Dissertation report

# Prospects for development of Solar and Wind projects and challenges in integrating into the Grid system

By

PRAKASH KENGANUR (SAP ID 500024873)

Guided by

JAGADISH GURAV (Associate Vice President, IL&FS Energy Development Company Limited, Mumbai)

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# APPENDIX – II

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Prakash KENGANUR
Lotus Boulevard, Tower 12, flat no 903,
Sector 100, Noida, 201304
Uttar Pradesh
Land line: 0120 3357888
Cell number: +91 9899654740
e-mail: prakashkenganur@gmail.com
Date: 31/10/2015
Place: Noida

## APPENDIX – III

A Declaration by the Guide

This is to certify that Mr. PRAKASH KENGANUR, a student of Executive MBA , SAP ID 500024873 of UPES has successfully completed this dissertation report on "Prospects for development of Solar and Wind projects and challenges in integrating into the Grid system" under my supervision.

Further, I certify that the work is based on the investigation made, data collected and analysed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfilment for the award of degree of MBA.

**Jagadish Gurav**

Associate Vice President
IL&FS Energy Development Company Limited
The IL&FS Financial Centre
Plot C-22, G Block
Bandra-Kurla Complex
Bandra (East), Mumbai - 400 051
Tel: +91 22 2659 3808
Mobile: +91 9930 992975

Email: Jagadish.Gurav@ilfsindia.com

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## Abstract:

India is blessed with huge potential of Solar and Wind energy, and to tap this, present government has set an ambitious target of 100 GW Solar and 65 GW of Wind power by 2022. Already the share of renewable power is increasing year-on-year, going forward it is only going to grow exponentially. India's growing renewable share in energy mix prompted me to capture the changing dynamics of power sector and policy framework on renewables (especially Solar) and the challenges renewables poses on the grid stability/Integration. The project work / the dissertation paper cover largely the following:

- Brief on Indian electricity sector
- Government policies and regulatory framework / structure prevailing in India for renewable energy sources (especially for Solar).
- Brief on wind power and its impact on Solar as far as grid stability is concerned.
- Challenges in evacuation and integration of generated power from renewables (Solar & Wind) into the grid system and measures planned by Power Grid Corporation of India.
- Evaluating the concept of Wind Solar hybrid integrated with grid interactive Energy Storage (ES) applications and other avenues for smooth integration of large scale renewables in to grid system

The purpose of the project is to see the viability of the renewables (Wind and Solar) and the hurdles or constraints it imposes on the grid systems (contributing to grid instability/Integration).

Secondary data available in public domain is used for the project work.

Outcome of the project work would help to understand the policy frame of renewables and the potential opportunities in development of Solar and or Wind plants.

# 1 Introduction:

Energy remains pivotal in meeting human needs worldwide. The situation still remains grim as around 1.3 billion people have unreliable or no access to electricity. As a general trend, energy and electricity consumption are likely to increase over the next 25 years across the world. UN in 2011 launched "sustainable Energy for All initiative". It hopes to achieve three interlinked objectives by 2030, one of which is doubling the share of renewable energy in the global energy mix.

Among the renewable energy technologies, solar photovoltaic (PV) technology is filled with a lot of promises. The Indian PV programme has marched from strength to strength in several ways, bringing in its fold a whole spectrum of curious technology believers. Capacity building initiative has emerged as one off the clearly identified requirements under well acclaimed "Jawaharlal Nehru National Solar Mission"

Renewable energy continued to grow in 2014 in parallel with global energy consumption and falling oil prices. Despite rising energy use, for the first time in 40 years, global CO2 emissions associated with energy consumption remained stable over the course of the year while the global economy grew. The landmark" decoupling" of economic and CO2 growth is due in large measure to China's increased use of renewable resources, and efforts by countries in the OECD to promote renewable energy and energy efficiency. This decoupling clearly signals that renewables have become a mainstream energy resource. We are still not on the pathway to 100% renewable energy globally; a lot remains to be done. It is accelerating in many parts of the world. With the implementation of ambitious targets and innovative policies, renewables can continue to surpass expectations and create a clean, equitable energy future.

Costs for wind power and solar photovoltaics (PV) have dropped dramatically and markets have grown substantially between 2005 and the end of 2014 over 496,000 MW of new solar and wind power plants have been installed - equal to the total capacity of all coal and gas power plants in Europe! In addition 286,000 MW of hydro, biomass , concentrated solar and geothermal power plants have been installed, totalling 783,000 MW of new renewable power generation connected to the grid in the past decade - enough to supply the current electricity demand of India and Africa combined.

Renewable power generation has become main stream in recent years. Onshore wind is already the most economic power source for new capacity in a large and growing number of markets, while solar PV is likely to follow within the next 3 to 5 years.

The global renewable energy market in 2014 was dominated by three power generation technologies: solar photovoltaics (PV), wind, and hydro. Combined, these technologies added 127 GW of new power generation capacity worldwide by year's end, renewables made up an estimated 60% of net additions to the global power capacity. In several countries renewables represented a higher share of added capacity (REN21-2015). The increase in market volume and strong global competition led to significant cost reductions, especially for solar PV and wind power.

Renewable energy sources accounted for 12% the world's primary energy demand in 2012. By 2050, 92% of the electricity produced worldwide will come from renewable energy sources in the basic Energy [R]evolution scenario. 'New' renewables - mainly wind, Pv, CSP and geothermal energy - will contribute 68% to the total electricity generation. Already by 2020, the share of renewable electricity production will be 31% and 58% by 2030. The installed capacity of renewables will reach about 7,800 GW in 2030 and 17,000 GW by 2050.

A 100% electricity supply from renewable energy resources in the Advanced scenario leads to around 23,600 GW installed generation capacity in 2050. By 2020, wind and Pv will become the main contributors to the growing market share. After 2020, the continuing growth of wind and Pv will be complemented by electricity from solar thermal, geothermal and ocean energy. The Energy [R]evolution scenarios will lead to a high share of flexible power generation sources (Pv, wind and ocean) of already 31% to 36% by 2030 and 53% to 55% by 2050. Therefore, smart grids, demand side management (DSM), energy storage capacities and other options need to be expanded in order to increase the flexibility of the power system for grid integration, load balancing and a secure supply of electricity.

Indian government has set ambitious target of 175 GW of renewables power by 2022, to achieve this government has formulated policies and frameworks, although there are some shortcomings when it comes to implementation is some segments and the challenges it poses on the existing grid system. Therefore this study is to understand the trends and other challenges in connection with the renewables.

Currently renewables account for 13% of the installed base, going forward the share is going to increase as government inches towards achieving the ambitious target of 175GW, though not will be grid ineractive but forms a formidable share. How this impact the integration with the grid and what challenges it bring is something needs to be addressed. On transmission side the gestatation of the solar or wind period is less whereas for a transmission network to be connected to the generation site is less therefore, there needs be a coordinated efforts to bridge the paces. As of now the grid frequency band is available so therefore renewable coming in and out will have not much of effect ( due to less renewables) and moreover hydro will take the impact and stabilize the grid. We have decent gas based power plant, although it is not commercial viable to use them as a peaker, coal based are meant for base load, however there is potential to keep upcoming supercritical power plant in part load to take the impact of renewable variations. Other options like pumped storage power plant, energy storage systems are available options to be explored and factored into grid system planning.

Battery storage is not yet ready for prime time to support renewable generation. In the meantime, we need flexible, efficient gas-fired power for primary supporter of renewables on the grid and to ensure transition away from the much dirtier high-carbon coal-fired power.

In the long run, at the grid level, batteries can be used to integrate renewable energy and supplement ancillary services, which help with minute-to-minute grid stability. Batteries will store wind energy produced at night and/or stabilise hourly variability in solar production. This will offset the need for gas-fired peakers that would otherwise be needed for this purpose.

## 2 Electricity sector in India

The utility electricity sector in India had an installed capacity of 280.32 GW as of 301 October 2015. Renewable Power plants constituted 28% of total installed capacity and Non-Renewable Power Plants constituted the remaining 72%. India became the world's third largest producer of electricity in the year 2013 with 4.8% global share in electricity generation surpassing Japan and Russia.

During the year 2014-15, the per capita electricity generation in India was 1,010 kWh with total electricity consumption (utilities and non-utilities) of 938.823 billion or 746 kWh per capita electricity consumption.

### 2.1 Captive power

The installed captive power generation capacity (above 1 MW capacity) in the industries is 47,082 as on 31 March 2015. Another 75,000 MW capacity diesel power generation sets (excluding sets of size above 1 MW and below 100 KVA) are also installed in the country.

### 2.2 Demand:

Over 300 million in the India have no access to electricity. The International Energy Agency estimates India will add between 600 GW to 1,200 GW of additional new power generation capacity before 2050. The technologies and fuel sources India adopts, as it adds this electricity generation capacity, may make significant impact to global resource usage and environmental issues.

## 2.3 Demand trends

During the fiscal year 2014-15, the electricity generated in utility sector is 1,030.785 billion KWh with a short fall of requirement by 38.138 billion KWh (-3.6%) against the 5.1% deficit anticipated. The peak load met was 141,180 MW with a short fall of requirement by 7,006 MW (-4.7%) against the 2.0% deficit anticipated. In a May 2015 report, India's Central Electricity Authority anticipated, for the 2015-16 fiscal year, a base load energy deficit and peaking shortage to be 2.1% and 2.6% respectively. Southern and North Eastern regions are anticipated to face energy shortage up to 11.3%. The marginal deficit figures clearly reflect that India would become electricity surplus during the 12th five-year plan period.

Despite an ambitious rural electrification programme, some 400 million Indians lose electricity access during blackouts. While 80% of Indian villages have at least an electricity line, just 52.5% of rural households have access to electricity. In urban areas, the access to electricity is 93.1% in 2008. The overall electrification rate in India is 64.5% while 35.5% of the population still live without access to electricity.

The 17th electric power survey of India report claims·

- Over 2010-11, India's industrial demand accounted for 35% of electrical power requirement, domestic household use accounted for 28%, agriculture 21%, commercial 9%, public lighting and other miscellaneous applications accounted for the rest.
- The electrical energy demand for 2016-17 is expected to be at least 1,392 Tera Watt Hours, with a peak electric demand of 218 GW.
- The electrical energy demand for 2021-22 is expected to be at least 1,915 Tera Watt Hours, with a peak electric demand of 298 GW.

McKinsey claims that India's demand for electricity may cross 300 GW, earlier than most estimates. To explain their estimates, they point to four reasons:

- India's manufacturing sector is likely to grow faster than in the past
- Domestic demand will increase more rapidly as the quality of life for more Indians improve
- About 125,000 villages are likely to get connected to India's electricity grid
- Blackouts and load shedding artificially suppresses demand; this demand will be sought as revenue potential by power distribution companies

A demand of 300 GW will require about 400 GW of installed capacity, McKinsey notes. The extra capacity is necessary to account for plant availability, infrastructure maintenance, spinning reserve and losses.

In 2010, electricity losses in India during transmission and distribution were about 24%, while losses because of consumer theft or billing deficiencies added another 10–15%.

Power cuts are common throughout India and the consequent failure to satisfy the demand for electricity has adversely effected India's economic growth.

## 2.4 Electricity generation

Power development in India was first started in 1897 in Darjeeling, followed by commissioning of a hydropower station at Sivasamudram in Karnataka during 1902.

State-owned and privately owned companies are significant players in India's electricity sector, with the private sector growing at a faster rate. India's central government and state governments jointly regulate electricity sector in India.

Major economic and social drivers for India's push for electricity generation include India's goal to provide universal access, the need to replace current highly polluting energy sources in use in India with cleaner energy sources, a rapidly growing economy, increasing household incomes, limited domestic reserves of fossil fuels and the adverse impact on the environment of rapid development in urban and regional areas.

### 2.4.1 Thermal power

Coal and lignite accounted for about 60% of India's total installed capacity. India's electricity sector consumes about 72% of the coal produced in the country.

India expects its projected rapid growth in electricity generation over the next couple of decades to be largely met by thermal power plants.

#### 2.4.1.1 Coal supply constraints

A large part of Indian coal reserve is of low calorific value and high ash content. The carbon content is low in India's coal, and toxic trace element concentrations are negligible. On average, the Indian power plants using India's coal supply consume about 0.7 kg of coal to generate a kWh, whereas United States thermal power plants consume about 0.45 kg of coal per kWh. India imported nearly 95 Mtoe of steam coal and coking coal which is 29% of total consumption to meet the demand in electricity, cement and steel production.

The high ash content in India's coal affects the thermal power plant's potential emissions. Therefore, India's Ministry of Environment & Forests has mandated the use of beneficiated coals whose ash content has been reduced to 34% (or lower) in power plants in urban, ecologically sensitive and other critically polluted areas, and ecologically sensitive areas.

#### 2.4.1.2 Natural gas supply constraints

The installed capacity of natural gas-based power plants and the ready to be commissioned with the commencement of natural gas supply is nearly 26,765 MW at the end of financial year 2014-15. These base load power plants are operating at overall PLF of 25% only due to severe shortage of Natural gas in the country. Imported LNG was too costly for the power generation. Many of these power stations are shut down throughout the year for lack of natural gas supply. Natural gas shortage for power sector alone is nearly 100 MMSCMD. The breakeven price for switching from imported coal to LNG in electricity generation is estimated near 6 US$/mmBtu. Indian government has taken steps to enhance the generation from the stranded gas based power plants for meeting peak load demand by waiving applicable import duties and taxes due to drastic fall in the LNG and crude oil international prices.

#### 2.4.1.3 Replacement of old thermal power plants

India's coal-fired, oil-fired and natural gas-fired thermal power plants are inefficient and offer significant potential for greenhouse gas ($CO_2$) emission reduction through better technologies. Compared to the average emissions from coal-fired, oil-fired and natural gas-fired thermal power plants in European Union (EU-27) countries, India's thermal power plants emit 50% to 120% more $CO_2$ per kWh produced. The central government has firmed up plans to shut down 11,000 MW of thermal power generation capacity that are at least 25 years old and replace with bigger size plants of super-critical pressure technology totalling to at least 20,000 MW with the coal being consumed presently by these old and small units.

### 2.4.2 Hydro power

India is endowed with economically exploitable and viable hydro potential assessed to be about 84,000 MW at 60% load factor. In addition, 6740 MW in terms of installed capacity from Small, Mini, and Micro Hydel schemes have been assessed. Also, 56 sites for pumped storage schemes with an aggregate installed capacity of 94,000 MW have been identified. It is the most widely used form of renewable energy. India is blessed with immense amount of hydro-electric potential and ranks 5th in terms of exploitable hydro-potential on global scenario.

The present installed capacity as of 31 May 2014 is approximately 40,661.41 MW which is 16.36% of total electricity generation in India. The public sector has a predominant share of 97% in this sector. National Hydroelectric Power Corporation (NHPC), Northeast Electric Power Company (NEEPCO), Satluj jal vidyut nigam (SJVNL), Tehri Hydro Development Corporation, NTPC-Hydro are a few public sector companies engaged in development of hydroelectric power in India.

Pumped storage schemes are perfect centralised peaking power stations for the load management in the electricity grid. Pumped storage schemes would be in high demand for meeting peak load demand and storing the surplus electricity as India graduates from electricity deficit to electricity surplus. They also produce secondary /seasonal power at no additional cost when rivers are flooding with excess water. Storing electricity by other alternative systems such as batteries, compressed air storage systems, etc. is more costlier than electricity production by standby generator. India has already established nearly 6800 MW pumped storage capacity which is part of its installed hydro power plants.

### 2.4.3 Nuclear power

As of 2013, India had 5.78 GW of installed electricity generation capacity using nuclear fuels. India's Nuclear plants generated 32455 million units or 3.75% of total electricity produced in India.

Nuclear Power Corporation of India Limited is a public sector enterprise, wholly owned by the Government of India, under the administrative control of its Department of Atomic Energy. Its objective is to implement and operate nuclear power stations for India's electricity sector. The state-owned company has ambitious plans to establish 63 GW generation capacity by 2032, as a safe, environmentally benign and economically viable source of electrical energy to meet the increasing electricity needs of India.

In 2011, India had 18 pressurised heavy water reactors in operation, with another four projects of 2.8 GW capacity launched. The country plans to implement fast breeder reactors, using plutonium based fuel. Plutonium is obtained by reprocessing spent fuel of first stage reactors. India successfully launched its first prototype fast breeder reactor of 500 MW capacity in Tamil Nadu, and now operates two such reactors.

India's share of nuclear power plant generation capacity is just 1.2% of worldwide nuclear power production capacity, making it the 15th largest nuclear power producer. Nuclear power provided 3% of the country's total electricity generation in 2011. India aims to supply 9% of it electricity needs with nuclear power by 2032.

India's government is also developing up to 62, mostly thorium reactors, which it expects to be operational by 2025. It is the "only country in the world with a detailed, funded, government-approved plan" to focus on thorium-based nuclear power. The country currently gets under 2% of its electricity from nuclear power, with the rest coming from coal (60%), hydroelectricity (16%), other renewable sources (12%) and natural gas (9%). It expects to produce around 25% of its electricity from nuclear power.

### 2.4.4 Non-conventional sources

Renewable energy in India is a sector that is still in its infancy.

India's electricity sector is amongst the world's most active players in renewable energy utilization, especially wind energy. As of 31 July 2015, India had grid connected installed capacity of about 36.64 GW non-conventional renewable technologies-based electricity capacity, about 13.32% of its total.

**Table 1: Renewal Energy Installed Capacity in India (as of 31 July 2015)**

| Type | Technology | Capacity (in MW) |
|---|---|---|
| **Grid Connected Power** | | |
| | Wind | 23,864.91 |
| | Small Hydel Power Projects | 4,130.55 |
| | Biomass Power & Gasification and Bagasse Cogeneration | 4,418.55 |
| | Solar | 4101.68 |
| | Waste to Power | 127.08 |
| ***Total - Grid Connected Power*** | | 36,642.77 |
| **Off-Grid/Captive Power** | | |

**Table 1: Renewal Energy Installed Capacity in India (as of 31 July 2015)**

| Type | Technology | Capacity (in MW) |
|---|---|---|
| | Biomass (non-bagasse) Cogeneration | 602.37 |
| | SPV Systems (>1 kW) | 234.35 |
| | Waste to Power | 146.51 |
| | Biomass Gasifiers | 180 |
| | Water Mills/Micro Hydel | 17.21 |
| | Aerogenerator/Hybrid Systems | 2.67 |
| *Total - Off-Grid/Captive Power* | | *1173.11* |
| *TOTAL* | | *37,815.88* |

As of August 2011, India had deployed renewal energy to provide electricity in 8846 remote villages, installed 4.4 million family biogas plants, 1800 microhydel units and 4.7 million square metres of solar water heating capacity. India anticipates to add another 3.6 GW of renewal energy installed capacity by December 2012.

India plans to add about 30 GW of installed electricity generation capacity based on renewal energy technologies, by 2017.

Renewable energy projects in India are regulated and championed by the central government's Ministry of New and Renewable Energy.

#### 2.4.4.1 Solar power

India is endowed with vast solar energy. The solar radiation of about 5,000 trillion kWh per year is incident over it's land mass with average daily solar power potential of 0.25 kWh per $m^2$ of used land area with the available commercially proven technologies. As of 13 July 2015, the installed capacity is 4097 MW. India expects to install an additional 10,000 MW by 2017, and a total of 100,000 MW by 2022.

There are vast tracts of land suitable for solar power in all parts of India exceeding 8% of its total area which are unproductive barren and devoid of vegetation. Part of waste lands (32,000 square km) when installed with solar power plants can produce 2000 billion Kwh of electricity (two times the total generation in the year 2013-14) with land productivity/yield of 1.5 million Rs per acre (6 Rs/kwh price) which is at par with many industrial areas and many times more than the best productive irrigated agriculture lands.

In 2015, the levelized tariff in US$ for solar electricity has fallen below 4 cents/kWh which is far cheaper than the electricity from coal based electricity generation plants in India

Land acquisition is a challenge to solar farm projects in India. Some state governments are exploring means to address land availability through innovation; for example, by exploring means to deploy solar capacity above their extensive irrigation canal projects, thereby harvesting solar energy while reducing the loss of irrigation water by solar evaporation.

#### 2.4.4.2 Wind power

India has the fifth largest installed wind power capacity in the world. In 2010, wind power accounted for 6% of India's total installed power capacity, and 1.6% of the country's power output.

The development of wind power in India began in the 1990s by Tamil Nadu Electric Board near Tuticorin, and has significantly increased in the last few years. Suzlon is the leading Indian company in wind power, with an installed generation capacity of 6.2 GW in India. Vestas is another major company active in India's wind energy initiative.

As December 2011, the installed capacity of wind power in India was 15.9 GW, spread across many states of India. The largest wind power generating state was Tamil Nadu accounting for 30% of installed capacity, followed in decreasing order by Maharashtra, Gujarat,Karnataka, and Rajasthan.

# 3 Energy policy of India

The energy policy of India is largely defined by the country's burgeoning energy deficit and increased focus on developing alternative sources of energy, particularly nuclear, solar and wind energy.

The energy consumption in India is the fourth biggest after China, USA and Russia. The total primary energy consumption from crude oil (29.45%), natural gas (7.7%), coal (54.5%), nuclear energy (1.26%), hydroelectricity (5.0%), wind power, biomass electricity and solar power is 595 Mtoe in the year 2013. In the year 2013, India's net imports are nearly 144.3 million tons of crude oil, 16 Mtoe of LNG and 95 Mtoe coal totalling to 255.3 Mtoe of primary energy which is equal to 42.9% of total primary energy consumption. About 70% of India's electricity generation capacity is from fossil fuels. India is largely dependent on fossil fuel imports to meet its energy demands — by 2030, India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption. In 2009-10, the country imported 159.26 million tonnes of crude oil which amounts to 80% of its domestic crude oil consumption and 31% of the country's total imports are oil imports.

## 3.1 Oil and gas

India imports nearly 75% of its 4.3 million barrels per day crude oil needs but exports nearly 1.25 million barrels per day of refined petroleum products which is nearly 30% of its total production of refined oil products. India has built surplus world class refining capacity using imported crude oil for exporting refined petroleum products . The net imports of crude oil is lesser by one fourth after accounting exports and imports of refined petroleum products.

During the financial year 2012–13, the production of crude oil is 37.86 million tons and 40,679 million standard cubic meters (nearly 26.85 million tons) natural gas. The net import of crude oil & petroleum products is 146.70 million tons worth of Rs 5611.40 billions. This includes 9.534 million tons of LNG imports worth of Rs. 282.15 billions. Internationally, LNG price (One mmBtu of LNG = 0.1724 barrels of crude oil (boe) = 24.36 cubic meters of natural gas = 29.2 litres diesel) is fixed below crude oil price in terms of heating value. LNG is slowly gaining its role as direct use fuel in road and marine transport without regasification. The breakeven price for switching from imported coal to LNG in electricity generation is estimated near 6 US$/mmBtu.

