastics used for the packaging of the cells are non-biodegradable, thereby impacting the environment. Although some of the wastage generated during the manufacturing process is recyclable (silicon), not all other materials are recyclable and disposal of the same is a challenging process.

Nuclear Energy

Nuclear power is the fourth-largest source after thermal, hydroelectric and renewable sources of electricity. Our power generation plan visualizes having 20,000 MWe nuclear capacities on line by 2020, 63,000 MWe by 2032 and by 2050, 25% of electricity requirement are expected to be met from nuclear power. As of 2010, India has 20 nuclear reactors in operation in six nuclear power plants, generating 4,780 MW while 5 other plants are under construction and are expected to generate an additional 2,720 MW. India's domestic uranium reserves are small and the country is dependent on uranium imports to fuel its nuclear power industry. Due to inadequate uranium fuel supply, electricity generation from nuclear power in India even declined. Following a waiver from the Nuclear Suppliers Group in September 2008, India has signed bilateral deals on civilian nuclear energy technology cooperation with several other countries. With improved supply, not only the efficiency of nuclear power plants improved but, India now envisages increasing the contribution of nuclear power to overall electricity generation capacity from present 2.75% to 9% within 25 years.

Questions Raised by the Critics. Following the Fukushima nuclear accident, many are questioning the government policy of meeting the part of the power demand with Nuclear power. Jaitapur Nuclear Power Project has become the rallying point for the critics who dub the plant as inherently unsafe due to its location in seismic zone III. Secondly, much of the nuclear programme in India has been domestically developed; hence, they question the import of technology at an exorbitant cost to the nation. It is asserted that since we have already developed 700 MWe plants, we can easily scale them up to 1000 MWe for expanding the power generation to 40000 MWe by 2030. Besides, the critics even question the quantum of the future demand, they also point out on need to control transmission losses which are nearly to the tune of 40-50%. Critics have also sought India to invest on the thorium based nuclear power technology for power generation. Yet another concern is India's limited capacity to handle Fukushima type of disaster. A minor radiation accident caused by a cobalt pencil which landed in Mayapuri Junk yard in West Delhi a year ago is stark example of careless handling and low awareness of a teaching institution and other Personnel involved in radiating material.

Are Locations of Nuclear Power Seismically Safe?

All Nuclear power plants in India are designed to withstand natural disasters like earthquakes and are situated in Zone II and III except Narora plant in Uttar Pradesh, which is situated in Zone IV. All our plants are situated 300-2,000 km away from the tectonic Himalayan boundary. All nuclear power plants in the country have operated safely during earthquakes. The 7.9 magnitude quake which hit the western state of Gujarat in 2001 and the 2004 Indian Ocean tsunami proved that our nuclear facilities could withstand a major natural disaster. In fact, earthquakes are more prevalent in the Pacific. Nuclear stations in Japan and Taiwan have survived many earthquakes. There is enough evidence that earthquakes themselves are not the major risk. Fukushima was undone by the giant tsunami. The plant had shut down after the earthquake as designed. In the future nuclear power stations must not be built on low lying land off tsunami-prone seas without putting up some high defences. Other two major accidents, i.e. at Three Mile Island and Chernobyl were caused by failure/ lack of adequate safety standards and not by earthquakes.

Foreign Technology at High Cost

As per NPCIL, there is lot of misconception on the cost of Nuclear Power. It is clarified that the cost of generation of one KW Nuclear power is $3000. It would cost $3000x1000MW= $3,000,000 ($3 million per MW) for generation of 40 MW by 2020 it would cost $120 billion and not $250-300 billion. Moreover, this actually shrinks to $40billion if one takes indigenisation in to account. Foreign technology and fuel are also expected to boost India's nuclear power plans considerably.