The state-owned Oil and Natural Gas Corporation (ONGC) acquired shares in oil fields in countries like Sudan, Syria, Iran, and Nigeria - investments that have led to diplomatic tensions with the United States. Because of political instability in the Middle East and increasing domestic demand for energy, India is keen on decreasing its dependency on OPEC to meet its oil demand, and increasing its energy security. Several Indian oil companies, primarily led by ONGC and Reliance Industries, have started a massive hunt for oil in several regions in India, including Rajasthan, Krishna Godavari Basin and north-eastern Himalayas. India is developing an offshore gas field in Mozambique. The proposed Iran-Pakistan-India pipeline is a part of India's plan to meet its increasing energy demand.

### 3.2 Coal

India has the world's 4th largest coal reserves. In India, coal is the bulk of primary energy contributor with 54.5% share out of the total 595 Mtoe in the year 2013. India is the third top coal producer in 2013 with 7.6% production share of coal (including lignite) in the world. Top five hard and brown coal producing countries in 2013 (2012) are (million tons): China 3,680 (3,645), United States 893 (922), India 605 (607), Australia 478 (453) and Indonesia 421 (386). However, India ranks fifth in global coal production at 228 mtoe (5.9%) in the year 2013 when its inferior quality coal tonnage is converted in to tons of oil equivalent. Coal-fired power plants account for 59% of India's installed electricity capacity. After electricity production, coal is also used for cement production in substantial quantity. In the year 2013, India imported nearly 95 Mtoe of steam coal and coking coal which is 29% of total consumption to meet the demand in electricity, cement and steel production.

Gasification of coal or lignite produces syngas or coal gas or coke oven gas which is a mixture of hydrogen, carbon monoxide and carbon dioxide gases. Coal gas can be converted in to synthetic natural gas (SNG) by using Fischer–Tropsch process at low pressure and high temperature.

### 3.3 Bio-fuels

Gasification of bio mass yields wood gas or syngas which can be converted in to substitute natural gas by Methanation. Nearly 750 million tons of nonedible (by cattle) biomass is available annually in India which can be put to higher value addition use and substitute imported crude oil, coal, LNG, urea fertiliser, nuclear fuels, etc. It is estimated that renewable and carbon neutral biomass resources of India can replace present consumption of all fossil fuels when used productively.

#### 3.3.1 Hydrogen energy

Hydrogen Energy programme started in India after joining the IPHE (International Partnership for Hydrogen Economy) in the year 2003. There are nineteen other countries including Australia, USA, UK, Japan, etc. This global partnership helps India to set up commercial use of Hydrogen gas as an energy source. This will be implemented through Public Private Partnership.

### 3.4 Nuclear power

India boasts a quickly advancing and active nuclear power programme. It is expected to have 20 GW of nuclear capacity by 2020, though they currently stand as the 9th in the world in terms of nuclear capacity.

India has also done a great amount of work in the development of a Thorium centered fuel cycle. While Uranium deposits in the nation are extremely limited, there are much greater reserves of Thorium and it could provide hundreds of times the energy with the same mass of fuel. The fact that Thorium can theoretically be utilized in heavy water reactors has tied the development of the two. A prototype reactor that would burn Uranium-Plutonium fuel while irradiating a Thorium blanket is under construction at the Madras/Kalpakkam Atomic Power Station.

Uranium used for the weapons programme has been separate from the power programme, using Uranium from scant indigenous reserves.

### 3.5 Hydro electricity

The installed capacity of hydro power is 41,267 MW as of March, 2015. India ranks sixth in hydro electricity generation globally after China, Canada, Brazil, USA and Russia in the year 2013. During the year 2013, the total hydro electricity generation in India is 132 billion kWh which works out to 25,000 MW at 60% capacity factor. Till now, hydroelectricity sector is dominated by the state and central government owned companies but this sector is going to grow faster with the participation of private sector for developing the hydro potential located in the Himalaya mountain ranges including north east of India. However the hydro power potential in central India forming part of Godavari, Mahanadi andNarmada river basins has not yet been developed on major scale due to potential opposition from the tribal population.

India has already established nearly 6800 MW pumped storage capacity which is part of its installed hydro power plants.

### 3.6 Wind power

India has the fifth largest installed wind power capacity in the world. As of 30th June 2015, the installed capacity of wind power was 24 GW an increase of 2312 MW over the previous year Wind power accounts nearly 8.5% of India's total installed power generation capacity and generated 28.314 billion kWh in the fiscal year 2014-15 which is nearly 2.6% of total electricity generation. The capacity utilisation factor is nearly 15 % in the fiscal year 2014-15. The Ministry of New and Renewable Energy (MNRE) of India has announced a revised estimation of the potential wind power resource (excluding offshore wind power potential) from 49,130 MW assessed at 50m Hub heights to 102,788 MW assessed at 80m Hub height at 15% capacity factor.

### 3.7 Solar energy

India's solar energy insolation is about 5,000 T kWh per year (i.e. ~ 600 TW), far more than its current total primary energy consumption. India's long-term solar potential could be unparalleled in the world because it has the ideal combination of both high solar insolation and a big potential consumer base density. With a major section of its citizens still surviving off-grid, India's grid system is considerably under-developed. Availability of cheap solar can bring electricity to people, and bypass the need of installation of expensive grid lines. Also a major factor influencing a region's energy intensity is the cost of energy consumed for temperature control. Since cooling load requirements are roughly in phase with the sun's intensity, cooling from intense solar radiation could make perfect energy-economic sense in the subcontinent, whenever the required technology becomes competitively cheaper.

There are vast tracts of land suitable for solar power in all parts of India exceeding 8% of its total area which are unproductive barren and devoid of vegetation. Part of waste lands (32,000 square km) when installed with solar power plants can produce 2000 billion kWh of electricity (two times the total generation in the year 2013-14) with land productivity/yield of 1.5 million Rs per acre (6 Rs/kWh price) which is at par with many industrial areas and many times more than the best productive irrigated agriculture lands. There is unlimited scope for solar electricity to replace all fossil fuel energy requirements (natural gas, coal, lignite and crude oil) if all the marginally productive lands are occupied by solar power plants in future. The solar power potential of India can meet perennially to cater per capita energy consumption at par with USA/Japan for the peak population in its demographic transition.

### 3.8 Policy framework

In general, India's strategy is the encouragement of the development of renewable sources of energy by the use of incentives by the federal and state governments. Other examples of encouragement by incentive include the use of nuclear energy (India Nuclear Cooperation Promotion Act), promoting wind farms such as Muppandal, and solar energy (Ralegaon Siddhi).

A long-term energy policy perspective is provided by the Integrated Energy Policy Report 2006 which provides policy guidance on energy-sector growth. Increasing energy consumption associated primarily with activities in transport, mining, and manufacturing in India needs rethinking India's energy production.

Recent steep fall in international oil prices due to shale oil production boom, would tilt the energy policy in favour of crude oil / natural gas.

The per capita electricity consumption is low compared to many countries despite cheaper electricity tariff in India. Despite low electricity per capita consumption in India, the country is going to achieve surplus electricity generation during the 12th plan (2012 to 2017) period provided its coal production and transport infrastructure is developed adequately. India has been exporting electricity to Bangladesh and Nepal and importing excess electricity in Bhutan. Surplus electricity can be exported to the neighbouring countries in return for natural gas supplies from Pakistan, Bangladesh and Myanmar.

Bangladesh, Myanmar and Pakistan are producing substantial natural gas and using for electricity generation purpose. Bangladesh, Myanmar and Pakistan produce 55 million cubic metres per day (mcmd), 9 mcmd and 118 mcmd out of which 20 mcmd, 1.4 mcmd and 34 mcmd are consumed for electricity generation respectively Whereas the natural gas production in India is not even adequate to meet its non-electricity requirements.

Bangladesh, Myanmar and Pakistan have proven reserves of 184 billion cubic metres (bcm), 283 bcm and 754 bcm respectively. There is ample opportunity for mutually beneficial trading in energy resources with these countries. There is ample trading synergy for India with its neighbouring countries in securing its energy requirements.

# 4 Overview of renewable energy sector in India

Renewables contributes about 13% (36.4 GW) of the total installed capacity (280 GW) in the country (CEA, 2015). Around 96.7% of the installed capacity is grid-connected and off-grid power constitutes a small share (MNRE, 2015). Wind continues to be the mainstay of grid connected renewable power in India. Globally, India ranks sixth in terms of renewable electric power global capacity. The historical growth of renewables has been tremendous with a compounded annual growth rate of 22% over the last decade (2002–2012). The total gird-interactive Wind and Solar power capacities as on 30th September 2015 is 24376.26 MW and 4344.91 MW respectively.

Further, the Government of India has projected to add 175,000 MW of renewables by end of the Thirteenth Plan (2022), of which solar is expected to contribute 57%. The policy thrust to renewables has been significant and specific targets have been announced to accelerate the deployment of renewable energy. The National Action Plan on Climate Change (NAPCC, 2008) envisages a dynamic RPO target of 10% at the national level for 2015 with an annual increase of 1% so as to reach around 15% by2020.

## 4.1 Legal and institutional framework

The key legislation which guides the development of renewable energy in India is the Electricity Act, 2003. The Electricity Act 2003 mandates the State Electricity Regulatory Commissions (SERCs) to promote generation of electricity from renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any person. The National Tariff Policy, 2006, directs SERC to fix certain minimum percentages for purchase of renewable power.

There are multiple agencies involved in the renewable energy sector in India. At the central level, the Ministry of New and Renewable Energy (MNRE) is the nodal ministry of the Government of India (GoI) for all matters relating to new and renewable energy. The broad aim of the ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country. MNRE also conducts resource assessments for renewable energy and supports R&D in renewable energy technologies. There are specialized technical institutions set up under MNRE such as the Solar Energy Centre, C-WET, and Sardar Swaran Singh National Institute of Renewable Energy (SSS-NIRE), which serve as technical focal institutes for solar, wind, and bio-energy, respectively.

At the state level, there are nodal agencies and departments which operate under the purview of the respective state governments for the effective implementation of all renewable energy and cogeneration schemes. These agencies promote renewable energy deployment at the local level by channelling central-level subsidies, implementing demonstration projects, and providing assistance to interested parties. Many of the state agencies are also designated agencies for the implementation of the Energy Conservation Act, 2001. The MNRE provides grants to these agencies for their recurring and non-recurring expenditure. Financial assistance to renewable energy projects is provided through the Indian Renewable Energy Development Agency (IREDA) – the financial arm of the MNRE – which provides loans and also channels funds and other initiatives to promote renewable energy. IREDA is registered as a non-banking financial company and arranges its resources through market borrowing and lines of credit from bilateral and multilateral lending agencies. In addition, there are a number of government institutions whose mandate encompasses the renewable energy sector. For example, the Ministry of Power (MoP) is responsible for the national electricity policy and national tariff policy, both of which play a key role in promoting procurement of renewable energy-based power. The Ministry of Environment and Forests (MoEF) is responsible for providing environmental clearances for renewable energy projects. The institutions classified according to their roles in the renewable energy sector are depicted.

Table 2: Role of state andcentral government agencies in public development, regulation, and promotion of renewable energy

| Level | Central government (Ministry of Power/ Ministry of Finance) | MNRE | CERC |
|---|---|---|---|
| Central | • Develops national electricity tariff policies, which also cover renewable energy<br>• Provides fiscal incentives for promoting renewable energy | • Develops national renewable energy laws<br>• Sets technical standards for renewable energy<br>• Conducts resource assessments for renewable energy; supports R&D in renewable energy technologies<br>• Promotes effective use of information technology for renewable energy, manages database<br>• Reviews renewable energy programmes to understand their effectiveness and efficiency | • Sets guidelines for feed-in tariff design for different renewable energy technologies<br>• Regulates the regional electricity corporation mechanism<br>• Regulates interstate open access, and third party sales |
| State | State government | State nodal agency | SERCs |
| | • Develops state-level renewable energy policy<br>• Provides fiscal incentives for promoting renewable energy sources | • Conducts resource assessments for various renewable energy sources<br>• Allocates renewable energy projects and progress monitors<br>• Provides facilitation services to project developers — Facilitates clearances and land acquisition<br>• Creates awareness and educates the masses about adoption of renewable energy<br>• Maintains database on renewable energy sources | • Develops feed-in tariff methodologies for different renewable energy technologies<br>• Determines RPOs and enforcement mechanism<br>• Sets regulations on intrastate wheeling, open access, and third party sale |

*Source:* World Bank (2010).

## 4.2 Policy framework:

The Government of India (GoI) has enacted several policies which support the expansion of renewable energy. The National Electricity Policy 2005 allows the SERCs to establish a preferential tariff for electricity generated from renewable sources to enable them to be cost-competitive. The Tariff Policy 2006 requires fixation by SERCs of a minimum percentage of RPO from such sources taking into account availability of such resources in the region and its impact on retail tariffs. The Tariff Policy also states that procurement of renewable power for future requirements shall be done through a competitive bidding process and in the long-term, renewable energy technologies would need to compete with other sources in terms of full costs. To this effect, the MNRE brought out the guidelines and standard bidding documents for grid-connected renewable energy in December 2012 after several rounds of consultations with stakeholders. The guidelines for competitive procurement have been framed under Section 63 of the Electricity Act, 2003 which states: Notwithstanding anything contained in Section 62, the Appropriate Commission shall adopt the tariff if such tariff has been determined through transparent process of bidding in accordance with the guidelines issued by the Central Government. While the allocation for solar has already been done through competitive bidding under the National Solar Mission and state solar policies, these guidelines seek to also cover all other renewable energy sources, such as wind, small hydro, geothermal, biomass, tidal, etc. The guidelines seek to create competition in the grid-connected renewable energy sector, bring transparency and fairness in allocation, reduce information asymmetries among bidders, bring standardization, and hence reduce ambiguity in the whole process of project allocation. The guidelines are on the same lines as drafted by the MoP for conventional power wherein bidding takes place through two routes: (i) in the first case where location and technology is not specified by the procurer and hence the developer has full freedom to decide these factors and (ii) in the case with location- and fuel-specific bidding, i.e., the procurer specifies the location and/or fuel and is also responsible for arranging the same. States such as Rajasthan and Karnataka have adopted the competitive bidding model. Rajasthan has announced that it may also allow competitive reverse bidding for wind parks. The flagship policy initiative for solar energy in India is the Jawaharlal Nehru National Solar Mission (JNSSM) launched in 2010, which has set ambitious goals on generation capacity additions from solar technology — solar thermal and solar photovoltaic — in terms of both grid-connected and offgrid applications. The Mission has adopted a three-phase approach, spanning the period of the Eleventh Plan and the first year of the Twelfth Plan (up to 2012–13) as Phase I. The remaining four years of the Twelfth Plan (2013–17) has been marked as Phase II and the Thirteenth Plan (2017–22) will be Phase III of the project. 3 The JNNSM establishes a national-level policy framework for solar energy utilization including power generation in India. The first phase of the mission has seen significant progress in the deployment of utility-scale solar projects enabled by the reverse bidding mechanism introduced by the Government of India. To achieve 500 MW of PV and 500 MW of solar thermal, the central government conducted two batches of reverse auctions (Batch 1 and Batch 2) Phase I of the mission has been concluded, though not all projects have been commissioned. Post the launch of JNNSM, several significant regulatory and policy developments have taken place. The National Tariff Policy was amended in January 2011 prescribing solar-specific RPOs to be increased from a minimum of 0.25% in 2012 to 3% by 2022. The Central Electricity Regulatory Commission (CERC) and State Electricity

Regulatory Commissions (SERCs) have issued various regulations including solar RPOs, Renewable Energy Certificates (REC) framework, tariff, grid connectivity, forecasting, etc., for promoting solar energy.

JNNSM in many ways is a first of its kind national-level programme for solar energy in India. The process of price discovery in JNNSM was unique, discovered through a process of reverse bidding carried out in two successive batches. This was introduced mainly because of the overwhelming response from developers who had bid for more than 30 times of the capacity on offer. Applications were received for more than 5,000 MW much higher than 1,100 MW on offer. Project developers were selected based on discounts offered on CERC-determined tariffs. It was executed through NTPC Vidyut Vyapar Nigam (NVVN) which acted as the nodal agency to purchase 1,000 MW of solar power from the project developers, bundle it with the unallocated power available from the NTPC coal-based stations, and sell this 'bundled' power to the Distribution Utilities. This new concept called Bundling was introduced to keep the cost of bundled power low compared to the cost of only solar power. Reverse bidding resulted in steep fall in prices to as low as Rs 5.45/kWh. Batch 1 saw a 32% reduction in solar PV tariffs and a 25% reduction in solar thermal prices (from the CERC-determined tariffs). In Batch 1, around 150 MW solar PV projects and 470 MW solar thermal projects were allocated. In Batch 2, the remaining 350-MW solar PV projects were allotted. Batch 2 saw an ever steeper reduction in prices, which were approximately 43% lesser than the CERC-determined prices. Some state projects which were already at different stages of development were also given the option of migrating to the JNNSM, scheme subject to the interest of developers and state governments. A total of 16 projects of 84-MW capacity were selected under the migration scheme. Apart from these large-scale grid-connected plants, small rooftop plants – of capacity less than 2 MW each – totalling to 88MW capacity, were also allotted under Generation based incentive (GBI ) scheme in the Rooftop PV and Small Solar Power Generation Programme (RPSSGP). While initially there were concerns regarding the bidding process which allowed some small inexperienced players to quote aggressive prices, this was allayed with all but one project coming online. Furthermore, with stringent penalty clauses and guidelines set by the govt. stating that firms that do not commission their projects within the stipulated time (12 months for photovoltaic and 28 months for CST) stand to lose significant amounts of money relative to their initial capital investments, the process ensured that checks and balances were in place. Also since tariffs are generation based, any underperformance results in losses to the project developer, therefore incentives are in place to ensure appropriate performance (Deshmukh et al. 2011b).

### 4.3 State solar policies:

Encouraged by the success of JNNSM in 2010, several states have announced their own state solar policies and programmes with the exception of Gujarat which took a lead in announcing its solar policy a year before JNNSM. State policies are broadly aligned with the JNNSM objectives; however, there are some deviations as well. For example, many of the state policies have not mandated domestic content requirement for the projects as opposed to the approach taken by JNNSM. Gujarat, Karnataka, Tamil Nadu, and Andhra Pradesh have not mandated domestic content requirement while Rajasthan has a Domestic Content Requirement (DCR) clause.

**Table 3: State with solar policies in India (As on 31 Nov 2013)**

**Table 1: States with solar policies in India (As on 31 Nov 2013)**

| State | Month of release | Target addition (MW) |
|---|---|---|
| Andhra Pradesh | September 2012 | Has not set a target |
| Chhattisgarh | October 2012 | 500–1,000 MW by 2017 |
| Gujarat | 2009 | 500 MW |
| Karnataka | 2011 | 350 MW by 2016 |
| Kerala | November 2013 | 500 MW by 2017 and 2,500 MW by 2030 |
| Madhya Pradesh | January 2012 | |
| Punjab* | December 2012 | 1,000 MW by 2022 |
| Rajasthan | 2011 | 12,000 MW by 2022 |
| Tamil Nadu | October 2012 | 3,000 MW by 2015 |
| Uttarakhand | September 2013 | 500 MW by 2017 |
| Uttar Pradesh | 1st Quarter of 2013 | 500 MW by 2017 |

*Note:* *Solar targets are part of the Renewable Energy Policy

Table 4: Overview of state solar policies

Table 2: Overview of state solar policies

| | Tamil Nadu | Andhra Pradesh | Karnataka | Punjab | Madhya Pradesh | Uttar Pradesh | Rajasthan | Total/ average |
|---|---|---|---|---|---|---|---|---|
| Allocation date | June 2013 | June 2013 | Apr 2012 | July 2013 | May 2012 | July 2013 | Mar 2013 | Most of the allocations happened in the first half of 2013 |
| PPAs signed as on September 2013 (MW) | 0 | 60 | 60 | 0 | 225 | 0 | 75 | 420 |
| Tariff (INR/ kWh) | 6.48 (with an escalation of 5% p.a. for the first 10 years) | 6.49 | 7.94–8.5 (60 MW) 5.51–8.05 (130 MW) | 7.2–8.63 | 7.9–8.05 | 8.01–9.27 | 6.45 | 7.59 |
| New PPAs expected to be signed by the year end (MW) | 500 | 80 | 100 | 230 | 0 | 120 | 0 | 1,330 |
| Further allocations (MW) | None | 500* | None | None | None | None | RfS for 1 MW x 50 announced | 550 |
| Delayed projects (MW) | NA | NA | 50 | NA | 120 | NA | NA | 170 |
| Expected commissioning date of projects under deployment | Dec 2014 | Dec 2014 | Mar 2014 (50 MW) Dec 2014 (110 MW) | Dec 2014 | Mar 2014 | Dec 2014 | Mar 2014 | 250 MW by March 2014; 1,240 MW by Dec 2014 |
| Expected period of procurement | Jan 14–Mar 14 | Jan 14 – Mar 14 | Ongoing | Jan 14 – Mar 14 | Ongoing | Jan 2014 – Mar 2014 | Ongoing | Most of the procurements will take place between Jan–Mar 2014 |

*Source*: (Bridge to India, 2013)

While the introduction of state solar policies are certainly good steps in complementing the JNNSM, and attracting private investment, the way in which the bidding process was managed in some states has created regulatory uncertainty and negatively impacted the investor's confidence. The capacity allocation process in Tamil Nadu and Andhra Pradesh were modified during the course of bidding. Andhra Pradesh announced a change in allocation policy after the completion of bidding, where the lowest bid (L1) 5 process was changed to a fixed tariff of Rs 6.49/kwh. In Tamil Nadu, the state utility managing the bidding TANGEDCO, revised the tariff and extended the deadline for interest submission impacting the bidding process.

## 4.4 Regulatory framework:

The regulatory oversight in the sector is provided by the CERC and SERCs. However, at present, only grid-connected renewable energy based systems come under the regulatory purview. The offgrid decentralized renewable energy based systems are not regulated in the present set-up. For the grid-interactive systems, the CERC sets guidelines for feed-in tariffs for different renewable energy technologies and issues regulations for interstate open access. The SERCs determine feed-in tariffs for different renewable energy technologies, set RPOs for states, issue regulations on open access, third party sales, etc. The SERC have the most direct impact on feed-in tariffs, RPOs, and openaccess charges and they are loosely bound by the directives and guidelines of the CERC .As on 31 January 2013, 27 states have issued RPO regulations and 25 states have come out with regulations for REC (including draft regulations) (Renewable Energy Regulatory Framework, MNRE, 2012). Most of the states have announced feed-in tariffs for renewables and regulations for intra-state open access. It is important to note that the final say on how renewable energy projects should be developed rests with state-level agencies and the progress on the ground depends mainly on state-level policies on feed-in tariffs and RPOs, evacuation, clearances, open access, and facilitation from state nodal agencies.

The regulatory framework for renewables in India is continuously evolving with increasing penetration and progressively higher shares coming from these sources. The GoI has brought the Renewable Regulatory Fund (RRF) regulations in 2010 as per the provisions of the Indian Electricity Grid Code Regulations, 2010. This fund seeks to bring in better prediction of generation by wind/solar generators and participation in scheduling and hence better system operation. It aims to achieve better generation prediction using weather forecasting tools and immunize wind generators from paying deviation in Unscheduled Interchange (UI )charges up to a certain level of variation, beyond which the deviation charges will be socialized across states. The key renewable energy support policies implemented in India for renewable energy promotion have been summarized in

**Table 5: Key renewable energy policies implementing in India for grid-based projects**

**Table 3: Key renewable energy policies implemented in India for grid-based projects**

| | Solar | Wind | Biomass | Small Hydro |
|---|---|---|---|---|
| **Targets** | | | | |
| **Targets** | • | • | • | • |
| **Price-based Instruments** | | | | |
| **Feed-in tariff** | • | • | • | • |
| **Generation-based incentives** | • | • | o | o |
| **Concessional wheeling charges for captive users** | • | • | • | o |

| | | | | |
|---|---|---|---|---|
| **Net metering** | • | o | o | o |
| **Banking** | o | • | • | o |
| **Carbon market/CDM transactions** | • | • | • | • |
| **Renewable Energy Certificates (REC)** | • | • | • | • |
| **Quantity-based Instruments and Procurement Mechanisms** | | | | |
| **Renewable Purchase Obligation (RPO)** | • | • | • | o |
| **Competitive bidding/auctions** | • | o | o | • |
| **Investment Cost Reduction/Financial Incentives** | | | | |
| **Accelerated depreciation** | • | o | • | • |
| **Green Funds (e.g., soft loans, grants)** | • | • | • | • |
| **Capital subsidy** | o | o | o | o |
| **Equity participation** | • | • | • | • |
| **Tax Exemptions** | • | • | • | • |
| **Custom/excise duty exemption** | • | • | • | • |
| **Grid connection and dispatch** | • | • | • | • |
| **Other Measures** | | | | |
| **R&D funds** | • | • | • | • |
| **Single window clearance systems** | • | • | • | • |

*Source*: Adapted from (Azuela & Barroso, 2011)

# 5 Jawaharlal Nehru National Solar Mission

The Jawaharlal Nehru National Solar Mission was launched on the 11th January, 2010 by our Prime Minister, Dr. Manmohan Singh. The Mission has set the ambitious target of deploying 20,000 MW of grid connected solar power by 2022 and aims at reducing the cost of solar power generation in the country through (i) long term policy; (ii) large scale deployment goals; (iii) aggressive R&D; and (iv) domestic production of critical raw materials, components and products. It has been envisaged to achieve grid tariff parity by 2022.

The Union Cabinet chaired by the Prime Minister, Shri Narendra Modi, gave its approval for stepping up of India's solar power capacity target under the Jawaharlal Nehru National Solar Mission (JNNSM) by five times, reaching 1,00,000 MW by 2022. The target will principally comprise of 40 GW Rooftop and 60 GW through Large and Medium Scale Grid Connected Solar Power Projects. With this ambitious target, India will become one of the largest Green Energy producers in the world, surpassing several developed countries.

The total investment in setting up 100 GW will be around Rs. 6,00,000 cr. In the first phase, the Government of India is providing Rs. 15,050 crore as capital subsidy to promote solar capacity addition in the country. This capital subsidy will be provided for Rooftop Solar projects in various cities and towns, for Viability Gap Funding (VGF) based projects to be developed through the Solar Energy Corporation of India (SECI) and for decentralized generation through small solar projects. The Ministry of New and Renewable Energy (MNRE) intends to achieve the target of 1,00,000 MW with targets under the three schemes of 19,200 MW.

Apart from this, solar power projects with investment of about Rs. 90,000 crore would be developed using Bundling mechanism with thermal power. Further investment will come from large Public Sector Undertakings and Independent Power Producers (IPPs). State Governments have also come out with State specific solar policies to promote solar capacity addition.

Scaling up of Grid Connected Solar Power Projects from 20,000 MW by the year 2021-22, to 1,00,000 MW by the year 2021-22 under National Solar Mission.

Table 6: Year-wise Targets (in MW)

| Category | 2015-16 | 2016-17 | 2017-18 | 2018-19 | 2019-20 | 2020-21 | 2021-22 | Total |
|---|---|---|---|---|---|---|---|---|
| Rooftop Solar Project | 200 | 4,800 | 5,000 | 6,000 | 7,000 | 8,000 | 9,000 | 40,000 |
| Ground Mounted Solar Project | 1,800 | 7,200 | 10,000 | 10,000 | 10,000 | 9,500 | 8,500 | 57,000 |
| Total | 2,000 | 12,000 | 15,000 | 16,000 | 17,000 | 17,500 | 17,500 | 97,000 |

## 5.1 JNNSM Phase 1

The first phase of this mission aims to commission 1000 MW of grid-connected solar power projects by 2013. The implementation of this phase is in hands of a subsidiary of National Thermal Power Corporation, the largest power producer in India. The subsidiary, NTPC Vidyut Vyapar Nigam Ltd (NVVN), laid out guidelines for selection of developers for commissioning grid connected solar power projects in India. NVVN will sign power purchase agreements with the developers. Since NVVN is not a utility, it will sell purchased power to different state utilities via separate agreements.

### 5.1.1 Technologies

For Phase 1 projects, NVVN started with a proposal for 50:50 allocations towards solar PV and solar thermal. The latter is quite ambitious given India has no operational solar thermal projects and less than 10MW of solar PV projects. While growing at a rapid pace lately, solar thermal technologies are still evolving globally. The first batch of projects allotted for Phase 1 included 150MW of Solar PV and 500MW of Solar Thermal. NVVN issued Request for Selection document outlining criteria for selection of projects under the Phase 1.

A growing solar PV industry in India is hoping to take off by supplying equipment to power project developers. Well known equipment manufacturers started increasing their presence in India and may give competition to local Indian manufacturers. Due to generally high temperatures in India, crystalline silicon-based products are not the most ideal ones. Thin film technologies like amorphous silicon, CIGS and CdTe could be more suitable for higher temperature situations.

Solar thermal technology providers barely have a foothold in India. A few technology providers like Abengoa have some Indian presence in anticipation of demand from this mission.

### 5.1.2 NVVN Solar PV allotment process for Phase 1

NVVN issued Request for Selection notice for allotment of capacity to Independent Power Producers (IPPs). 150MWs of Solar PV and 470MW of Solar Thermal were up for allotment under the first batch of Phase 1 projects. Project size per IPP was fixed at 5MW for Solar PV and 100MW for Solar Thermal projects. To avoid allocating entire capacity to a select few corporate, guidelines required no two projects to have the same parent company or common shareholders. In case of over subscription, a reverse bidding process was to be used to select the final IPPs based on lowest tariff they offer. Several hundred IPPs responded to this RfS. The final 30 solar PV projects selected had bids between INR 10.95 to INR 12.75. The Solar Thermal projects selected had bids between INR 10.24 to INR 12.24. PPAs were signed with IPPs.

## 5.2 JNNSM Phase-II, Batch I

JNNSM Phase-II, Batch-I: Solar Energy Corporation of India (SECI) was designated the nodal agency by MNRE for implementation of the first scheme of setting up of 750 MW of Grid Connected Solar PV Projects with VGF support from National Clean Energy Fund (NCEF). It entails purchase of power from developers at a fixed tariff of Rs.5.45/unit (Rs.4.75/unit in case benefit of Accelerated Depreciation is availed) and payment of VGF to the developers as per their bids, limited to a maximum of Rs.2.5 crore/MW. Bids for the VGF sought (reverse bidding on the VGF) were invited by SECI in October, 2013 in two Categories: 375 MW Capacity under DCR (Domestic Content Requirement) and 375 MW Capacity under Open Category.

Power Purchase Agreements (PPAs) with the successful bidders/ developers have since been signed in March 2014. The Projects have a Schedule of Commissioning within 13 Months from the Date of Signing of PPA i.e. up to April 2015.

Total capacity of 555 MW have been commisioned till 19th June 2015 under this scheme.

### 5.2.1 Phase-II, Batch-III

SECI is designated as the nodal agency for implementation of MNRE schemes for developing grid connected solar power capacity through VGF mode in the country. Under the Batch-III of Phase-II JNNSM, it is envisaged to add further a total solar PV capacity of 2000 MW.

The Solar Projects of 2000 MW Capacity under the State Specific VGF Scheme will be set up in the Solar Parks of various states, to be developed through coordinated efforts of Central and State Agencies. As implementation of solar parks have begun recently, it could be possible that Solar Parks in some of the States do not become available soon. For such States, Solar Projects would be allowed to be located outside solar parks with land being provided either by the State Government, or arranged by the Solar Power Developers (SPDs).

Out of the total capacity of 2000 MW, a capacity of 250 MW will be earmarked for bidding with Domestic Content Requirement (DCR)

## 5.3 Solar Park

Ministry of New and renewable Energy (MNRE) has drawn a scheme to set up number of solar parks across various states in the country, each with a capacity of Solar Projects generally above 500 MW. The Scheme proposes to provide financial support by Government of India to establish solar parks with an aim to facilitate creation of infrastructure necessary for setting up new solar power projects in terms of allocation of land, transmission and evacuation lines, access roads, availability of water and others, in a focused manner.

Solar Energy Corporation of India (SECI), a central public sector enterprises u nder MNRE , has been implementing various schemes to develop solar sector in the country. As per the policy, these solar parks will be developed in collaboration with the State Governments. The implementation agency would be Solar Energy Corporation of India (SECI) on behalf of Government of India (GOI). SECI will handle funds to be made available under the scheme on behalf of GOI. The states shall designate a nodal agency for implementation of the solar park.

The Solar Park is a concentrated zone of development of solar power generation projects. As part of Solar park development, land required for development of Solar Power Projects with cumulative capacity generally 500 MW and above will be identified and acquired and various infrastructure like transmission system, water, road connectivity and communication network etc., will be developed. The parks will be characterized by well-developed proper infra-structure where the risk & gestation period of the projects will be minimized. At the state level, the solar park will enable the states to bring in significant investment from project developers in Solar Power sector, to meet its Solar Purchase Obligation (SPO) mandates and provide employment opportunities to local population. The state will also be able to reduce its carbon footprint by avoiding emissions equivalent to the solar park's generated capacity.

## 6 Solar capacity addition and Implementation status of Solar Projects:

The Government of India has officially raised the National Solar Mission's solar installation target from 22 GW to 100 GW by 2022. The target was approved by the Cabinet and is split between large-scale projects (60 GW) and rooftop projects (40 GW).

After a long wait, the solar market in India is finally taking off. This year (2015) total solar capacity may exceed 2500MW.

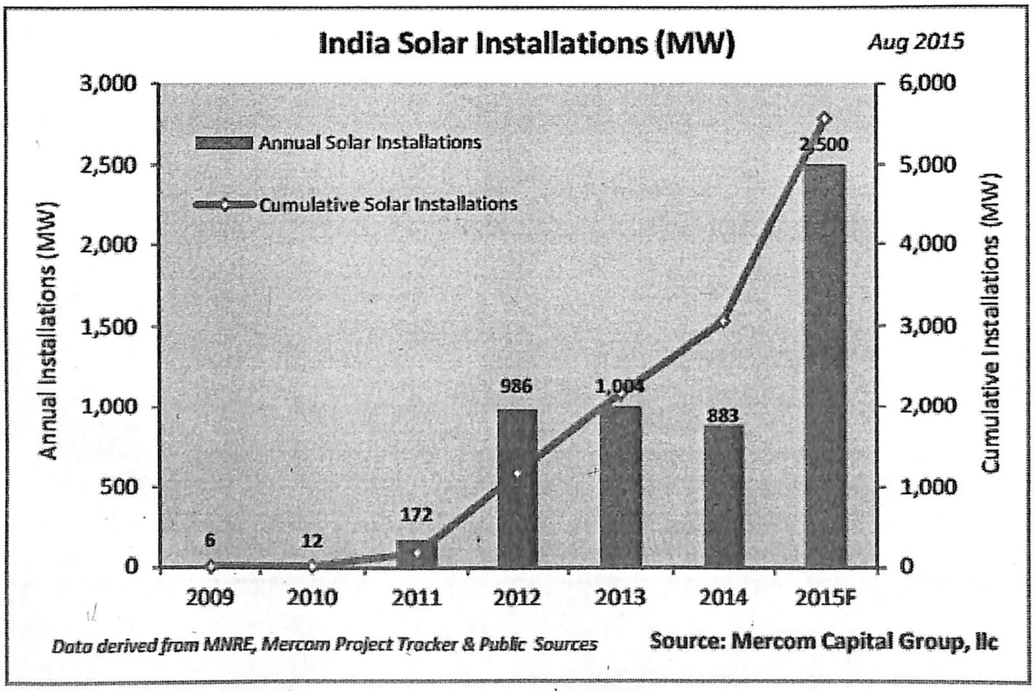



Figure1: India Solar Installation (MW)

The Government of India has officially raised the National Solar Mission's solar installation target from 22 GW to 100 GW by 2022. The target was approved by the

Cabinet and is split between large-scale projects (60 GW) and rooftop projects (40 GW).

Estimating cumulative installations at 5.0 GW by the end of 2015, 95 GW at a compound annual growth rate of 63 percent is required to reach the 100 GW goal by 2022. While 60 GW may be achievable with the right policies in place, 40 GW of rooftop in six years is very aggressive considering cumulative rooftop installations in India are just under 250 MW. China, which has a similar installation goal, has faced a host of issues such as grid constraints, payment issues and delays, rigid distributed energy deployment goals have hindered growth. Even though there will be many hiccups along the way, It is believed that the Indian solar market has turned the page and will be one of the Top 5 markets in the world over the next five years.

As government steps up its solar installation goals we are also seeing government-owned entities starting to enter the solar business, directly competing with private businesses. Solar Energy Corporation of India (SECI) was recently converted into a commercial entity, which means SECI can now directly engage in owning solar power projects, generating and selling power and also manufacturing solar products and materials. National Thermal Power Corporation (NTPC) announced that it is evaluating a plan to setup solar manufacturing.

**Table 7: MNRE: Year-wise Targets in MW to achieve 100,000 MW by 2022**

MNRE: Year-wise Targets in MW to Achieve 100,000 MW by 2022

| Category | 2015-16 | 2016-17 | 2017-18 | 2018-19 | 2019-20 | 2020-21 | 2021-22 | Total |
|---|---|---|---|---|---|---|---|---|
| Rooftop Solar | 200 | 4,800 | 5,000 | 6,000 | 7,000 | 8,000 | 9,000 | 40,000 |
| Ground Mounted Solar Power Projects | 1,800 | 7,200 | 10,000 | 10,000 | 10,000 | 9,500 | 8,500 | 57,000 |
| Total | 2,000 | 12,000 | 15,000 | 16,000 | 17,000 | 17,500 | 17,500 | 97,000* |

** 3,743 MW commissioned up to 2014-15*

Source: MNRE

## 6.1 Policy Developments:

Recent reverse auctions held in the states of Madhya Pradesh and Telangana resulted in record low bids. SkyPower Southeast Asia's bid of ₹5.05 (~$0.08)/kWh in Madhya Pradesh was the lowest bid. SkyPower was also the lowest bid in an auction held in Telangana with ₹5.17 (~$0.082)/kWh. The rationale for low bids in India has been the drop in system prices due to the time lag between the auction and project commissioning date which can be anywhere between a year-and-a-half to over two years. Most banks we spoke with said they were not comfortable financing projects at these tariff levels.

In terms of projects in the last quarter, which fall under Jawaharlal Nehru National Solar Mission (JNNSM) - Phase II Batch 2, 3,000 MW of projects are now being auctioned by National Thermal Power Corporation (NTPC) through competitive bidding, while SECI last week issued final guidelines for 2,000 MW in viability gap funding (VGF), also under Phase II Batch 2 projects. Telangana auctioned off 2,000 MW of PV projects with winners to be announced shortly, and Madhya Pradesh auctioned off 300 MW of projects.

## 6.2 JNNSM - Phase II Batch 1

As on 28th October 2015 total of 650MW out of 700 MW is commissioned. The list is enclosed below.

### Table 8: List of Projects commissioned under JNNSM Phase II Batch I

**SOLAR ENERGY CORPORATION OF INDIA**
**New Delhi-110017**
**List of Projects Commissioned under JNNSM Phase II Batch I**

as on 28-10-15

| Sl. No. | Project ID | SPD Name | Project Category | Project Capacity (MW) | Project Location | VGF eligibility (INR) | VGF Disbursement eligibility for FY 2015-16 (50% of total VGF) |
|---|---|---|---|---|---|---|---|
| 1 | 27FEPL-B-1N-2MP | Fortum Finnsurya Energy Pvt. Ltd. | Part-B | 10 | Madhya Pradesh | 9,69,90,000 | 4,84,95,000 |
| 2 | 6GSECL-B-1N-1GJ | Gujarat State Electricity Corporation Ltd. | Part-B | 10 | Gujarat | 10,40,00,000 | 5,20,00,000 |
| 3 | 34GPCL-B-1N-1GJ | Gujarat Power Corporation Ltd. | Part-B | 10 | Gujarat | 1,75,00,000 | 87,50,000 |
| 4 | 37SSPL1-A-3N-1MP | SEI Sitara Pvt. Ltd. | Part-A | 30 | Madhya Pradesh | 56,09,10,000 | 28,04,55,000 |
| 5 | 37SLPL-B-2N-1MP | SEI L'Volta Pvt. Ltd. | Part-B | 20 | Madhya Pradesh | 14,65,80,000 | 7,32,90,000 |
| 6 | 56RBPL-B-1N-1RJ | Rishabh Renergy Pvt. Ltd. | Part-B | 10 | Rajasthan | 8,50,00,000 | 4,25,00,000 |
| 7 | 37SSPL2-B-3N-1RJ | SEI Suryalabh Pvt. Ltd. | Part-B | 30 | Rajasthan | 26,18,54,820 | 13,09,27,410 |
| 8 | 54REPL-A-1N-1RJ | RDA Energy Pvt. Ltd. | Part-A | 10 | Rajasthan | 21,20,00,000 | 10,60,00,000 |
| 9 | 10PSPPL-A-1N-1RJ | Pallmarwar Solar Project Pvt Ltd. | Part-A | 10 | Rajasthan | 21,64,00,000 | 10,82,00,000 |
| 10 | 44HSEPL-A-1N-1MP | Clean Solar Power (Dhar) Pvt. Ltd. | Part-A | 10 | Madhya Pradesh | 23,90,00,000 | 11,95,00,000 |
| 11 | 44HSEPL-B-1N-2MP | Clean Solar Power (Dhar) Pvt. Ltd. | Part-B | 10 | Madhya Pradesh | 12,20,00,000 | 6,10,00,000 |
| 12 | 44HSEPL-B-1N-3MP | Clean Solar Power (Dhar) Pvt. Ltd. | Part-B | 10 | Madhya Pradesh | 13,10,00,000 | 6,55,00,000 |
| 13 | 55WREL-A-2N-1RJ | Welspun Solar UP Pvt. Ltd. | Part-A | 5 | Rajasthan | 12,28,00,000 | 6,14,00,000 |
| 14 | 49APIPL-B-4N-6RJ | Azure Clean Energy Pvt. Ltd. | Part-B | 40 | Rajasthan | 52,00,00,000 | 26,00,00,000 |
| 15 | 2SEIPL-A-1N-2RJ | Suryauday Solaire Prakash Pvt. Ltd. | Part-A | 10 | Rajasthan | 22,90,00,000 | 11,45,00,000 |
| 16 | 8IEDCL-A-2N-1MP | IL&FS Energy Development Company Ltd. | Part-A | 20 | Madhya Pradesh | 47,99,80,000 | 23,99,90,000 |
| 17 | 8IEDCL-A-2N-2MP | IL&FS Energy Development Company Ltd. | Part-A | 20 | Madhya Pradesh | 48,20,00,000 | 24,10,00,000 |
| 18 | 49APIPL-A-2N-1RJ | Azure Sunshine Pvt. Ltd. | Part-A | 20 | Rajasthan | 46,00,00,000 | 23,00,00,000 |
| 19 | 49APIPL-A-4N-3RJ | Azure Green Tech Pvt. Ltd. | Part-A | 40 | Rajasthan | 88,00,00,000 | 44,00,00,000 |
| 20 | 2SEIPL-A-2N-1RJ | Northern Solaire Prakash Pvt. Ltd. | Part-A | 20 | Rajasthan | 43,80,00,000 | 21,90,00,000 |
| 21 | 47VEPL-B-1N-1MH | Vishwaj Energy Pvt. Ltd. | Part-B | 10 | Maharashtra | 13,00,00,000 | 6,50,00,000 |
| 22 | 26RSEPL-A-2N-1RJ | Ranji Solar Energy Pvt. Ltd. | Part-A | 20 | Rajasthan | 48,99,97,440 | 24,49,98,720 |
| 23 | 26AMPPL-B-2N-2RJ | ACME Mumbai Power Pvt. Ltd. | Part-B | 20 | Rajasthan | 22,79,97,680 | 11,39,98,840 |
| 24 | 26AGPPL-B-2N-2RJ | ACME Gurgaon Power Pvt. Ltd. | Part-B | 20 | Rajasthan | 25,99,98,860 | 12,99,99,430 |
| 25 | 26MEPL-B-2N-2RJ | Medha Energy Pvt. Ltd. | Part-B | 20 | Rajasthan | 19,55,88,780 | 9,77,94,390 |
| 26 | 26ARPPL-B-2N-2RJ | ACME Rajdhani Power Pvt. Ltd. | Part-B | 20 | Rajasthan | 23,79,77,940 | 11,89,88,970 |
| 27 | 30SC&CPL-A-1Y-1MH | Sharda Construction & Corporation Ltd. | Part-A | 10 | Maharashtra | 13,95,00,000 | 6,97,50,000 |
| 28 | 51FESIPL-B-1N-1MP | Focal Photovoltaic India Pvt. Ltd. | Part-B | 10 | Madhya Pradesh | 9,98,90,000 | 4,99,45,000 |
| 29 | 51FESIPL-B-1N-2MP | Focal Renewable Energy Two India Pvt. Ltd. | Part-B | 10 | Madhya Pradesh | 11,99,90,000 | 5,99,95,000 |
| 30 | 51FESIPL-B-2N-3MP | Focal Energy Solar One India India Pvt. Ltd. | Part-B | 20 | Madhya Pradesh | 26,36,00,000 | 13,18,00,000 |
| 31 | 42WEPL-A-5N-1MP | Waaneep Solar Pvt. Ltd. | Part-A | 50 | Madhya Pradesh | 1,17,50,00,000 | 58,75,00,000 |
| 32 | 35KPCL-A-1N-1KA | Karnataka Power Corporation Ltd. | Part-A | 10 | Karnataka | 22,50,00,000 | 11,25,00,000 |
| 33 | 19SHEL-B-1N-1MH | Sunil Hitech Solar (Dhule) Pvt. Ltd. | Part-B | 5 | Maharashtra | 6,75,00,000 | 3,37,50,000 |
| 34 | 24SESL-A-1Y-1TN | Swelect Energy Systems Ltd. | Part-A | 10 | Tamil Nadu | 13,50,00,000 | 6,75,00,000 |
| 35 | 14BEL-B-1N-1GJ | Backbone Enterprises Ltd. | Part-B | 10 | Gujarat | 9,90,00,000 | 4,95,00,000 |
| 36 | 15EPPL-B-1N-1GJ | Enersan Power Pvt. Ltd. | Part-B | 10 | Gujarat | 10,80,00,000 | 5,40,00,000 |
| 37 | 58LDPL-B-1N-1RJ | Laxmi Diamond Pvt. Ltd. | Part-A | 10 | Rajasthan | 20,20,00,000 | 10,10,00,000 |
| 38 | 31THAIPL-A-1N-1RJ | Today Green Energy Pvt. Ltd. | Part-A | 10 | Rajasthan | 14,45,00,000 | 7,22,50,000 |
| 39 | 31THAIPL-A-1N-2RJ | Today Green Energy Pvt. Ltd. | Part-A | 10 | Rajasthan | 16,95,00,000 | 8,47,50,000 |
| 40 | 31THAIPL-B-1N-4RJ | Today Green Energy Pvt. Ltd. | Part-B | 10 | Rajasthan | 9,95,00,000 | 4,97,50,000 |
| 41 | 31THAIPL-B-1N-5RJ | Today Green Energy Pvt. Ltd. | Part-B | 10 | Rajasthan | 11,95,00,000 | 5,97,50,000 |
| | | Total | | 650 | | 10,51,40,55,520 | 5,25,70,27,760 |

## 6.3 JNNSM - Phase II Batch 2 State Specific Bundling Scheme (NTPC)

Now, the proposed 3,000 MW of solar PV projects in Batch 2 are being implemented by NTPC through open competitive bidding. These projects will be developed in solar parks (large areas designated for solar projects), and will be developed by central and state agencies on land provided by state governments or land identified and arranged by developers in their respective states.