Safety Standards

The country operates 20 nuclear plants and 18 of them were indigenous pressurized heavy water reactors and two at Tarapur plant are the boiling water reactors of the type being operated in Japan. The Tarapur plants were recently upgraded and meet all safety standards. After the Fukushima disaster, The Department of Atomic Energy and its agencies, including the Nuclear Power Corporation of India, were instructed by Prime Minister to undertake an immediate technical review of all safety systems/practices of our nuclear power plants, particularly with a view to ensuring that they would be able to withstand the impact of large disasters such as tsunamis and earthquakes. It has been reported recently

that review of the reactors has been completed. Further, to avoid complacency or internal organisational pressure, an Independent regulatory authority to carry out regular safety audit, has also been planned under an act of parliament to regulate nuclear energy in the country. The boiling water reactors at Tarapur 1 and 2 units have been in operation for 16 years more than their design lives. Reportedly these are much older than the reactors involved in the Fukushima nuclear accident; we may decommission them to enhance safety of the plant and address public concern.

Preparedness to Handle Emergency

India's nuclear power plants are reported seismically safe, but the country must build its capacity to respond should an emergency strike. We are still in preparatory stage. All necessary preparedness measures to deal with any nuclear or radiological emergency needs to be put in place which should cover mass evacuations of affected populations and better detection of radiation and medical treatment. In districts where there are nuclear installations, we must pre-position specialised medical teams, upgrade and equip hospitals and create better awareness amongst the general public on how to protect themselves.

Future Power demand

The questions have also been raised on fallacy of our future estimate of our power demand. The energy demand in past has grown on an average of 3.6% per annum over the past 30 years. Planning commission has estimated our by 2031-32 power generation capacity must increase to nearly 8, 00,000 MW if we are to sustain the growth. At the current rate of increase in demand by 2021-22 the installed capacity requirement would be approximately 400,000 MW. The capacity addition by 12 and 13th plan is 100000 MW per plan period. The requirement is expected to quadruple by 2032.

Cost Benefit Analysis

The time taken to construct the thermal power station is about three years in comparison to ten years of a nuclear power station during which there will be cost escalation too. Besides, the cost of a thermal power plant is approx. Rs 4000 crore compared to RS 12000 crores of the nuclear power plant . The attendant risk in the latter case is manifold. Is it wise to increase the present nuclear power share from 2.75 % to 9% with the attendant risk? This line of argument often fails to consider that we depend on import of fossil fuel. By 2030 our oil import would be 90%. Similarly; our coal import would increase to meet our rising demand for the coal. As per Coal India Ltd (CIL) Chairman Partha S Bhattacharyya, we need to employ new mining technologies to go deeper to explore the untapped resources; otherwise by 2040-41 our present coal blocks will run out of reserves due to the growing demand from consuming industries. Hence, besides climate concern, the fossil fuel too will have to be replaced with clean and sustainable fuel like Uranium. But still for long time our dependence on coal will remain. Risk can be looked after by following safe technology and practices as has been done by France which generates almost 80% of power from nuclear energy. Moreover, in real cost term, the cost of generation of power from NPCIL plants is between Rs 2.19 per KWh to Rs 2.30 KWh which almost matches the cost of thermal power and far cheaper at present from solar power which costs Rs 10-12 per KWh. In long run, the cost to maintain a thermal power station rises whereas, it comes down for the nuclear power station and hydro power both the source of clean energy.

India will have to employ multiple options as no single source of energy will meet the future energy requirement of India. The nuclear power generation capacity will rise to 60GW by 2030. During the same period the coal based power is expected to treble to 300 GW whose demand would be met by the imported coal. Only four countries have sufficient reserves to meet India's projected need. These are the USA, Russia, Australia, and South Africa whose combined exports (thermal plus metallurgical coal) today are about 440 million tonnes out of a global traded amount of about 800 million tonnes. India would have to compete with China for coal who despite being having a large reserve has become a coal importer in 2006. Even if the desired coal-fired generation capacity additions are possible, the required coal linkages remain an Achilles heel because of the cost and competition. In long run nuclear energy with renewable sources along with other sources alone can provide the solution.