NTPC has been issuing tenders in tranches:

**Table 9: JNNSM phase II Batch 2: NTPC tenders**

| JNNSM Phase II Batch 2: NTPC Tenders | | | |
|---|---|---|---|
| Location | MW | Capacity | Technical Bid Opening Date |
| Bhadla Phase II Solar Park, Jodhpur, Rajasthan | 420 | 6 X 70 MW | August 20, 2015 |
| Gani-Sakunala Phase II Solar Park, Kurnool, Andhra Pradesh | 500 | 3 X 50 MW and 1 X 350 MW | August 12, 2015 |
| Ghani Solar Park, Andhra Pradesh | 500 | 10 X 50 MW | July 31, 2015 |
| Rajasthan | 100 | 10 X 10 MW | September 7, 2015 |
| | 130 | 13 X 10 MW | September 9, 2015 |
| Uttar Pradesh | 100 | 10 X 10 MW | - |

**Source: NTPC**

## 6.4 JNNSM - Phase II Batch 3 (SECI)

SECI will be the implementing agency to set up 2,000 MW of grid-connected solar PV power projects under JNNSM Phase II Batch 3, "State Specific VGF Scheme." These projects will be set up in solar parks in various states. Out of 2,000 MW, 250 MW will be reserved under the DCR category and the remaining 1,750 MW will be in an open category. The VGF scheme will be implemented through competitive bidding at a pre-defined tariff of ₹5.43 /kWh for the first year escalated by five paisa /kWh each year until it reaches ₹6.43 /kWh, which would take 21 years, after which the tariff will remain at ₹6.43/kWh. The commissioning period is expected to be 13 months from the date of signing Power Purchase Agreements (PPA).

6.5 Other announced Solar Programs -

### 6.5.1 Ultra Mega Projects in Solar Parks

The Ministry of New and Renewable Energy's (MNRE) plan to set up 25 Solar Parks, each with a capacity of 500 MW and above, targeting 20,000 MW of installed capacity over a span of five years beginning in FY 2014-15, is under way. Fifteen states have so far agreed to setup 20 solar parks with a combined capacity of 12,999 MW.

**Table 10: Solar Parks and Ultra mega solar power projeccts**

| Solar Parks and Ultra Mega Solar Power Projects | | | | |
|---|---|---|---|---|
| **No.** | **State** | **Capacity (MW)** | **Name of the Solar Power Park/Developer** | **Area of Land Identified at** |
| 1 | Gujarat | 700 | GPCL | 1407 hectares at Vav, Distt. Banaskantha |
| 2 | Andhra Pradesh | 1,500 | AP Solar Power Corporation, JVC of SECI, APGENCO and NREDCAP | 4517 hectares at Anantpuramu, Kadapa Districts |
| 3 | | 1,000 | | 2,068 hectares at Kurnool District |
| 4 | Uttar Pradesh | 600 | JV between UPNEDA and SECI formed | 1,038 hectares at Jalaun, Sonbhadra, Allahabad & Mirzapur districts |
| 5 | Meghalaya | 20 | Meghalaya Power Generation Corporation (MePGCL) | 27 hectares at West Jaintia Hills & East Jaintia Hills districts |
| 6 | Rajasthan | 680 | Rajasthan Solar Park Development Company Ltd. (RSDCL), a subsidiary of RRECL | 1,797.45 hectares at Bhadla Phase II |
| 7 | | 1,000 | Surya Urja Company of Rajasthan; a JVC between State Govt. and IL & FS Energy Development Company | 2,000 hectares at Bhadla Phase III |
| 8 | | 1,000 | Surya Urja Company of Rajasthan; a JVC between State Govt. and IL & FS Energy Development Company | 2,000 hectares at Jaisalmer Phase I |
| 9 | Madhya Pradesh | 750 | JV of SECI and MPUVN | 1,400 hectares at Rewa |
| 10 | | 750 | | 800 & 600 hectares at Neemuch & Agar respectively |
| 11 | Karnataka | 2,000 | Karnataka Solar Power Development Corporation (KSPDCL), JVC of SECI and KREDL | Pavagada taluk Tumkur dist. (2,429 hectares) |
| 12 | Tamil Nadu | 500 | To be finalized | 568 hectare at Ramanathapuram district |
| 13 | Punjab | 500 | PEDA | 6,167 acres at Patiala, 1,786 acres at Fatehgarh Sahib, (5285 hectares) |
| 14 | | 500 | | 2,311 acres at Ludhiana and 2,790 acres at Gurdaspur |
| 15 | Telangana | 1000 | SECI, Telangana GENCO and Telangana New & Renewable Energy Development Corporation (TNREDC) | 2,189 hectare at Gattu, Mehboob Nagar District |
| 16 | Kerala | 200 | SECI | 4,858 hectares at Paivalike, Meenja, Kinanoor, Kraindalam and Ambalathara villages of Kasargode district |
| 17 | Uttarakhand | 39 | To be finalized | 77.853 hectares at Almora district |
| 18 | Arunachal Pradesh | 100 | Arunachal Pradesh Energy Development Agency (APEDA) | 2,700 acres of waste land Digaru Paya region in Sonpura circle of Lohit district |
| 19 | Nagaland | 60 | Directorate of New & Renewable Energy, Nagaland | Dimapur, Kohima and New Peren districts |
| 20 | A&N Islands | 100 | To be finalized | South Andaman |
| | TOTAL | 12,999 | 20 Solar Parks in 15 States | |

Source: MNRE — Mercom Capital Group, llc

## 6.5.2 JNNSM - Phase II Batch 5 (CPSUs)

Batch 5 (there is no Batch 4) calls for the establishment of grid-connected solar PV power projects by the Central Public Sector Undertakings (CPSUs) and Government of India organizations' self-use or third-party saleor merchant sale, with VGF over a span of three years from FY 2014-15 to 2016-17. DCR will be mandatory for Batch 5 projects.

NTPC alone has a target of developing 10,000 MW of solar projects. NTPC is already developing 250 MW of solar projects under this scheme in Andhra Pradesh and has invited tenders for 260 MW of solar projects in Rajasthan with bid pricing to be announced in August 2015. NTPC also invited tenders for 250 MW of solar projects in Madhya Pradesh. The National Hydro Electric Power Corporation (NHPC) has invited tenders to develop 50 MW. The tenders have been announced for 683 MW of solar projects by various CPSUs including NTPC, NHPC and shipyards.

**6.5.3 Solar Projects by Defence Sector**

Under this plan, more than 300 MW of grid-connected and off-grid solar PV power projects are proposed to be set up by defence establishments under the Ministry of Defence with VGF over the next five years, 2014-2019. It will be mandatory that all PV cells and modules used in solar projects set up under this program be made in India. The Ordinance Factory Board under the Ministry of Defence has proposed tenders for 150MW of solar projects and the office of the Engineer-in-Chief for another 281 MW.

**6.5.4 Grid Connected Solar PV Power Plants on Canal Bank sand Canal Tops**

MNRE launched a program for the development of 100 MW of grid-connected solar PV power projects on canal banks and canal tops at an estimated cost of ₹975 crore with Central Financial Assistance (CFA) of ₹228 crore . About 69 MW of projects under this program are under development in eight different states

**Table 11: State wise and year-wise Proposed Targets for 40GW grid connected roof top solar projects**

| State-wise and Year-wise Proposed Targets for 40 GW Grid Connected Rooftop Solar Projects | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| States | 2015-16 | 2016-17 | 2017-18 | 2018-19 | 2019-20 | 2020-21 | 2021-22 | Total (MW) |
| Andhra Pradesh | 10 | 240 | 250 | 300 | 350 | 400 | 450 | 2,000 |
| Bihar | 5 | 120 | 125 | 150 | 175 | 200 | 225 | 1,000 |
| Chhattisgarh | 4 | 84 | 88 | 104 | 120 | 140 | 160 | 700 |
| Delhi | 5 | 132 | 138 | 165 | 190 | 220 | 250 | 1,100 |
| Gujarat | 15 | 385 | 400 | 480 | 560 | 640 | 720 | 3,200 |
| Haryana | 5 | 200 | 200 | 235 | 280 | 320 | 360 | 1,600 |
| Himachal Pradesh | 2 | 38 | 40 | 48 | 56 | 64 | 72 | 320 |
| Jammu & Kashmir | 2 | 54 | 55 | 74 | 80 | 90 | 95 | 450 |
| Jharkhand | 4 | 96 | 100 | 120 | 140 | 160 | 180 | 800 |
| Karnataka | 10 | 275 | 290 | 344 | 403 | 460 | 518 | 2,300 |
| Kerala | 4 | 96 | 100 | 120 | 140 | 160 | 180 | 800 |
| Madhya Pradesh | 10 | 265 | 275 | 330 | 385 | 440 | 495 | 2,200 |
| Maharashtra | 20 | 565 | 588 | 704 | 823 | 940 | 1,060 | 4,700 |
| Orissa | 5 | 120 | 125 | 150 | 175 | 200 | 225 | 1,000 |
| Punjab | 10 | 240 | 250 | 300 | 350 | 400 | 450 | 2,000 |
| Rajasthan | 10 | 275 | 288 | 344 | 403 | 460 | 520 | 2,300 |
| Tamil Nadu | 15 | 420 | 438 | 524 | 613 | 700 | 790 | 3,500 |
| Telangana | 10 | 240 | 250 | 300 | 350 | 400 | 450 | 2,000 |
| Uttarakhand | 2 | 42 | 44 | 52 | 60 | 70 | 80 | 350 |
| Uttar Pradesh | 20 | 510 | 538 | 650 | 752 | 860 | 970 | 4,300 |
| West Bengal | 10 | 252 | 263 | 315 | 370 | 420 | 470 | 2,100 |
| Arunachal Pradesh | 2 | 5 | 5 | 8 | 10 | 10 | 10 | 50 |
| Assam | 4 | 30 | 30 | 38 | 42 | 50 | 56 | 250 |
| Manipur | 4 | 3 | 6 | 8 | 9 | 10 | 10 | 50 |
| Meghalaya | 1 | 6 | 6 | 8 | 9 | 10 | 10 | 50 |
| Mizoram | 1 | 6 | 6 | 8 | 9 | 10 | 10 | 50 |
| Nagaland | 1 | 6 | 6 | 8 | 9 | 10 | 10 | 50 |
| Sikkim | 1 | 6 | 6 | 8 | 9 | 10 | 10 | 50 |
| Tripura | 1 | 6 | 6 | 8 | 9 | 10 | 10 | 50 |
| Chandigarh | 1 | 12 | 12 | 14 | 18 | 20 | 23 | 100 |
| Goa | 1 | 20 | 20 | 22 | 23 | 30 | 34 | 150 |
| Dadra & Nagar Haveli | 1 | 24 | 25 | 30 | 35 | 40 | 45 | 200 |
| Daman & Diu | 1 | 12 | 12 | 14 | 18 | 20 | 23 | 100 |
| Puducherry | 1 | 12 | 12 | 14 | 18 | 20 | 23 | 100 |
| Andaman & Nicobar | 1 | 2 | 2 | 2 | 5 | 4 | 4 | 20 |
| Lakshadweep | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 10 |
| Total (MW) | 200 | 4,800 | 5,000 | 6,000 | 7,000 | 8,000 | 9,000 | 40,000 |

Source: MNRE — Mercom Capital Group, llc

## Status of implementation of various schemes to achieve 1,00,000 MW Solar Plan

Grid Connected Solar Power Projects Cumulative already commissioned as on 29/09/2015 is 4261.818MW. This comes from all MNRE, State policy, RPO, REC schemes, Pvt Initiatives (Rooftop), CPSUs. Out of which 517.838MW is commissioned under JNNSM in FY15-16.

Table 12: Commissioning status of Grid Connected Solar Power Projects as on 29th September 2015 ( cumulative)

**(i) Cumulative Commissioned as on 29-09-2015**

| Commissioning Status of Grid Conneceted Solar Power Projects | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sr. No. | State/UT | Total MNRE Projects MW | State Policy MW | RPO MW | REC Scheme MW | Pvt. Initiative (Roof top) MW | CPSUs MW | Total commissioned capacity till 18-09-15 (MW) |
| 1 | Andhra Pradesh | 94.75 | 133.17 | 0 | 38.7 | 2.82 | 10 | 279.44 |
| 2 | Arunachal Pradesh | 0.265 | 0 | 0 | 0 | 0 | 0 | 0.265 |
| 3 | Chhattisgarh | 4 | 34.08 | 0 | 4.6 | 0.5 | 0 | 43.18 |
| 4 | Gujarat | 20 | 873.05 | 50 | 6 | 51 | 0 | 1000.05 |
| 5 | Haryana | 7.8 | 0 | 0 | 0 | 0 | 5 | 12.8 |
| 6 | Jharkhand | 16 | 0 | 0 | 0 | 0 | 0 | 16 |
| 7 | Karnataka | 15 | 66 | 10 | 0 | 4.22 | 9 | 104.22 |
| 8 | Kerala | 0.025 | 12 | 0 | 0 | 0 | 0 | 12.025 |
| 9 | Madhya Pradesh | 225.25 | 277.55 | 0 | 80.78 | 0 | 65 | 648.58 |
| 10 | Maharashtra | 72 | 126 | 50 | 121.32 | 9.38 | 0 | 378.7 |
| 11 | Orissa | 12 | 30 | 0 | 4.5 | 0.42 | 10 | 56.92 |
| 12 | Punjab | 10.5 | 182.05 | 0 | 7.52 | 0.25 | 0 | 200.32 |
| 13 | Rajasthan | 889.1 | 35 | 40 | 210.6 | 0 | 0 | 1174.7 |
| 14 | Tamil Nadu | 26 | 18 | 0 | 98.16 | 15.82 | 0 | 157.98 |
| 15 | Telangana | 0 | 37.75 | 0 | 23.4 | 6.1 | 0 | 67.25 |
| 16 | Tripura | 0 | 0 | 0 | 5 | 0 | 0 | 5 |
| 17 | Uttar Pradesh | 12 | 42 | 0 | 0 | 1.75 | 15.51 | 71.26 |
| 18 | Uttarakhand | 5 | 0 | 0 | 0 | 0 | 0 | 5 |
| 19 | West Bengal | 2.05 | 5 | 0 | 0 | 0.16 | 0 | 7.21 |
| 20 | Andaman & Nicobar | 0.1 | 0 | 0 | 0 | 0 | 5 | 5.1 |
| 21 | Delhi | 0.335 | 0 | 0 | 2.14 | 4.237 | 0 | 6.712 |
| 22 | Lakshadweep | 0.75 | 0 | 0 | 0 | 0 | 0 | 0.75 |
| 23 | Puducherry | 0.025 | 0 | 0 | 0 | 0 | 0 | 0.025 |
| 24 | Chandigarh | 5.041 | 0 | 0 | 0 | 0 | 0 | 5.041 |
| 25 | Daman & Diu | 0 | 2.5 | 0 | 0 | 0 | 0 | 2.5 |
| 26 | Others | 0.79 | 0 | 0 | 0 | 0 | 0 | 0.79 |
| | TOTAL | 1418.781 | 1874.15 | 150 | 602.72 | 96.657 | 119.51 | 4261.818 |

**Table 13: Commissioning status of Grid Connected Solar Power Projects as on 29th September 2015 ( Under JNNSM in 2015-16)**

**(ii) Commissioned in 2015-16 as on 29/09/2015**

| Commissioning Status of Grid Conneceted Solar Power Projects under JNNSM in 2015-16 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sr. No. | State/UT | Total MNRE Projects MW | State Policy MW | RPO MW | REC Scheme MW | Pvt. Initiative (Roof top) MW | CPSUs MW | Total commissioned capacity till 18-09-15 (MW) |
| 1 | Andhra Pradesh | | 30.98 | | 4.4 | 1.2 | | 36.58 |
| 2 | Arunachal Pradesh | 0.24 | | | | | | 0.24 |
| 3 | Chhattisgarh | | 34.08 | | 1.5 | | | 35.58 |
| 4 | Gujarat | | | | | | | |
| 5 | Haryana | | | | | | | |
| 6 | Jharkhand | | | | | | | |
| 7 | Karnataka | 10 | 16 | | | 1 | | 27 |
| 8 | Kerala | | 12 | | | | | 12 |
| 9 | Madhya Pradesh | 40 | 45 | | 5 | | | 90 |
| 10 | Maharashtra | 15 | | | 2 | 0.95 | | 17.95 |
| 11 | Orissa | | 25 | | | 0.16 | | 25.16 |
| 12 | Punjab | | 15.05 | | | | | 15.05 |
| 13 | Rajasthan | 205 | 10 | | 17.6 | | | 232.6 |
| 14 | Tamil Nadu | 10 | | | | 5.4 | | 15.4 |
| 15 | Telangana | | 4.5 | | 1.5 | | | 6 |
| 16 | Tripura | | | | | | | |
| 17 | Uttar Pradesh | | | | | | | |
| 18 | Uttarakhand | | | | | | | |
| 19 | West Bengal | | | | | | | |
| 20 | Andaman & Nicobar | | | | | | | |
| 21 | Delhi | | | | | 1.247 | | 1.247 |
| 22 | Lakshadweep | | | | | | | |
| 23 | Puducherry | | | | | | | |
| 24 | Chandigarh | 0.541 | | | | | | 0.541 |
| 25 | Daman & Diu | 0 | 2.5 | 0 | 0 | 0 | 0 | 2.5 |
| | TOTAL | 280.781 | 195.11 | 0 | 32 | 9.957 | 0 | 517.848 |

Total Solar capacity likely to be commissioned in FY15-16 is 4345 MW out of which 3775MW is under state policy and 570 MW is under Government of India (GoI) policies.

Table 14: Likely to commissioned in 2015-15 under State policies

**a) Likely to commissioned in 2015-16 under State Policies**

| S.No | State | Likely to be commissioned by 31.03.2016 (MW) |
|---|---|---|
| 1 | Arunachal Pradesh | Nil |
| 2 | Ladakh (J&K) | Nil |
| 3 | Rajasthan | 50 |
| 4 | Chhattisgarh | 64.9 |
| 5 | J&K | Nil |
| 6 | Madhya Pradesh | 432 |
| 7 | Haryana | Nil |
| 8 | Mizoram | Nil |
| 9 | Himachal | Nil |
| 10 | Orissa | 25 |
| 11 | Telangana | 1166 |
| 12 | Chandigarh | Nil |
| 13 | Punjab | 229 |
| 14 | Sikkim | Nil |
| 15 | Daman &diu | 10 |
| 16 | Maharashtra | Nil |
| 17 | Andhra Pradesh | 350 |
| 18 | Delhi | Nil |
| 19 | Tamilnadu | 1214 |
| 20 | Uttarakhand | 30 |
| 21 | Tripura | Nil |
| 22 | Uttar Pradesh | 105 |
| 23 | Karnataka | 100 |
| | **Total** | **3775** |

**b) Projects likely to be commissioned in 2015-16 under Government of India Policies**

| S.No | Schemes | Likely to be commissioned by 31.03.2016 (MW) |
|---|---|---|
| 1 | Grid Connected VGF Scheme (Balance of Ph-II, Batch-I) | 330 |
| 2 | Rooftop Scheme | 240 |
| | **Total** | **570** |

Overall capacity addition/commissioning planned in FY16-17 is 10,859 MW out of which is 9244MW is under GoI support and 1615 MW is under State government.

## 6.6 Trends of Solar Tariff:

### Table 15: Trend of Solar Tariff

**Trend of Solar Tariff**

| Previous bid results | | | | | |
|---|---|---|---|---|---|
| -- | Year | Capacity on Offer (MW) | Highest Bid (Rs./KWh) | Lowest (Rs./KWh) | Weighted Avg. Price (Rs./KWh) |
| NSM Batch 1 | Dec'10 | 150 | 12.76 | 10.95 | 12.16 |
| NSM Batch2 | Dec'11 | 350 | 9.39 | 7.49 | 8.79 |
| Orissa Phase 1 | Mar'12 | 25 | 8.98 | 7.0 | 8.36 |
| Orissa Phase 2 | Dec'12 | 25 | 9.50 | 7.28 | 8.73 |
| Karnataka | Apr'12 | 60 | 8.5 | 7.94 | 8.34 |
| Madhya Pradesh | Jun'12 | 125 | 12.45 | 7.9 | 8.05 |
| Tamil Nadu | Mar'13 | 150 | 14.5 | 5.97 | 6.48* |
| Rajasthan | Mar'13 | 75 | 8.25 | 6.45 | 6.45 (L1) |
| Andhra Pradesh | Apr'13 | 226 | 15.99 | 6.49 | 6.49 (L1) |
| Punjab Phase 1 | June'13 | 270 | 8.75 | 7.2 | 8.41 |
| Uttar Pradesh Phase 1 | Aug'13 | 130 | 9.33 | 8.01 | 8.9 |
| Karnataka Phase 2 | Aug'13 | 130 | 8.05 | 5.5 | 6.87 |
| Madhya Pradesh Phase 2 | Jan'14 | 100 | 6.97 | 6.47 | 6.86 |
| Andhra Pradesh Phase 2 | Oct'14 | 500 | 5.99**(7.03 Levelized) | 5.25** (6.17 Level.) | 5.75** (6.75 Level.) |
| Karnataka | Nov'14 | 500 | 7.12 | 6.71 | 6.94 |
| Telangana | Nov'14 | 500 | 6.9 | 6.46 | 6.72 |
| Punjab (Capacity 5-24 MW) | Feb'15 | 100 | 7.45 | 6.88 | 7.17 |
| Punjab (Capacity 25-100 MW) | Feb'15 | 100 | 7.56 | 6.88 | 7.16 |
| NTPC Anantapur | May'15 | 250 | - | - | 6.16*** (L1) |
| Uttar Pradesh Phase 2 | June'15 | 215 | 8.6 | 7.02 | 8.04 |
| Madhya Pradesh | June'15 | 300 | 5.641 | 5.051 | 5.36 |
| Telangana Group 1**** | August'15 | 500 | 5.8727 | 5.4991 | 5.73 |
| Telangana Group 2**** | August'15 | 1500 | 5.8877 | 5.1729 | 5.62 |
| Punjab | Sept'15 | 500 | 5.98 | 5.09 | 5.65 |

*5% escalation for 10 years
** 3% escalation for 10 years. Separate L1 for 9 districts
*** EPC Bids with Domestic content requirement. Capital subsidy of Rs. 1 Cr/MW
****Results for the lowest bid for 500 and 1500 MW respectively. The sub-station wise final list to be declared soon

### 6.6.1 Decline in Solar Tariffs:

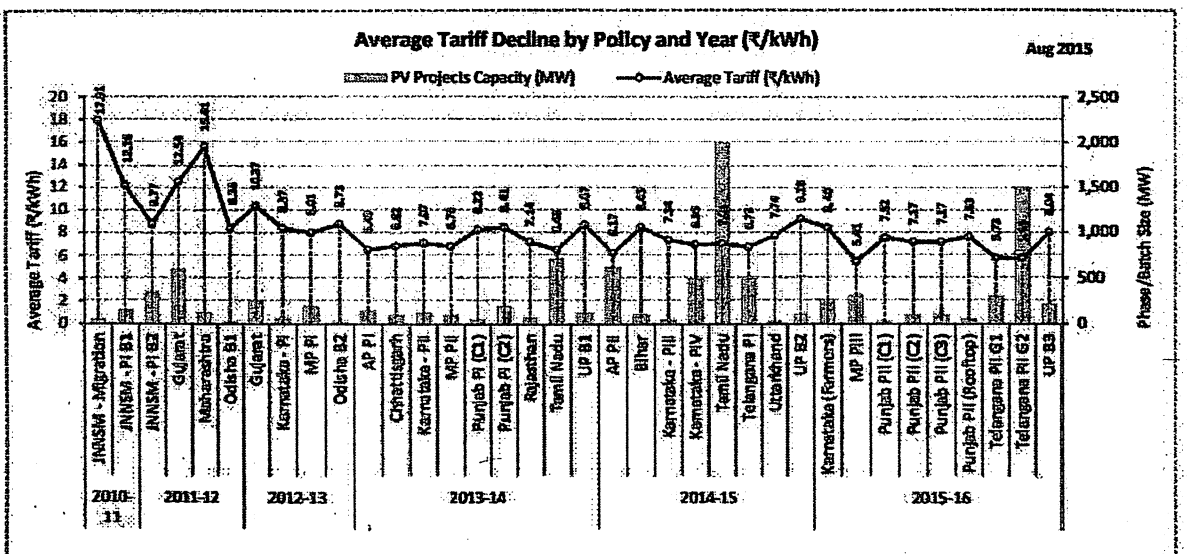
There has been a lot of noise recently about the record low tariff bids in the Madhya Pradesh reverse auction followed by the auction in Telangana. Looking at the tariff chart below (we have excluded VGF projects for consistency), starting with 2010 JNNSM migration projects which started at ₹17.91/kWh all the way to 2015 projects, we see a significant drop in bids over the last five years. The JNNSM Migration

Batch was not an auction, therefore if we calculate the drop in average bids from the first auction (JNNSM Phase I, Batch 1) which had an average tariff of ₹12.16 /kWh, to the latest auction results (Telangana Phase II Group 2), we see a 53 percent drop in the average tariff through reverse auctions across various state and central policies. From 2012 to 2015 we see a lot of peaks and valleys with bid prices going up and down in an inconsistent manner due to difference in insolation levels in various states. The drop in tariffs from the 2012 Odisha Batch 2 auction to the 2015 Telangana Phase II Group 2 auction is 35 percent.

Though costs of PV project include more than just panels, average Chinese module spot price chart as a reference point are inserted since panels makeup a significant portion of a solar project.

We should also note that most projects in India have anywhere between 12-18 months or more to commission which gives developers 6-12 months to procure panels at a lower price (assuming prices are always dropping which has its own risks). Looking at the spot price chart, there is a steep fall in module prices between 2011 and the end of 2012 (46 percent), but module price decline between January 2013 to July 2015 is only about 10 percent.

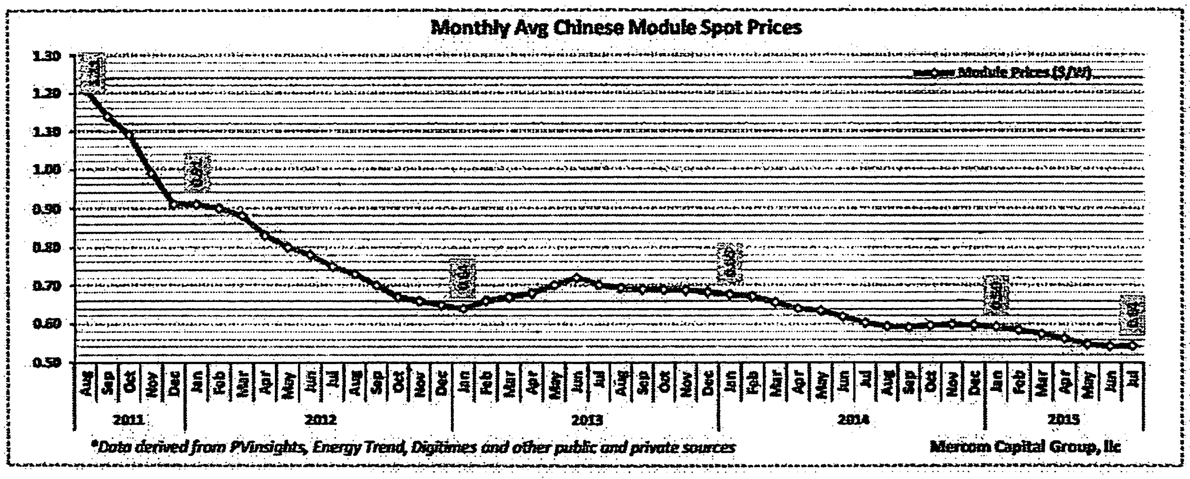
**Figure 2: Average tariff decline by policy and year ( Rs/KWh)**




Notes:
1. Gujarat - FY 2011-12 - levelized tariff is Rs.12.54/kWh for 25 yrs (Rs.15.00 for 12 yrs & Rs5.00 for next 13 yrs)
2. Gujarat - FY 2012-13 - levelized tariff is Rs.10.37/kWh for 25 yrs (Rs.11.25 for 12 yrs & Rs 7.50 for next 13 yrs)
3. AP Phase II - The range of first-year tariff offered by the successful bidders was Rs.5.25-5.99/kWh with a 3% per annum escalation for the first 10 years, then flat thereafter. The levelised tariff works out to Rs. 6.17/kWh.

Source: Mercom Capital Group, llc

**Figure 3: Monthly Average Chinese Module sport prices**




# 7 Outlook of Wind Power Projects and Key Trends Summary

## 7.1 Introduction

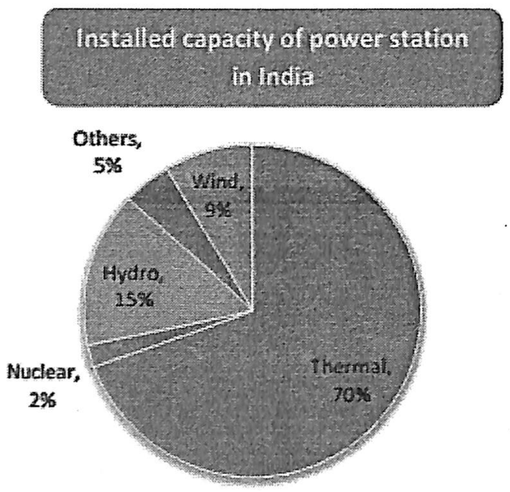
Worldwide, wind energy is accepted as one of the most developed, cost effective and proven renewable energy technologies to meet increasing electricity demands in a sustainable manner. While onshore wind energy technologies have reached a stage of large scale deployment and have become competitive with fossil fuel based electricity generation with supportive policy regimes across the world, exploitation of offshore wind energy is yet to reach a comparable scale. India has achieved significant success in the onshore wind power development with about 24 GW of wind energy capacity already installed and generating power. With introduction of this policy, the Government is attempting to replicate the success of offshore wind power development in the offshore wind power development.

India has about 80 GW of untapped wind power as on June 30, 2015. The factors favourable for development of wind power plants in India includes incentives from government in the form of Generation based incentives and accelerated depreciation, relatively cost competitive mode of power generation, low gestation period for setting up of the project and introduction of floor/cap pricing mechanism for trading of Renewable Energy Certificates. Furthermore, on account of expected increase in the cost of conventional energy sources such as thermal due to limited fossil fuels would provide fillip to the cost competitive renewable energy sources.

Considering the factors favouring the Independent Power Producers (IPP) in this segment coupled with the projects in pipeline, the wind based capacity additions going forward are expected to grow between 2000 MW to 2500 MW during FY16 - FY17 as against 2312MW of capacity addition during FY15. It is expected that the wind based IPPs would continue to prefer to sell its power to state Discoms by entering into PPA, for this assures stable cash flows to the projects and provides opportunities to avail the benefits of open access and banking facility.

India has a coastline of 7517 km, offering a huge potential for off - shore wind energy as well. India has around wind potential of around 102.77 GW out of which the total installed capacity as on June 30, 2015 was 23.76 GW. India's wind energy installed capacity was majorly spread across 8 states Rajasthan, Gujarat , Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and Kerala.

**Figure 4: Installed capacity of power in India**



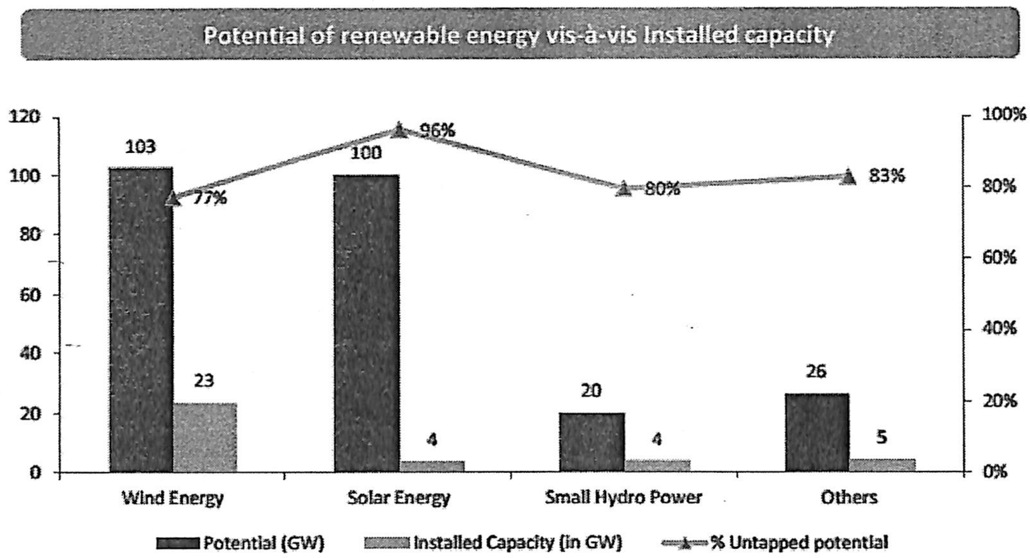

Source: Central Electricity Authority

7.2 Untapped potential of Wind power plants

The total installed capacity of renewable power projects as on June 30, 2015 aggregates to 36.4 7GW (excluding 42.47 GW of large hydro projects) against the total potential capacity of 249.19 GW. India has wind potential of around 102.77 GW out of which the total installed capacity as on June 30, 2015 was 23.76 GW with an untapped potential of about 77%. A major part of capacity addition and exploitation of Wind potential in the future is expected from private sector projects.

Huge untapped potential in wind power is attributed to lower Plant Load Factor (PLF) in comparison to fossil fuel, nuclear and hydropower plants. Furthermore, due to the limitation of grid infrastructure, it has been found that the amount of energy produced from wind farms could not be effectively transmitted to consumers causing wastage of energy. And also the financing structure of wind power projects in India is still bound in uncertainty. Due to aforementioned issues though the untapped potential is huge the extent to which the same can fructify still remains uncertain.

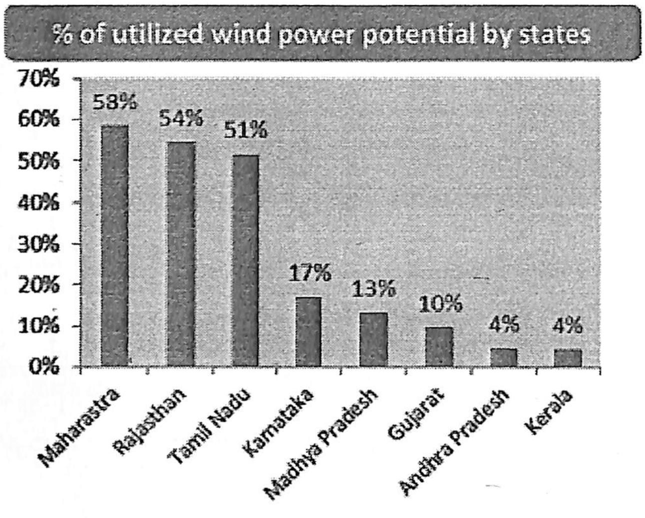
**Figure 5: Potential of renewable energy vis-à-vis Installed capacity**




Source: Central Electricity Authority

As on January 2014, states like Maharashtra, Rajasthan and Tamil Nadu had utilized their overall wind energy potential by more than 50%. Karnataka, Madhya Pradesh, Gujarat and Andhra Pradesh on the other hand has estimated wind potential of 13.6 GW, 2.9 GW, 35.1 GW and 14.5 GW, spread across 26, 7, 40 and 32 wind farmable sites out of which it has been able to utilize only 17%, 13%, 10% and 4% respectively of capacity.

**Figure 6: % of utilized wind power potential by states.**




Source: Central Electricity Authority

Tamil Nadu leads in terms of wind power installed capacity constitutes about 32% of the total installed capacity followed by Maharashtra, Gujarat, Rajasthan and Karnataka contributing 19%, 16%, 14% and 11% of total share respectively. Although the top 5 states contribute about 92% of the installed wind capacity, they still have 49% of the total untapped wind power potential.

7.3 Trend in wind energy capacity addition

The fresh wind energy capacity addition during FY15 was better compared to FY13 and FY14 on account of demand from IPP segment and government policies favouring the segment. The satisfactory trend can be corroborated with the fact that the wind energy capacity additions have surpassed the target set by MNRE by 16% during FY15. The wind energy capacity addition during FY15 was 2312 MW (2090 MW in FY14) with Rajasthan, Madhya Pradesh and Maharashtra contributing 23%, 20% and 15%.

**Table 16: Target Vs Achievement across of renewables during FY15( in MW)**

| Target Vs Achievement across of renewables during FY15(in MW) | | | |
|---|---|---|---|
| | Target | Achievement | % Surpassed |
| Wind | 2000 | 2312 | 16% |
| Solar | 1100 | 1112 | 1% |
| Small Hydro | 250 | 251 | 0% |
| Others | 420 | 413 | -2% |
| Total | 3770 | 4088 | 8% |

Source: MNRE

In order to build the growth trajectory going forward, companies need to maintain reliable wind data bank, pin down the best locations and designs, maintain a team of expert executors of electrical grid connectivity and proficient tariff negotiating skills considering various trade-offs.

**Increase in cost of generation of conventional power can act as competitive advantage for RE Source**

Although the cost of coal in the international market has shown consistent decline for about last five years, the trend is unlikely to continue for long period considering the limited availability of fossil fuels and increase in demand coupled with heightening operational and logistics costs. Considering the increase in prices of fossil fuels such as coal and R-LNG going forward and rise in fuel shortages, there would be upward pressure in cost of generation of conventional power. This situation would result in providing competitive advantage for renewable IPP especially wind considering the competitiveness in their tariff rates.

**Table 17: Overall cost of generation of thermal fuel vs wind tariff across state**

| Overall cost of generation of thermal fuel versus wind tariff across states | Rs/Kwh* |
|---|---|
| Cost of generation - imported coal | 3.82 |
| Cost of generation - gas (60%) & R LG (40%) | 4.60 |
| Cost of generation - domestic coal (50%) & Imported coal (50%) | 4.04 |
| | |
| Wind : Maharashtra | |
| Wind power density range 200-250 | 5.67 |
| Wind power density range 250 – 300 | 4.93 |
| Wind power density range 300-400 | 4.20 |
| Wind power density range >400 | 3.78 |
| | |
| Wind Tariff – Tamilnadu | 3.51 |
| Wind Tariff - Andhra Pradesh | 3.50 |
| Wind Tariff – Karnataka | 3.70 |
| Wind Tariff – Gujarat | 4.23 |
| Wind Tariff – Rajasthan | 4.90 |

* (Including Accelerated Depreciation benefits)

Source: India Renewable Energy Status Report 2014

## 7.4 Government policies favoring growth of wind power projects:

### 7.4.1 Accelerated Depreciation:

Acceleration depreciation was withdrawn with effect from April 01, 2012. However, the Ministry of Renewable Energy has reinstated the policy in July 2014. This tax benefit allows projects to deduct upto 80% of value of wind power equipment during the first year of project operation. Investors are given tax benefits upto 10 years.

### 7.4.2 Generation Based Incentive (GBI) Scheme:

Under this scheme, GBI will be provided to wind electricity producers who come under these categories:

- Wind electricity producer would be provided with an incentive of Rs.0.50/kWh per unit of electricity fed into gird with a maximum capacity of Rs. 1.00 crore per MW.
- Incentives are provided for the projects with duration more than 4 years and less than 10 years
- Total disbursement in a year not to exceed Rs.25 lakhs per MW during the first four years.
- GBI scheme is applicable for the 12th Financial Year Plan period having a target of 15,000 MW
- Captive producers are allowed for GBI but open access (merchant power) not allowed.

### 7.4.3 Renewable Purchase Obligation (RPO)

Several states have implemented RPOs to meet the power requirements from 1% to 15% of total power generated. The impact of the RPOs on wind development would depend on the penalties and enforcement of the targets as well as an effective REC market to promote development of areas of the country with the most abundant wind resources. Although National Action Plan on Climate Change has set an ambitious RPO target 15% of total power generated by 2020, most of the states have performed abysmally low in achieving the same.

## 7.5 Current Issues and Challenges

### 7.5.1 Counter party credit risk relating to state DISCOMs

The power generating companies usually have Power Purchase Agreement (PPA) with either the distribution companies or captive power consumers. However, while the PPA tends to reduce the demand risks for operational wind power projects, the projects continue to face counter party payment risk. Even if the SPV generates and supplies the adequate power and supplies the same to the buyer, any delay in payments by the buyer can significantly impact the SPV's credit quality, these risks may vary from buyer to buyer.

### 7.5.2 Technological risk

Lack of Transmission infrastructure leads to difficulties pertaining to evacuation of power generated; apart from that due to variable wind levels throughout the day and across the seasons there would be fluctuation in voltage and power factor, which can cause difficulties in linking with Central Transmission Utility. Most of the favorable wind sites having PLF in the range of 28% have already been developed thus leaving the sites with low PLF to develop.

### 7.5.3 Regulatory risk

Involvement of multiple regulators bodies such as MNRE, IREDA, SERCS etc makes the entire subsidy structure complex. Furthermore, delays in acquiring land and obtaining statutory clearances during the project stage and lack of an appropriate regulatory framework to facilitate RPO would adversely affect the project in terms of cost and time overruns and mismatch of cash flows.

## 7.6 Offshore wind:

Over 8.7 GW offshore wind capacity has already been installed around the world and approximately an equal capacity is under construction. There are offshore wind farms existing and under development in United Kingdom (4494MW), Denmark (1271 MW), Germany (1049 MW), Belgium (712 MW), China (670 MW), The Netherlands (247 MW) and Sweden (212 MW)

### 7.6.1 Developments in India

In India, preliminary assessments along the coastline have indicated prospectsof development of offshore wind power. W ind resource data collected for the coastline of Rameshwaram and Kanyakumari in Tamil Nadu and Gujarat Coast shows reasonable potential. A preliminary assessment suggests potential to establish around 1 GW capacity wind farm each along the coastline of Rameshwaram and Kanyakumari in Tamil Nadu.

The significant challenges that exist in offshore wind power deployment relates to resource characterization, subsea cabling, turbine foundation, installation of turbines including logistics, grid interconnection and operation, development of transmission infrastructure and coastal security during construction and operation period. Adding large capacities of offshore wind generation to the power system would also require reliable integration to the national grid.

### 7.6.2 Vision of the Government

Electricity generation from renewable sources of energy is an important element in the Government's National Action Plan on Climate Change (NAPCC) announced in the year 2008. With introduction of this plan, the Government of India is committed to provide a conducive environment for harnessing offshore wind energy in India. In consonance with the mandate and responsibility, the Government envisions to carry forward, in a systematic manner, the development of offshore wind energy in the country, to overcome the existing barriers and to create technological and implementation capabilities within the country.

The Government of India in its interest to develop Offshore Wind Farm has decided to have a Policy in October 2015 that will enable optimum exploitation of Offshore Wind energy in the best interest of the nation.