Small versus Large Nuclear Plants

After the Fukushima disaster, issue of small nuclear plats in favour of large nuclear plants had also come up during the various discussions essentially to meet the specific industry/ area need. Such a proliferation would not only increase the requirement of the nuclear trained staff but, also significantly enhance the chances of nuclear mishaps at multiple locations. Risk from nuclear disaster will increase manifold from a nuclear accident as well from the non-state actors. Hence, such a course is best avoided. The criticism that to meet the total demand 655,000 MWe nuclear power generation by the year 2050 merits consideration as we would need several power plants to accommodate 655 nuclear power reactors each of 1000 MWe capacity, along a total coastline of about 7000 kilometres with attendant risks does not appear convincing as France generates 75% of its power requirement (63GWe) from 58 nuclear reactors. We are targeting the almost same extent of power generation by 2050. The nuclear plants would have wider separation as India is much larger in size than France. We must remain on path to fructify our plans to sustain growth and improve the living standard of the masses.

Lessons Learned from Fukushima

Nuclear Oversight Reform. An independent Nuclear Regulatory Commission is being established under the act of parliament to have transparent safety evaluation of the plants.

Emergency Response System. There is a need to setup and train an emergency response team to act effectively in case of a major nuclear accident. NDMA is still not fully geared up to handle such emergencies.

Public Awareness and Information Transparency. There is need for timely and transparent information release and education in the event of an accident. The cover-up as in Japan may exacerbate the crisis.

Education of Nuclear Professionals. There is a necessity of focusing more resources on training of nuclear engineers.

Safety Standards and Monitoring. Keep the growth of the nuclear industry at a "reasonable rate" to ensure plants comply with high safety and monitoring requirements.

Strengthening IAEA Safety Standards. As civil nuclear plants operate as per International Atomic Energy Association (IAEA) guidelines, standardised and comprehensive parameters must be laid down and checked to avoid accidents/incidents.

Recommendations

For a large country like India with its over one billion population and rapid economic growth rate, no single energy resource or technology constitutes a panacea to address all issues related to availability of fuel supplies, environmental impact. Therefore, it is necessary that all non-carbon emitting resources become an integral part of an energy mix, as diversified as possible, to ensure energy security. Available sources are low carbon fossil fuels, renewable and nuclear energy and all these should be subject of increased level of research, development, demonstration and deployment. Following are some recommendations to achieve the aim:-

(a) Future Energy requirement can be met by combination of sources including nuclear energy as planned.

(b) Build pool nuclear trained personnel. Nuclear engineering programmes to train the manpower required to support the development of nuclear power has been initiated by some of the leading academic institutions at IIT Kanpur and IIT Madras. Same needs to be pursued vigorously.

(c) Nuclear safety practices at National and multinational level with the role of multilateral body like IA EA /UN.

(d) Climate change though a major concern but, we should not accept curtailment of generation of energy through fossil fuel as per capita consumption is far below even the emerging economies such as China and Brazil.

(e) Induct clean carbon capture technologies so that our power generation from the fossil fuel is not inhibited.

(f) Focus on the development of nuclear energy technology based on fast breeder and thorium based reactors for rapid build up of indigenous nuclear capacity post 2032.

(g) Credible R&D for cost effective generation of energy from renewable power sources viz. Solar, wind and hydroelectric so that large-scale deployment can take place as and when these technologies (especially solar) become cost-effective.

(h) Very large reduction in total energy used is possible in heating, cooling and lighting of buildings through efficiency gains and better planning. Rapid adoption of these systems can be achieved by amending municipal bye-laws to mandate desired standards for urban buildings.

(i) India should partner in the global R&D effort to reduce the cost of solar systems and the development of cost-effective and industrial scale technologies for photo-chemical and thermal splitting of water into hydrogen or to hydrocarbon fuels directly.

(j) Transmission Strategy with focus on development of National Grid including Interstate connections, technology up gradation & optimization of transmission cost.

(k) Distribution Reforms with focus on system up gradation, loss reduction consumer service orientation and quality power supply.

(l) Develop decentralized distributed generation based on renewable energy source for rural areas and inaccessible areas.

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Views expressed in this paper are those of the panellists and do not represent the views of the CENJOWS.

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