# 8 Renewable operational trends and Challenges and Mitigation measures in Renewable Grid integration

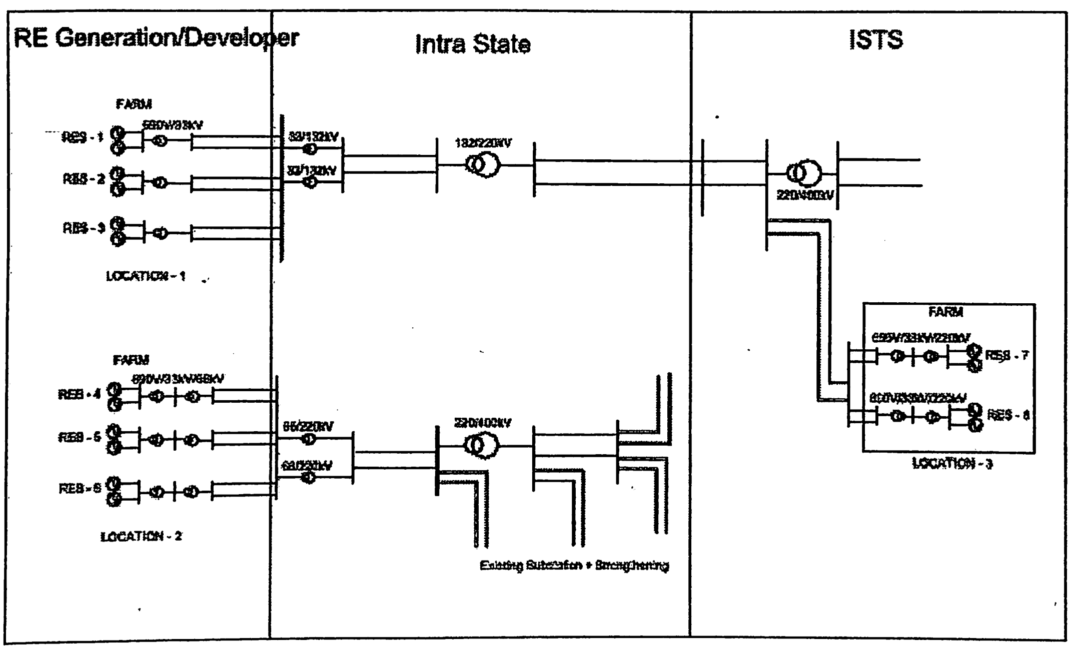
## 8.1 Operational trend of Renewables

Presently the total installed electricity generation capacity in India is about 280 GW. Out of this about 13.2 % is through renewable generation mainly wind (24 GW) and balance is in the form of small hydro (4101 MW), Biomass (4418 MW) and solar (4060 MW).

Various policies, regulatory and fiscal incentives have accelerated development of renewable energy (RE) generation. Due to such initiatives, large capacity addition though renewable generation is envisaged in the 12 h Plan period. Recognizing the criticality of large scale development of RE capacity and its integration with grid, Ministry of New & Renewable Energy (MNRE) and Forum of Regulators (FOR)/CERC have entrusted POWERGRID to carry out studies to identify transmission infrastructure and other control requirements for RE capacity addition programme in 12th Plan and prepare a comprehensive report with estimation of capex requirement and financing strategy.

The Renewable energy generating stations are connected with the grid normally at 33 kV, 66kV, 1 10kV & 132 kV level. The EHV transmission system beyond first connection point is either at 132kV, 220kV or 400kV depending on the quantum of power being pooled at EHV Substations. However large size generating stations are directly connected with the grid normally at 132 kV, 220kV level. Typical Schematic of various RE stations connectivity shown in

**Fig.7: Typical connection Arrangement of RE generation farm with Grid**



From the past profile of renewable generation mainly wind and solar, it has been observed that the generation from the wind increases in other than peak demand period generally ramping of wind generation start from 11:00 hours in most of the states except in Rajasthan which starts usually from 18:00 hours. Further maximum wind generation occurs in the monsoon season. Typical daily wind generation patter for Tamil Nadu & Rajasthan is as shown in Fig 8 & 9.

**Figure 8: Tamilnadu daily wind generation pattern month wise ( sources TN SLDC)**

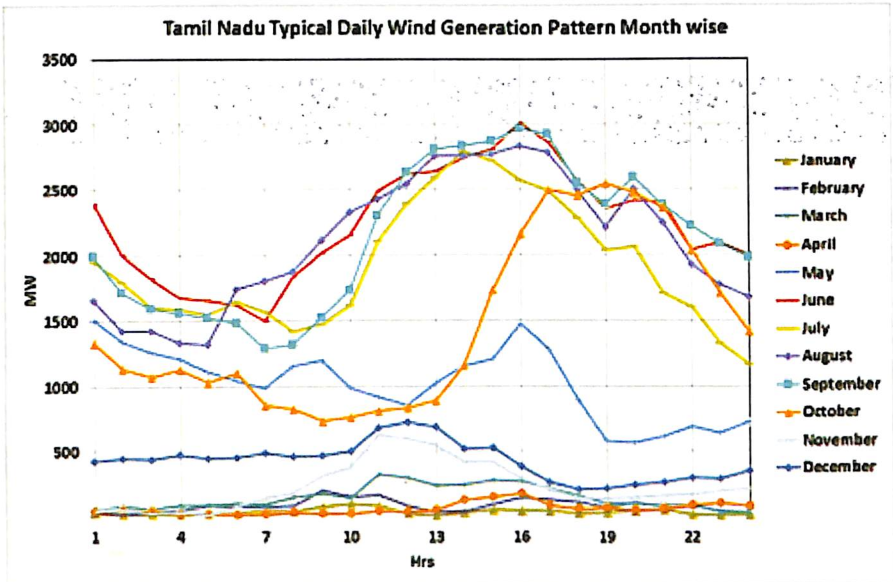
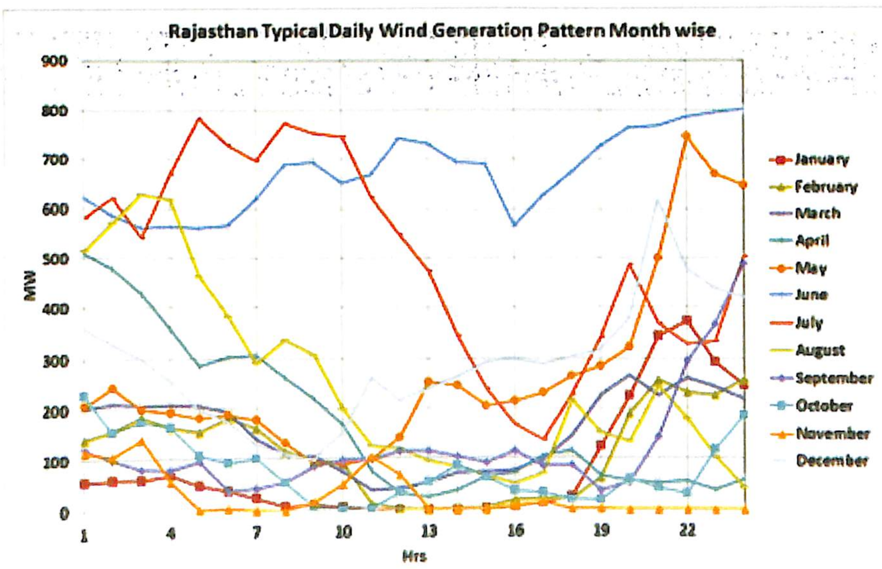



**Figure 9: Rajasthan typical daily wind generation pattern month wise (Sources Raj- SLDC)**



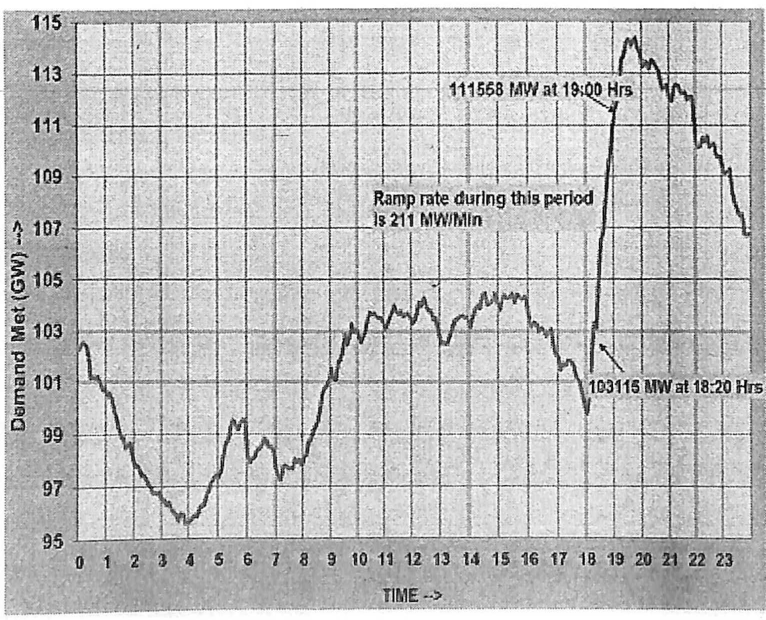
Solar output is from 07:00 hours to 19:00 with peak ranging from 12:00-15:00. In case of small hydro plants, there is not much daily variability in output, however, it varies seasonally. According studies have been carried out with maximum wind dispatch (70% of installed capacity) and solar dispatch (80%) during demand other than peak condition. However sensitivity analysis has been carried out with peak demand scenario with low wind dispatch (30%) and solar dispatch (10%)

Looking at the wind generation pattern and demand profiles of above mentioned wind rich states, it can be observed that during evening peak hours 19.00 hrs to 2000 hr when evening loads are picking up wind generation falls except for the Maharashtra where it remains almost flat and Rajasthan where wind starts to ramp up.

Overall reduction in wind generation during evening peak hours adds to the problem of peak load management that requires additional flexible generation to be added up for proper load generation balance. Such issues in wind generation add to the problem of reactive power management (voltage control) also. However, wind being extremely variable in nature, scenario may change over any period of time.

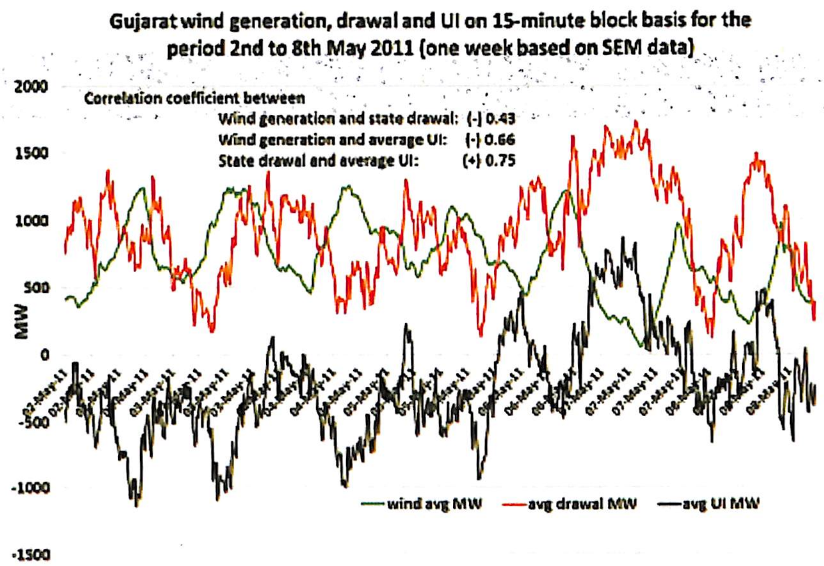
Typical all India daily load curve is shown in fig-10. It could be seen that the ramp rate during evening peak is of the order of 200 MW/minute for nearly sixty (60) to ninety (90) minutes which is catered to mainly by hydro generation.

**Figure 10: Typical All India daily load curves (Sources -POSOCO)**



Study of impact of variation of wind generation on the host state is also analyzed which reveals that the co-relation co-efficient between change in drawl of host state with respect to change in wind generation is actually closer to zero. This indicates that re-scheduling of conventional energy sources helps in mitigating whatever minimal effect that intermittency has on a state's imbalance and wind conclusively does not significantly add to the variability . Correlation between Wind Generation, Drawl & UI of Gujarat for one week period is shown at Figure-11 below.

**Figure 11: Correlation between Wind Generations, Drawals and UI of Gujarat (Sources -POSOCO)**




Above analysis indicates that intermittent generation can be handled, provided adequate transmission infrastructure is made available for transfer of power without congestion as well as balancing through conventional resources and/or other solutions are available.

## 8.2 Proposed measures to address intermittency and variability of generation

In order to facilitate transfer of RE power from the RE rich potential States to other States as well as absorption of RE power within the RE rich states (host state), transmission system strengthening both at intra state and inter state level have been identified. Intra State transmission system strengthening primarily comprises of pooling stations at 132kV , 220kV and 400kV level and associated transmission lines including other STU grid strengthening schemes. Major Inter State transmission strengthening (ISTS) mainly comprises of development of high capacity hybrid corridors.

The output of the wind and solar based RE plants vary according to the available resources – the wind speed/ direction and the sun's insolation level. With high penetration level of RE capacity coupled with sudden drop in generation due to unexpected cloud cover or a lack of wind can impact grid stability . Therefore fast-ramping conventional energy sources, energy storage, demand side/demand response management must be carried out to meet demand. Measures to smooth out the intermittency and variability include enlarging the balancing area, load shifting, building in more flexibility in the generation portfolio etc.

Measures proposed to take care of intermittency and variability of grid connected RE generation is:

- Strong Grid interconnections
- Flexible generation, Ancillary Services, Reserves etc. for supply-balancing
- Demand Side management, Demand Response and Storage for load balancing
- Forecasting of Renewable generation
- Forecasting of Demand
- Establishment of Renewable Energy Management Centers (REMC) equipped with advanced forecasting tools along with reliable communication infrastructure
- Deployment of Synchrophasor technology i.e. PMUs/WAMS on pooling stations and interconnection with centralized control centre through Fiber Optic Communication for real time information, monitoring and control
- Capacity building at respective LDC/PCC/Conventional/Non-Conventional Generator regarding RE handling
- Institutional Arrangement s with defined roles & responsibilities of various agencies/generation developer
- Technical Standard Requirements (Grid code, Connectivity standards, Real time monitoring etc.)
- Policy advocacy for development of power-balance market and pricing mechanism

### 8.2.1 Strong Grid interconnection

Strengthening/expansion of grid interconnection shall enlarge the power balancing area. In a large interconnected system variation in frequency would be lesser for a given variation in generation/demand as well as it will help in reaping out the benefits of diversity in terms of spinning reserve and utilizing quick-start hydro/gas generation capacity in different parts of the grid for power balancing.

Hydro potential in Northern-eastern region (NER), Sikkim and Bhutan may also be harnessed by development of high capacity transmission corridors between NER/Sikkim/Bhutan and load centers. Further, to take care of seasonal variation in generation from such hydro plants, the transmission corridors must be planned with hybrid HVDC and AC system so that grid parameters can be maintained.

### 8.2.2 Flexible generation

Spinning reserves (hot and cold), flexible high ramp rate generation would be required to handle variability and ramp ing associated with RE for power balancing. Spinning reserves through following type of generating units may be provided.Hydropower

### 8.2.3 Plant with Reservoir

It provides reserve capacity and expected to respond to grid frequency changes and in flow fluctuations. They also provide fast ramp up and ramp down (orderof few seconds) capabilities.

### 8.2.4 Pumped Storage Hydropower Plant-

Pumped storage plants due to their fast response and storage capacity have been proved to be excellent reserves. Presently , pumped storage Hydro capacity in operation is only about 1550 MW (Kadamparai - 400MW , Purulia-900MW , Ghatghar - 250 MW). This provides approximately 3000 MW variation between peak and off peak. Tehri PSP (1000MW) is also proposed to be added in 12th plan period. Revival of SrisailamLBPH (900 MW) and early commissioning of T ehri PSP (1000 MW) would provide a total of nearly 6500 MW regulation in the Indian grid.

Further several Pumped Storage Stations have been planned and developed in the Country which is not being operated in pumped mode due to commercial as well as technical issues. In addition there are many hydro plants which are feasible to be convertible into Pumped Storage Hydro Plant. Feasibility should be evolved to encourage participation of such Pumped storage plants for introducing more regulation into the grid with the increased Renewable penetration. In addition, some regulatory interventions/policy measures are required for encouragement of such projects through incentives so that such projects become financially viable and sustainable.

### 8.2.5 Combined cycle gas plants:

These plants are efficient and can ramp up and down quickly but are expensive plants. Need judicious operations.

### 8.2.6 Thermal plants:

Coal based plants are less flexible in response to load changes. Such plants can be used as reserve plants only if they are running at Technical Minimum. For this suitable market design is to be done through regulatory intervention.

Establishment of super-critical coal fired units is an important milestone in the Indian thermal plant scenario. Super-critical units are known for higher efficiency, but a lesser known aspect is more flexibility in terms of regulating generation. Typically, a supercritical unit can operate at the designed supercritical steam parameters between 80-100% of rated capacity. Thus, system can have about 20% variation in a flexible manner due to super critical technology. However this can be harnessed if the units are able to participate in the 'downward regulation' electricity market, which requires policy/regulatory measures.

### 8.2.7 Demand Side Management/Demand Response

Demand-Side Management (DSM) or Demand-response is one option to increase flexibility to accommodate variable renewable. It helps to reduce the operational costs of renewable integration through measures such as load shifting and peak shaving, which can reduce the need for a system operator to maintain costly ancillary services. Smart grids would enable operators to better manage generation, transmission and storage in ways that more effectively respond to supply fluctuations and demand. Development of Smart Grid with DSM functionality and new storage mechanism may be expedited.

### 8.2.8 RE Generation Forecasting

Wind and Solar power forecast is the most important pre-requisite for their large scale integration in the grid. Significant amount of wind generation integration will largely depend on the accuracy of the wind power forecast. Decentralised forecasting with centralised control is the current best approach for reliable grid operation.

Forecasting shall be done from the micro level i.e. at the plant level and then shall be integrated/aggregated further at the SLDC and RLDC and then at the national level. For effective monitoring and control, forecasting tool must be integrated with the SCADA / EMS system

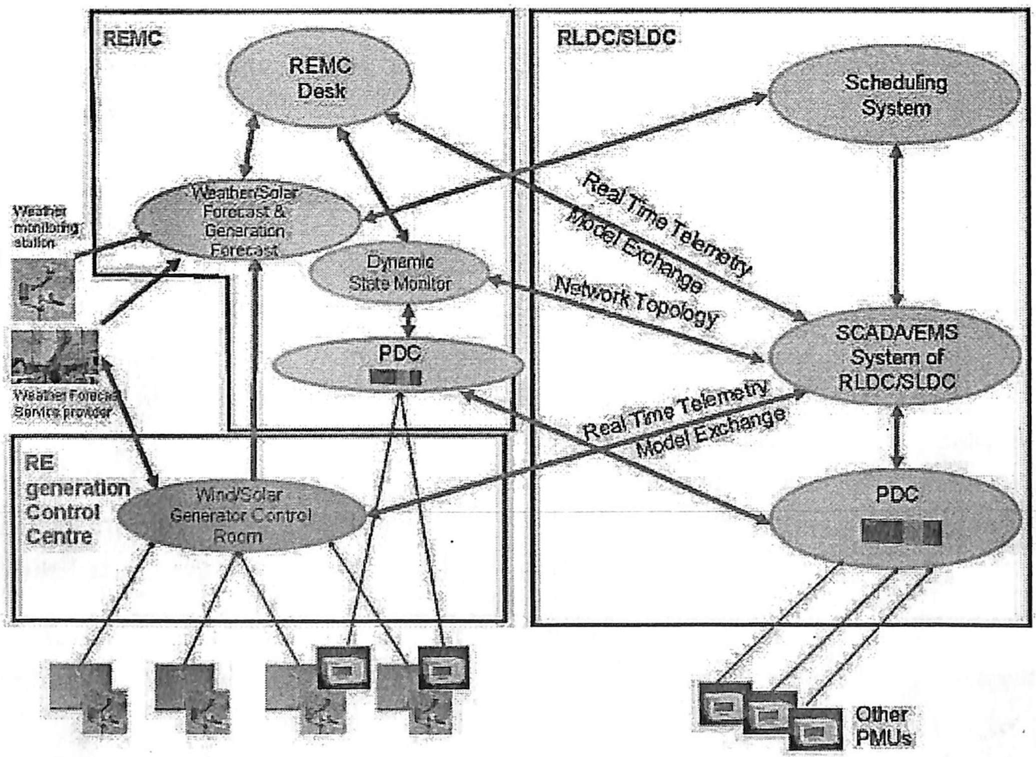
### 8.2.9 Energy Storage

Energy storage technologies offer a great solution to accommodate large scale Renewable penetration and address its inherent issues like variable and uncertain output. Energy Storage can handle the excess availability of renewable during off peak demand period and provide energy support during peak hours just like another hot /spinning generation reserve. Focus must be given to develop suitable energy storage solutions.

## 8.3 Establishment of Renewable Energy Management Centre (REMC)

A separate hierarchy of Renewable Energy Management Centre (REMC) is proposed which will work in tandem with SLDC / RLDC / NLDC for maximization of Renewable Energy generation and integration with main grid without compromising security and stability of power system. All Renewable Energy Management Centres (REMCs) at State and Regional level shall be co-located with respective Load dispatch centers (LDC). REMC shall coordinate with SLDC/RLDC for discharging various functionalities related to management of renewable energy generation. The typical data flow for various functionalities envisaged at the Renewable Energy Management Center is given in the Fig-12 below:

**Figure 12: Typical renewable energy data flow**




## 8.4 Market Design

Presently in Indian electricity market, Scheduling & dispatch, imbalances and congestion management is already implemented in India. Recent change that has been introduced in the Electricity Market for promotion of renewable is the introduction of 15-minute bidding in the Power Exchanges (instead of hourly bidding) with effect from 1st April 2012.

In addition to above, introduction of the following market mechanisms would further help in large scale integration of renewable sources of energy:

**8.4.1 Flexible Generators:**

A New product in the mark et may be developed where various generators with surplus capacity may submit their bid and based on their bid price during low frequency conditions they can be scheduled by the power system operator. Similarly the bid price shall be submitted by the generators which are ready to back down during high frequency condition and scheduled by operator during such high frequency scenarios. Regulator may define the bid-price band for the flexible generator. This will facilitate the optimization of generation and smooth integration of variable and intermittent renewable power

**8.4.2 Ancillary Market:**

The central regulator Regulator is already in the process of introduction of Ancillary Services Market in the Country. This would help in harnessing services such as reactive power, Demand Response etc.

**8.4.3 Evening Market:**

More frequent operation of the Electricity Market through the Power Exchanges such as introduction of Evening Market as this would provide more opportunities to the market participants.

**8.4.4 Real time monitoring systemusing Synchrophasor Technology**

Wide area Special Protection Schemes (W ASS) using Wide Area Monitoring System / Phasor Measurement Units at pooling stations and Phasor data concentrators at strategic locations int egrated with REMC can help in predicting as well as can be used for controlling grid lines/ transformers being switched in and out. Installation of PMUs and PDCs at various locations along with optical fiber communication links integrated with REMC / LDCs are proposed for real time measurement and monitoring of system states.

**8.4.5 Technological, Policy and Standard Requirements**

To facilitate the high wind penetration, new regulations/connectivity standards are to introduced to ensure that their large scale integration don't affect the power system security & reliability. Such regulations/standards will also provide necessary guidelines to the developers for connectivity with the grid as well as other technical requirements like fault ride through, reactive power support etc.

**8.4.6 Institutional Arrangements required for integration of wind**

Technology and markets can work smoot hly only with proper institutional arrangements in place. Therefore, Role and Responsibilities of Developer/

DISCOM/STU/SLDC (in addition to statutory responsibilities already provided in Electricity Act 2003, Grid Codes)

Activities by Statutory Bodies/Authorities towards implementation of measures to address issues

In order to facilitate implementation of above discussed measures in addressing the issues associated with large scale integration of renewable, it is proposed that following actions may be taken up respectively by the Regulator , Statutory Authorities/MNRE, CTU/STU etc.

**8.5 Load-Generation scenario along with RPO targets**

From All India load generation Scenario, it has been observed that various states have different combination of renewable generation, Renewable Purchase Obligation (RPO) targets as well as their net surplus/deficit scenarios. Following strategy has been adopted while formulating the load-generation scenarios for study purpose. RE generation is considered as "must run" type and it is assumed that RPO targets shall be fulfilled by the respective States. A detailed exercise has been done to evaluate RE generation surplus/deficit situation based on proposed RPO requirement and RE capacity addition programme by 2016-17 as well as RE dispatch (wind & solar) in other than peak demand scenario. Following cases have emerged:

Case-A: State overall surplus (conv entional generation) as well as RPO Surplus

It is assumed that RPO surplus capacit y to be dispatched outside the surplus State. Surplus capacity from conventional sources may be exported to meet other state's deficits but it may be backed down (in case required) only up to the extentof net RPO surplus capacity .

Case-B1: State overall surplus but RE deficit and overall surplus >RPO deficit

Case-B2: State overall surplus but RE deficit and overall surplus <RPO deficit

In the above two cases, state must import RE capacity at least to the extent of its RPO targets fulfillment. However, being surplus in conventional generation, state must back down its conventional capacity up to the extentof RE import capacity .

Case-C: State overall deficit as well RPO deficit

In this case, state must import RE capacity at least to the extent of its RPO targets fulfillment. In case of marginal overall deficit, state must import RE capacity at least to the extent of its RPO fulfilment by backing down conventional generation.

It is to mention that while establishing load generation scenarios for demand other than peak in 2016-17, it has been observed that various states may have overall surplus capacity after considering Renewable generation. Therefore, while finalizing load generation scenario for surplus condition, conventional generation backed down as per merit order dispatch wherein high cost gas based plants are being first to be backed down and then high cost State thermal plants. Secondly ,reservoir based hydro plants are also considered to be not dispatched in such scenarios whereas Run-off-the-River plants are dispatched as maximum RE generation being monsoon season.

Further, to simulate worst ca se scenario, in case of high potential RE complexes, special area dispatches have been considered wherein generation from conventional resources in such pockets are kept at maximum dispatch.

### 8.5.1 Pooling of RE Generation

States have provided information about existing connectivity as well as connectivity granted at their STU network to future RE projects. For load flow simulation, such connectivity has been established depending upon the availability of network information (up to 220kV level) in load flow simulation cases. However, for future cases i.e. beyond 2014, wherein STU have not finalized the connectivity and STU/SNA provided the pockets of upcoming RE projects, assumptions have been made regarding pooling of such RE projects to nearest 220kV STU substations. In case of large capacity (more than 300-400 MW), pooling has been done at 400kV level also. Therefore, in case of revision in point of connectivity , transmission system shall have to be reviewed near the pooling stations.

### 8.5.2 Demand and Generation

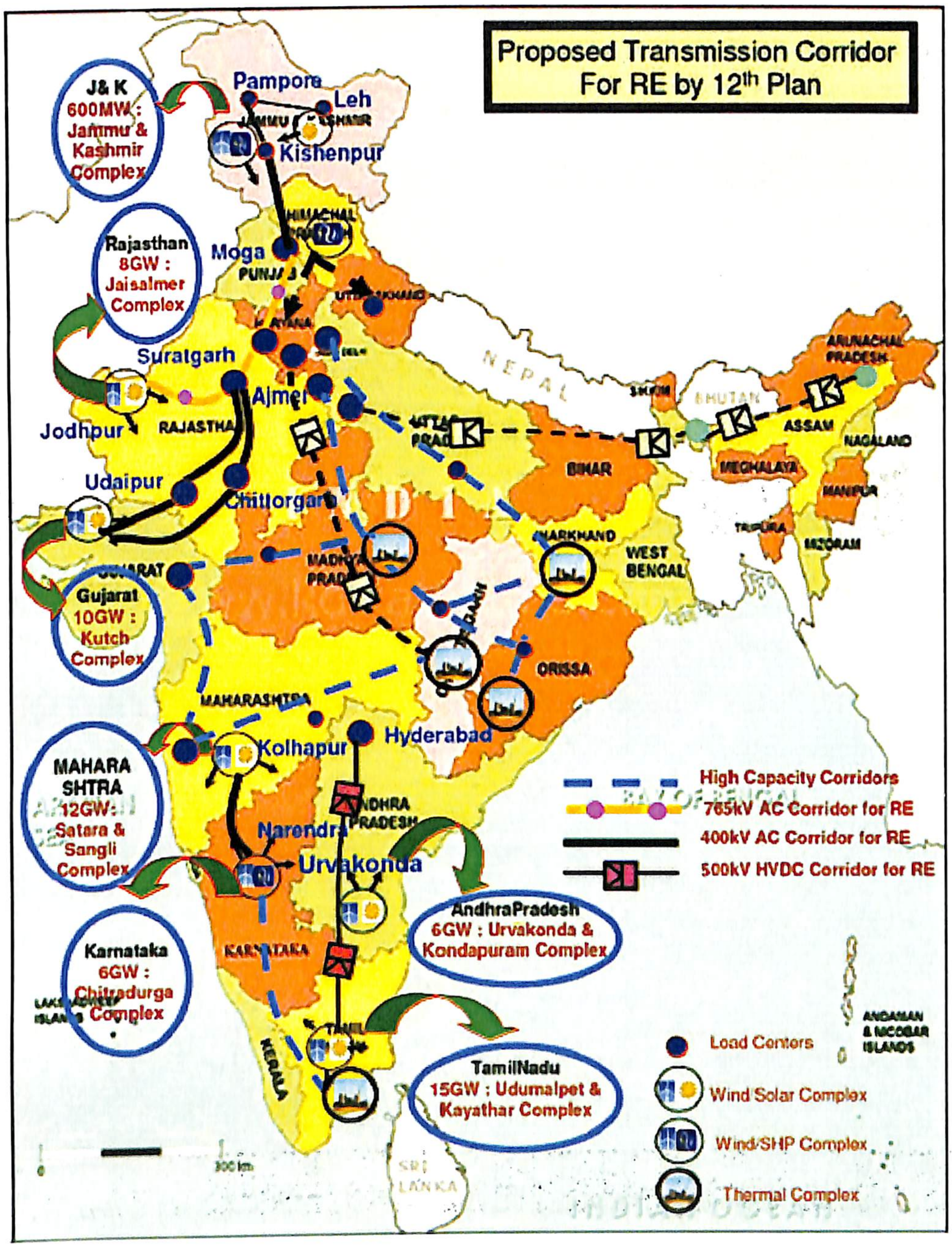
Peak demand of various States of different regions has been considered as per the available draft 18th Electric Power Survey (EPS) Report corresponding to 2016-17 study time frame. In addition, motoring load of pumped-storage hydro plants in T amil Nadu (400MW), West Bengal (900MW), Uttarakhand (1000MW) and Maharashtra (250 MW) are also considered as load in the respective States over and above the draft 18th EPS peak demand. In the motoring mode a pumped storage plant usually consumes 20 % more power than it produces during generator mode.

It is assumed that total demand of all the constituent States is being met through State's own generating stations, allocation of power from central sector generating stations, target allocations from private sector generation projects located in that particular region and import from other regions. For the studied time frame, all new generation schemes likely to be commissioned by that time frame have been considered.

### 8.5.3 Transmission System

A number of transmission schemes are likely to be implemented by 2016-17 in various regional grids as a part of Inter-State Generating Stations/IPP/Grid strengthening schemes. Eleven (11) High Capacity Transmission Corridors in all the regions are under different stages of implementation. In addition, transmission system of different regions including STU networks (220kV level and above) which will be available during time frame of the study has been simulated based on the data available with POWERGRID. Some of the future network (400kV & 220kV level) has been considered from the details provided in regional maps of respective STUs.

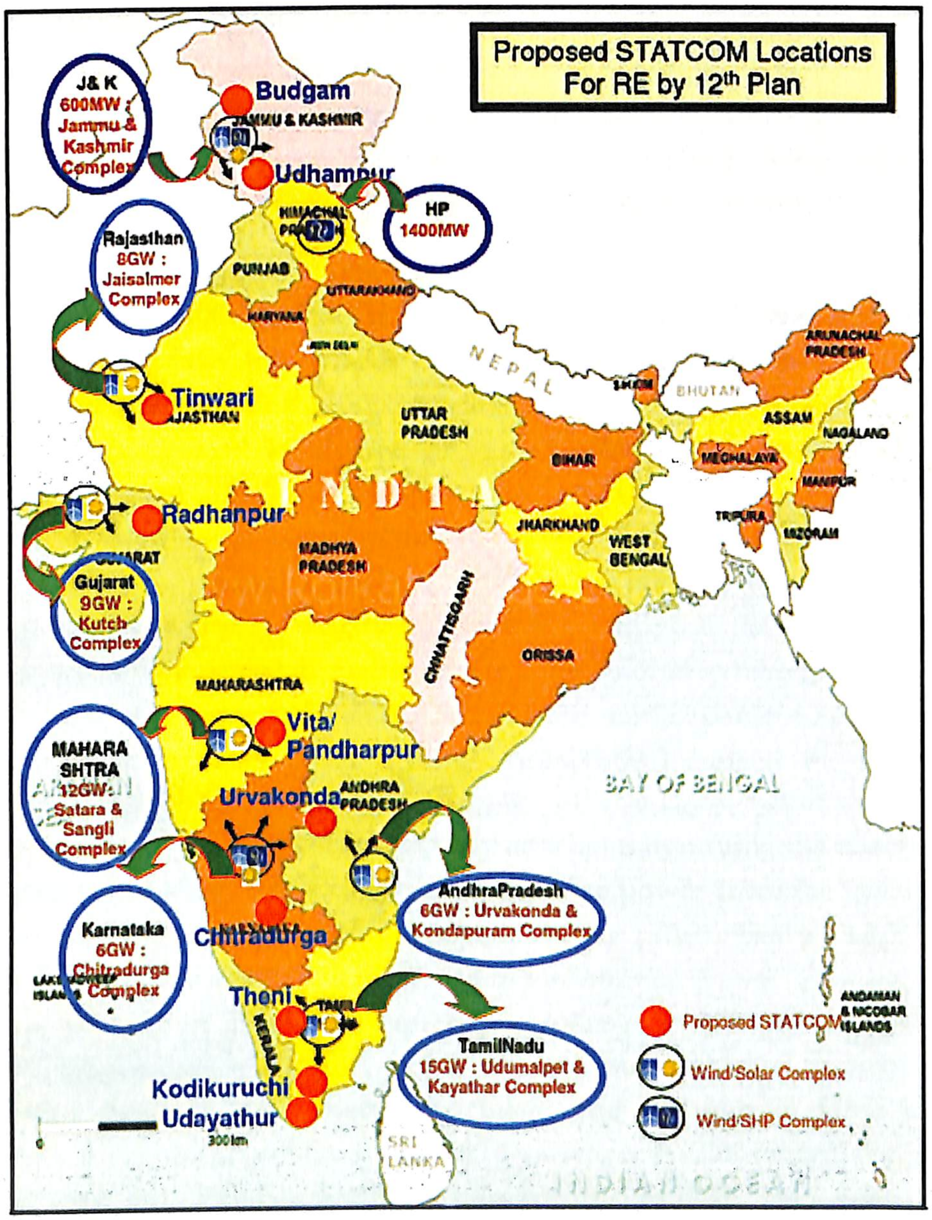
**Figure 13: High capacity transmission corridor for RE by 12th Plan**




## 8.5.3.1 Need of Reactive Compensation

Requirement of following Bus reactors (Switchable/ Controlled reactor) are identified to deal with the High Voltage Situation in the Grid at 220kV & above voltage level. In addition, to provide dynamic voltage support, ST A TCOM are also proposed at strategic locations

**Figure 14: Proposed STATCOM Location**




## 8.6 Challenges in Integration of Large Scale Renewables

### 8.6.1 Challenges in Grid Planning

- Large Scale Wind/Solar integration may introduce new patterns in the flow of power which may cause congestions in transmission & distribution networks in case of a conservative planning.
- Wind/Solar Plants have low gestation period than transmission strengthening, constraints may arise on account of large difference of

gestations periods. Therefore, transmission system has to be undertaken well before the activities at such plants commence.

- Wind/Solar plants are generally located in remote/concentrated locations. The probability of such area not being a load centre is quite high. The power network is also peak in such area. Concentration of wind farms in one complex lack benefits of geographical diversity
- Wind/Solar farms are known to be prov iding lesser grid support during system disturbances/exigencies than the conventional.

### 8.6.2 Challenges in Grid Operations

- Wind being variable & intermittent may c ause severe stresses of the system and calls for suitable reserves/spinning capacities. With the lack of sufficient flexible support available from other conventional resources, it is very difficult to operate the system with large amounts of wind power
- Concentration of such resources in one complex may cause supply management issues in case of sudden drop in wind generation.
- Wind plants generally are not capable to supply ancillary services like active power ramp up/down, reactive support to the system in a dispatchable, controllable manner like conventional generators.
- At present most of the wind plants are not capable to operate during severe voltage sags (Ride through capabilities) caused by system faults. In case this happens and large amount of wind generation trips in certain pocket, the system will be adversely affected magnifying the effect of fault.
- Some of the Wind turbines consume reac tive power from the Systems, which can adversely impact the system during disturbances/high loadings unless suitable mitigating measures are taken.
- Due to lack of primary frequency respons e in the present Indian grid, systemoperators often find it difficult to maintain the system frequency within the permissible frequency band. The addition of large amount of wind (or solarphotovoltaic solar) generation could potentially aggravate the problem. The concern is most acute during light load conditions with wind plants at high output, when fewer synchronous generators would be running, and overall grid inertial response will consequently be reduced.
- Harmonic voltage distortion at the connection point of Wind farms and solar parks are likely to increase due to the deployment of power electronic equipments for RE generation integration.

## 8.7 Mitigating measures in Integration of Large Scale Renewables

Large scale renewable integration calls for addressing numerous challenges. This imposes many technical/regulatory requirements and therefore need may arise foradoption of new technologies, equipment, control & protection, market mechanism, regulatory interventions as well as modifications in technical standards for connectivity .

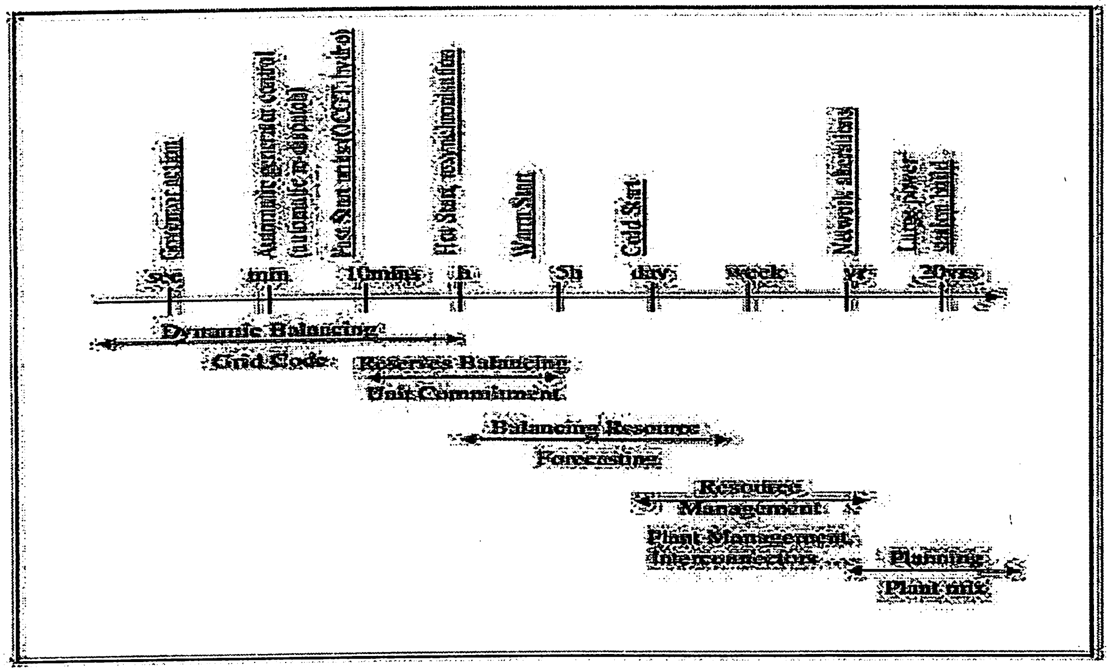
Measures to address smooth integration of large scale renewables broadly includes forecasting of renewable generation, availability of flexible generation, robust transmission interconnection between various balancing areas, spinning reserves, demand Side Management / demand response, energy storage capacities and suitable market design for handling the reserve. Detailed operational, technical as well as regulatory requirements are described as under:

### 8.7.1 Operational/Technical Requirement of Large Scale Wind/Solar Integration

Successful operation of power system requires continuously achieving a balancebetween generation output and system load plus losses. This delicate balance must be maintained over periods ranging from instantaneous to years ahead. Such a wide boundary encompasses machine and system transient response, automatic governor action, Automatic Generation Control, and re dispatch, unit commitment, capacity procurement and infrastructure dev elopments. The continuum is illustrated in the Figure 15.

High quality forecasting and confidence in the forecast are necessary to aid management of balancing energy from conventional plants. Availability of balancing plants in a range of sizes and time scales are critical resources. Use of markets and interconnections shall help to achieve energy balance.

**Figure 15 boundary of various balancing resources:**




Balancing resources and other infrastructure include;

- Reserves like spinning/hot reserves, quick ramp up plants like pumped storage/gas turbines as well as frequency dependent loads in the system to address power-balance
- Flexible Generators which can respond to system requirement
- Demand Side Management & Demand Response
- Energy storage
- Strong transmission interconnections
- State-of-the-art in Centralized Forecasting centre and integration with SCADA through telemetry
- Suitable market design to handle reserves for power balancing
- Possibility must be explored to regul ate or continuously control wind power through means like pitch control, wind farms SCADA etc.
- Deployment of synchrophasor technolog y i.e. PMUs/WAMS on pooling stations and interconnection with centralized control centre through Fiber optic communications for real time information, monitoring and control.
- FACTS devices such as ST A TCOM/SVC at strategic locations in the grid
- Relay Protection coordination

Figure 16 illustrates the impact that variability and uncertainty have on system control. V ariability and uncertainty , including uncertainty caused by limited telemetry , grows with time and requires control of an increasing range of resources. The result is an expanding cone that must be filled with a sufficient quantity of flexible resources; otherwise power system reliability is jeopardized. As variability and uncertainty increase with increasing wind integration, the mouth of the cone widens, requiring additional system flexibility , either from existing resources or by addition of new resources.

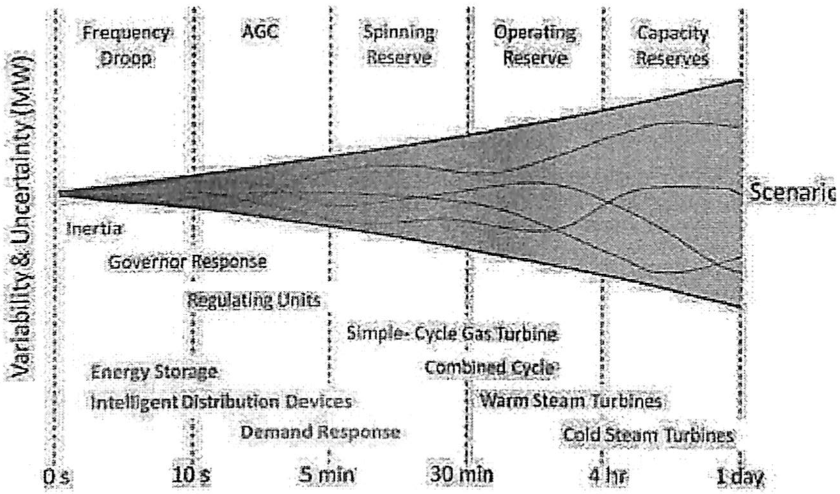



**Figure 16: Growth of variability and uncertainty with time and associated resources available to maintain power-balance**

While we are seeing an increase in wind integration, we are also seeing new technologies, such as FACTS devices, synchrophasors, energy storage, and demand response, which are accelerating the evolution of control systems. These technologies provide opportunities to improve visibility and control of the power grid, but also require new tools to manage and integrate a rapidly growing volume of data. At all times, the power grid must have a sufficient number of flexible and controllable resources to respond to variability . Though the magnitude of this variability decreases as we approach real-time operations, the number of flexible resources and their response capabilities (e.g., tosupport ramping) also decreases .

At present, flexible frequency band and availability based tariff (UI mechanism) plays a major role in balancing minute-to-minute variation in load and supply along with some reserve. These mechanisms also take care of unscheduled outages of a generator . In traditional practice, contingency reserve and operating reserve are used infrequently to provide replacement power. Variability of RE requires a reserve response that is both more frequent and bi-directional (i.e., requiring both curtailment and replacement power). With increasing integration of RE, we will see increasing variability of "net load" (load minus renewable generation), such as from the magnitude and duration of ramp events. Present practice of real time unbalance management may not be sufficient for handling large scale uncertainty in RE generation and may limit the integration of RE.

Details of the proposed key operational requirements are deliberated as under:

### 8.7.2 Flexible Generation and Generation Reserves:

To handle the intermittent & variable nature of renewable resources especially wind, fast response from flexible generation which can ramp up and down in response to supply variation is required. The mix of different type of generation with varying degree of response is desired so that at all point of time the generation of power could be matched with load. Since these power fluctuations vary from milli second to few hours or days, different types of generation reserves are used. System Reserves are primarily classified in three categories depending upon their activation time:

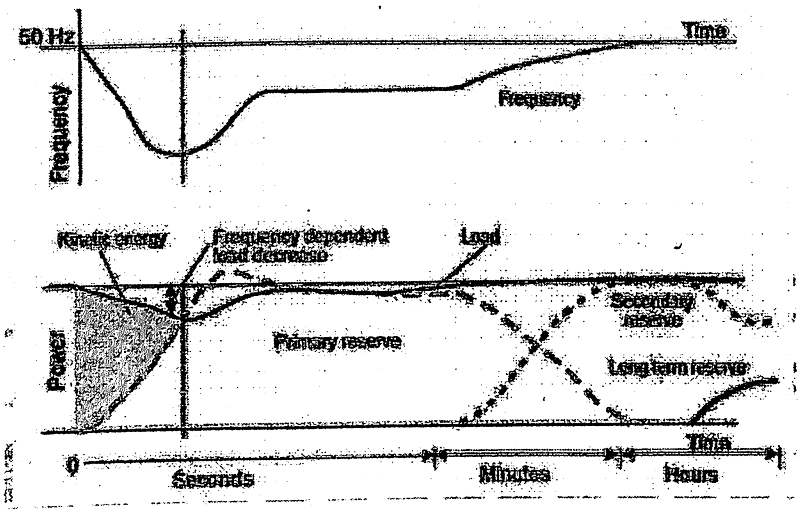
**Primary reserve/ Frequency response reserve:** These are usually provided by units which are connected to the grid and can ramp up fast (within few seconds to a minute) in response of frequency fluctuations.

**Secondary reserve or Spinning & non spinning reserves:** Units which may or may not be on-line butprovide ramp -up and ramp-down in 10-15 minutes.

**Tertiary reserve :** Units that are usually offline but require time varying from few hours to days for start-up or shut down.

These reserves are required to maintain the integrity of the system in case of imbalances between power consumption and power generation.

**Figure 17: System Reserve**




The experience of countries with higher penetration of renewable suggests requirement of long duration fast ramping spinning reserves. Such reserve comes from the plant like Hydro, Gas turbine or Thermal base load plant operating at part load. They are briefly discussed in terms of availability of. their capacity into Indian Grid and meeting the reserve requirement of large scale renewable generation penetration:

### 8.7.3 Hydropower Plant with Reservoir

Hydro generating station in India account for 20% of installed capacity. Hydro power plant with reservoir, store water in a dam for use later during low water inflow-condition. Therefore power generation from these plants is more stable and less variable as compared to Run o the River (RoR) plants. They generate electricity when needed. They provide reserve capacity and can respond to load changes within seconds. In India, such power plants operate during peak hours to meet system peak demand. Hydro Plants expected to respond to grid frequency changes and inflow fluctuations. They also provide fast ramp up and ramp down (order of few seconds) capabilities

### 8.7.4 Pumped Storage Power Plant:

Pumped storage plants are not energy sources, instead they are storage devices. Water is pumped from a lower reservoir into an upper reservoir, during off-peak hours. The stored water is used to generate electricity during the peak load period or whenever there is demand. Because of their fast response and storage capacity, such stations proved to be an excellent reserve.

In India, pumped storage Hydro capacity in operation is only about 1550 MW (Kadamparai - 400MW, Purulia-900MW, G hatghar - 250 MW). This provides approximately 3000 MW variation between peak and off peak. Another Pumped storage plant of capacity 1000 MW is under construction at T ehri. As a thumb rule a PSP need about 20% more power so as to operate at its rated capacity e.g. a 900 MW PSP would need about 1 100 MW to pump up water into upper reservoir due to frictional and cavitations losses in the turbine, water conductor system and pump. Considering the large scale renewable integration, their requirement into Indian grid is much needed.

Hitherto considering their energy requirements and capital cost, it was felt that some regulatory interventions/policy measures are required for the financial encouragement of such projects, particularly regarding allocation of night power for pumping. The situation has undergone some change over the last few years with a vibrant Day Ahead Market (DAM) in electricity. The DAM over the last two years has shown up a difference of the order of Rs.2 to Rs. 3 per unit between the night off peak hours and the evening peak hours.

Revival of Srisailam LBPH (900 MW) and early commissioning of Tehri PSP (1000 MW) would provide a total of nearly 6500 MW regulation in the Indian grid. Further several Pumped Storage Stations have been planned and developed in the Country which is not being operated in pumped mode due to commercial as well as technical issues. In addition there are many hydro plants which are feasible to be convertible into Pumped Storage Hydro Plant. Feasibility should be evolved to encourage participation of such Pumped storage plan for introducing more regulation into the grid with the increased Renewable penetration.

### 8.7.5 Combined cycle plants

Combined cycle plants which constitute <10% of the installed capacity in India presently are among the most flexible options to balance the variations. These plants are efficient and can ramp up and down quickly but they are expensive in terms of fuel/capital costs

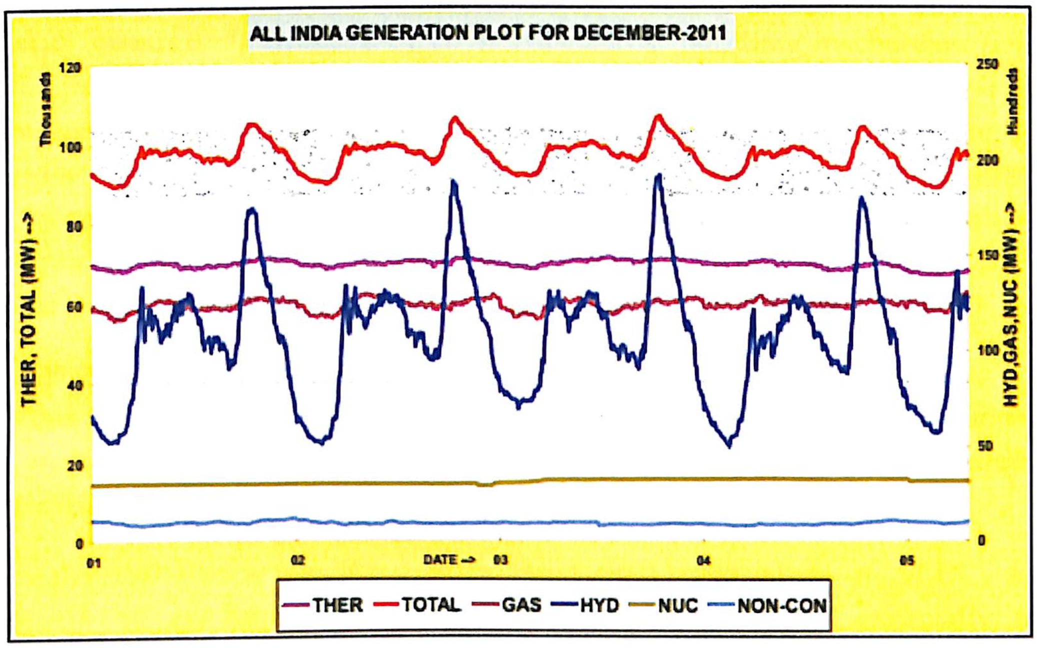
### 8.7.6 Thermal plants:

Coal plants accounts for 56% of total installed generation capacity .Since they have low variable cost and cannot be put on and off instantly (due to specific temperature and pressure requirement) they are made to run as base load plant. These plants are less flexible in response to load changes because of their longer startup ( 6 hrs when cold start-up & 4 hrs when hot startup) and shut down times. Their output has to be reduced radually at 3 MW/min. Such plants can be used as reserve plants if they are running at or near Technical Minimum. However, in Indian context, the thermal generators are reluctant to operate at lower output because of reduce efficiency and no additional commercial benefit for reducing output.

One important change in the Indian thermal plant scenario is the establishment ofsuper-critical coal fired units. In the 11th Plan, eight supercritical units have been synchronized (all in Western region) adding to a capacity of 5450 MW. In the 12 Plan, the coal fired capacity proposed to be added is 66,600 MW as per the draft National Electricity Plan out of which 42% or 27,900 MW would be super-critical units. In the 13th Plan, the coal fired capacity addition is expected to be 49,200 MW, all of which would be super-critical units. While the super-critical units are known for higher efficiency , a lesser known aspec t is more flexibility in terms of regulating generation as compared to the natural circulation units having a boiler drum. Typically , a supercritical unit can operate at the designed super-critical steam parameters between 80-100% of rated capacity . Thus if we have about 70,000 MW capacity of super-critical units on bar at any point of time after the 13th Plan, 14,000 MW (20% of total available capacity) variation could be provided in flexible manner. This can be harnessed if the units are able to participate in the 'downward regulation' electricity market.

The utility of various types of generation, as reserves in Indian system to meet the demand, is depicted in Figure-18. It shows the behavior of different types of generation in the month of Dec'11 on all India basis.

**Figure 18: Participation of different resources in meeting demand**




From the above figure 7.7, it may be noted that whenever the total generation (red color) dips, hydro plants (blue color) provides the support. Thermal plants (Magenta color) & gas plants (brown color) fail to provide immediate support whereas Nuclear plant (dark Green color) output does not respond to variation. Non-conventional i.e.wind in this case (Light blue color) has its own pattern which depend upon wind speed, direction etc.

It is observed that coal based plants act as base load generation source and hydro & gas provides peaking requirement. But due to high cost of gas, it is not a preferred reserve. Thus, pumped storage and reservoir type hydro plants remain the only viable reserve sources. With the expected large penetration of renewables, such reserves will also need to be encouraged & developed. Other option to maintain reserve is through thermal generating plants with suitable compensation mechanism

### 8.7.7 Scheduling Philosophy

In India, decentralized control and operation have been adopted, which means that demand & generation is to be balanced at state level. The generation of each plant is scheduled on "day ahead basis" but they are permitted to dispatch as per the system conditions with the aim to bridge demand -supply gap. Indian Electricity Grid Code (IEGC) permits the frequency to fluctuate within a band of 49.5 Hz to 50.2Hz. The renewable generation presently constitutes about 12 % of total generation capacity in the country . The variations which ar e associated with such renewables do not affect the total generation in a substantial way . It is, ther efore, easier to maintain frequency in the prescribed band through "frequency linked imbalances handling mechanism (UI)". But as the penetration of renewables increases, the impact of their variability & intermittency may cause substantial variation in the total generation leading to wider load-generation gap. To handle these imbalances, forecasting and dispatching of renewable power will be an important aspect for their reliable & secure integration with the grid. Methodology for Wind Power forecasting is deliberated asunder:

### 8.7.8 Wind power forecasting

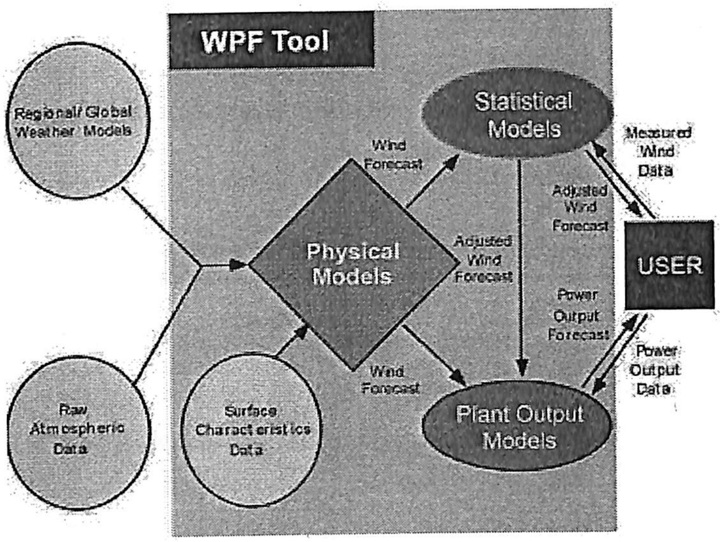
Wind forecasting helps in optimization (Unit Commitment) and scheduling of conventional power plants (Economic Dispatch) & provides adequate caution or spinning reserve to balance out contingencies.

As per the Renewable Regulatory Fund (RRF) procedure of NLDC, forecasting should be an important requirement to avoid UI/RRC especially for wind. Since the wind generation has daily and seasonal pattern, the challenge before operator is its short term (upto few hours ahead) and next day forecast. Short term forecast helps in grid operations in managing reserve capacity dispatch in an optimal fashion, whereas the next day forecast will help in optimally scheduling the conventional generation.

### 8.8 Methodologyof Wind Power Forecasting (WPF)

Advanced approaches for short-term wind power forecasting necessitate predictions of meteorological variables as an input using numerical weather prediction (NWP) models. Predictions of meteorological variab les are converted to predictions of wind power production. Such advanced methods are traditionally divided into two groups. The first group, referred to as physical approach, focuses on the description of the wind flow around and inside the wind farm, and use the manufacturer's power curve, for proposing an estimation of the wind power output. In parallel the second group, referred to as statistical approach, concentrates on capturing the relation between meteorological predictions (and possibly historical measurements) and power output through statistical models whose parameters have to be estimated from data, without making any assumption on the physical phenomena

**Figure 19: Methodology of Wind power forecasting.**




Around the world the wind power forecasting is done on three different time scales (1) very short-term (0-6 hrs); (2) short-term (6-72 hours), and (3) medium range (3-10 days). Forecast performance is expressed as a mean absolute error as a percentage of a wind plant capacity .

From the wind farm or solar power developer's perspective, forecast would greatly affect the revenue stream, particularly if the developer is made fully responsible for imbalance payments. Thus for the purpose of working out imbalances, the schedules should be based on the developer's forecast viz. a decentralized one. At the SLDC level many such decentralized forecast from different developers would be aggregated to work out the forecast for the state as a whole. The SLDC could run its independent algorithm to obtain the state level forecast. Such SLDC level forecasts are essentially for the purpose of system security viz. balancing actions, rescheduling and network constraint mitigation. The RLDCs would aggregate state level forecasts while the NLDC would aggregate the regional level forecast.

Thus we need both decentralized and centralized forecasts, the former for commercial reasons and for which the developer is responsible while the latter is essentially for system security for which all the Load Despatch Centres (LDCs) are responsible.

In addition to above, with increasing solar penetration as well as intermittent/varying solar output in adverse weather conditions, Solar Forecasting is also very much essential.

## 8.9 Demand Side Management & Demand Response

Demand Side Management (DSM) or Demand Response (DR) through Smart Grid is another important option to increase the flexibility in accommodating the variable nature of large scale renewables. DSM/DR is designed to encourage consumers to modify patterns of electricity usage. In this way, DSM/DR helps to reduce the operational cost of renewable integration through measures such as load shifting and peak shaving thereby reducing the requirement of reserves. For this Smart Grid backbone system like advanced metering Infrastructure which includes provision for smart meters at the consumer premises, with two way (consumer and utility) communication and control features, time of use tariff mechanism to encourage consumers to shift their demand etc. need to be established.

### 8.10 Energy Storage

Energy storage technologies offer a great solution to accommodate large scale Renewable penetration and address its inherent issues like variable and uncertain output. Energy Storage can handle the excess availability of renewable during off demand period and energy support during peak hours just like another hot / spinning generation reserve.

Energy storage applications are classified into two broad categories: power applications and energy applications. Energy storage designed for power applications has the capacity to store small amounts of energy per kW of rated power output, and require high power output for relatively short periods of time (from several seconds to 10-15 minutes). Storage designed for energy applications has large energy capacity with discharge durations up to many hours.

There is a large variety of energy storage technologies either emerging or commercially available. Each technology has some inherent limitations or disadvantages that make each practical for a limited range of applications. The capability of each technology for high power and high energy applications is well defined and has been the subject of many studies. Utilities in several U.S. states have recently embraced new MW-scale energy storage technologies as part of their testing and demonstration projects to mitigate the effects of wind power variability .

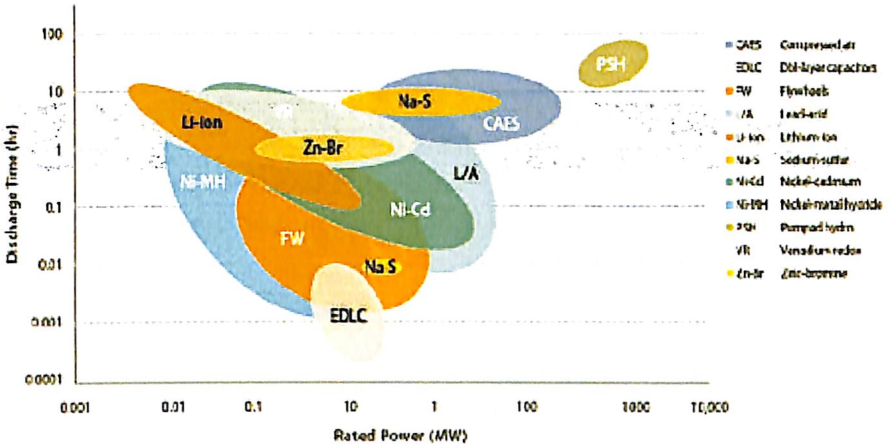
There are multiple energy storage concepts employing various technologies that have wide ranges of capital and per-cycle costs, effici encies, and energy densities (sizes and weights). List of such technologies are as under:

- Large Scale Batteries
- Flywheels
- Compressed Air Energy Storage (CAES)

- ➢ Thermal Storage (Molten Salt)
- ➢ Vehicle to Grid (V2G)
- ➢ Others like Super capacitors, super conducting Magnetic Storage, Hydrogen
- ➢ Energy Storage etc.

Comparison of above technologies with system ratings and grid support duration in terms of discharge time is depicted in Fig – 20 as under

**Figure 20: Comparison of Storage Technologies**




A brief description on large scale Battery Storage and Compressed Air Energy Storage is deliberated as under:

### 8.10.1 Large Scale Battery Storage

Several types of batteries are used for large-scale energy storage. Technologies that are used in field systems include lead acid, nickel/cadmium, sodium/sulfur , lithiumIon, and vanadium-redox flow batteries.

Recently introduced Sodium-Sulfur (NaS) battery is the most mature hightemperature battery and has been demonstrated at over 190 sites in Japan totaling more than 270 MW with stored energy suitable for six hours daily peak shaving. The largest NaS installation is a 34 MW/245-MWh system for wind power stabilization in northern Japan. In the United States, several utilities have deployed NaS batteries for testing and demonstration purposes

### 8.10.2 Compressed Air EnergyStorage

Compressed air energy storage (CAES) technology is based on conventional gas turbines and stores energy by compressing air in an underground storage cavern.The CAES gas turbine uses 40% of the gas used in conventional gas turbines to produce the same amount of output power . This is achieved by combusting fuel after mixing it with stored air in the turbine

The primary disadvantage of CAES is the need for an underground cavern created inside salt rock. It also relies on fossil fuels for operation. These factors may limit CAES applications in small island grids.

## 9 Conclusion:

According to IEA (International Energy Agency) World Energy Outlook report going forward the electricity growth and the CO2 emission are going to decouple meaning a happy divorce. This is going to happen mainly because of multiple factor one being that renewable are going to play vital role and their share in electricity generation is going to increase, according to Greenpeace report by 2050 there will be 100% renewables, but WEO do not state the same. Nevertheless they state renewable is going to play a key role. Further to that the energy efficiency, slowdown in coal based power plant and demand side management are going to play key role in decoupling of electricity demand and CO2 emission. However, in India coal is going to play key role for times to come, at the same time government is taking measures to reduce CO2 emission by encouraging super critical coal based power plant, and encouraging renewables. Indian government has set ambitious target of 175GW by 2022. In 2015 itself Solar is forecasted to add more than 2500MW of power taking to the total to 4500MW plus. The capacity addition of renewable will continue to grow be it wind, Solar or solar thermal. If the target capacity addition is to be achieved it will pose significant threat to grid stability if measures are not taken. Power Grid Corporation has made study to understand operational trends of renewables and the issues and mitigations in integration of renewables to the Grid. As the gestation period of renewables is 10 to 12 months, the action from Grid authority to augment the facility to take off the available RE generation need to be fast. Further, how will Grid stability be affected by the huge RE coming on stream? There are some interesting observation, India is huge country, as of now the renewable that is being added is relatively small knowing that the grid authority allows the grid to be operated within a frequency band, which means if there is sudden cut off or cut in the load the grid can sustain and will not pose immediate threat, but going forward the RE addition increases, we need to be prepared on many fronts especially on Hydro reserve which comes up very fast, pump storage plants have to come up and in states like Rajasthan where there is complementary wind and solar energy will not really have an effect. Gas based power plant reserve capacities have to utilized for peaking for which Government have to incentivise developers. It is now believed that supercritical power plat can maintain close to 20% load reserve to come up quickly or ramp down when RE capacity increase. Here also government has to support developers and bring in key changes. Other than the host of things highlighted many other actions/initiatives have to be put in place or worked out simultaneously such as energy storage, demand side management, advanced forecasting tools, maintaining database of all RE addition ( including Roof top), improving transmission capacity for sale of excess power to deficit state ( meeting RPO), etc. If right measures are taken on time the issues related to grid stability/integration of RE can be fixed, we already see that in developed countries, India can overcome with the issue of RE integration and RE can and will play a key role and shall increase the share in coming years.

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Gmail by Google

Prakash kenganur <prakashkenganur@gmail.com>

# Fw: External Guide for Mr. Prakash Kenganur (SAP No. 5000 248 73)

1 message

**Jagadish.Gurav@ilfsindia.com** <Jagadish.Gurav@ilfsindia.com> Wed, Nov 4, 2015 at 11:49 AM
To: sgrover@upes.ac.in
Cc: Pakkya <Prakashkenganur@gmail.com>

Dear Mr. Grover,

Further to trailing mail, plz find enclosed signed copy of the enclosed Appendix - III, i.e., Declaration by the Guide........As per our company internal guidelines, I can't submit the Declaration on our companies letter head.........Hope this should be ok

Regards,
Jagadish Gurav

*(See attached file: 20151104111942.pdf)*

----- Forwarded by Jagadish Gurav/IEDC on 04-11-2015 11:17 -----

From: Jagadish Gurav/IEDC
To: sgrover@upes.ac.in
Cc: "Pakkya" <Prakashkenganur@gmail.com>, prakash.kenganur@power.alstom.com
Date: 30-08-2015 21:58
Subject: External Guide for Mr. Prakash Kenganur (SAP No. 5000 248 73)

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Rererence:

Name: Prakash Kenganur

SAP NO: 500024873

Semester: Six (6) EMBA (Power Management)

Dear Mr. Grover,

This is with ref. to above, I here by confirm that I am accepting to be an External Guide for Mr. Prakash Kenganur who is perusing EMBA in Power Management at UPES (Distance)

It may be noted that, the Appendix III mentioned in the guidelines will be submitted after completion of the dissertation work. Plz revert for clarifications, if any

Regards,

Jagadish Gurav

Associate Vice President
IL&FS Energy Development Company Limited
The IL&FS Financial Centre
Plot C-22, G Block
Bandra-Kurla Complex
Bandra (East), Mumbai - 400 051
Tel: +91 22 2659 3808
Mobile: +91 9930 992975



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