Engineering Interventions Necessary for Achieving 175 GW of Renewable Power by 2022

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Indian National Academy of Engineering (INAE)

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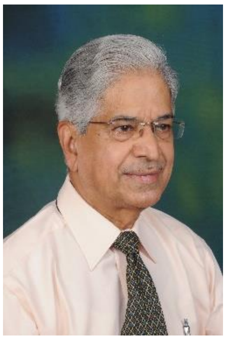
Foreword



Dr. BN Suresh
FNAE, FAeSI, FASI, FSSI, MIAA

I am delighted to note that the INAE Research Study on "Engineering Interventions Necessary for Achieving 175GW of Renewable Power by 2022" with Mr. Pradeep Chaturvedi, FNAE as Coordinator, jointly with IREDA and Deloitte has been brought out. The "Renewable Energy Target of Achieving 175 GW by Year 2022" is a challenging task and needs appropriate engineering inputs for its realization. Therefore, in the present context the study on this aspect of providing effective engineering inputs for achieving this goal, which is crucial for meeting India's global commitment on reduction in GHG emissions, is of vital importance.

The basic objective of the study was to identify the issues to bridge the gap between what was 'perceived as achievable' and 'what needs to be achieved' in order to meet the laid down targets through large scale deployment of renewable energy systems. The following five sub-topics covered in the study provide an Action Framework for supporting the target in terms of technology; business models for renewable energy supply; strategy for grid integration and balancing power; policy interventions; creation of manufacturing capacities and project management capabilities.

Inputs from Deloitte has been sought for conduct of the study with the needed expertise on engineering issues, financing and investment matters, regulatory issues and marketing issues. The support from IREDA for the Study is duly acknowledged. We also wish to convey our thanks to all experts, particularly the experts from the World Energy Council who were involved in deliberations and preparation of the study report. The contributions of Mr. Pradeep Chaturvedi, FNAE and Coordinator of the study are noteworthy. The inputs from Mr. Shubhranshu Patnaik, Partner, Deloitte India are appreciated. I would also like to place on record the significant contributions of Dr. Ajay Mathur, FNAE, Mr. B Prasada Rao, FNAE; and other members of INAE Sectional Committee on Energy, Mr. K.S. Popli, CMD, IREDA and Mr. J.K. Mehta, Regional Manager, World Energy Council for ensuring the successful completion of the study.

It is earnestly hoped that the study will serve as a base document for all stakeholders in the allied fields from industry and Government Departments/agencies. Needless to say that the recommendations emanating from the study shall be actively pursued with the concerned Departments. This will no doubt be very useful in achieving the envisaged target of 175 GW of Renewable Power by 2022.

I am confident that this study report will be of immense benefit to all stakeholders from Government, industry and R&D organizations and will be well received by all interested engineering communities.

(BN Suresh)
President, INAE

Preface

Mr. Pradeep Chaturvedi
FNAE

The Indian National Academy of Engineering (INAE) Research Study on "Engineering Interventions Necessary for Achieving 175 GW of Renewable Power by 2022" in India, was initiated with the objective of supporting the national effort of providing electricity for economic development through sustainable pathways. India's Intended Nationally Determined Contribution (INDC) submission to United Nations Framework Convention on Climate Change (UNFCCC) highlights that achieving 175 GW of renewable energy power is an important factor of India's future energy plan.

INAE Fellows represent eminent engineers in the country, and as such it was felt that the intellectual inputs from the relevant experts and the engineering interventions suggested by them in a Research Study would indeed help in achieving the goal set forth by the Hon'ble Prime Minister of India. Keeping in view the importance of this issue, INAE Sectional Committee on Energy Engineering, during its meeting on May 2, 2016, deliberated on the purpose of the Research Study and laid down the following objectives and contents.

The objective of the Research Study is to bridge the gap of 'what is perceived as achievable' and 'what India must achieve' in order to realize the targets envisaged. Following topics were identified to be covered under the study, so as to provide an effective Framework of Action:

- Advancement in systems technology development for cost-effective solutions for project execution, operation and maintenance.
- Strategy and solution for grid integration and balancing power – including cost of balancing power.
- Evolving Business Models for renewable power supply, manufacturing renewable energy systems, installation and integration by studying and globally emerging business models.
- Policy interventions to support achieving the target cost-effectively.
- Creating manufacturing capacity of poly-silicon solar cells, modules and inverters of required quality at globally competitive price.

The broad methodology of conduct of the study was also formulated. It is pertinent to note that the contents of the study were multidisciplinary in nature and required professional inputs from a large number of organizations and individuals, especially from those who were working in diverse areas such as strategy, policy, regulation, marketing, technology and manpower development. It was, therefore, decided to have partnership with Deloitte India to supplement the technological strength of INAE and also seek inputs from other specialists. A joint research team was set-up under the guidance of the undersigned by INAE, comprising of members from the Sectional Committee on Energy Engineering along with Experts from Deloitte India.

The key recommendations of the Study are presented under the following thrust areas:

i. Technology focus and R&D focus including increase in R&D spending.

ii. Building an integrated manufacturing eco-system and promoting competitiveness; and enhanced capacity in terms of testing centres and labs.
iii. Standardization and adoption of new technologies/techniques (and tools) to enhance efficiency and reduce cost for renewable energy projects.
iv. Automation and data analytics to be leveraged to reduce cost, and skill development.
v. Renewable energy integration including forecasting capability, grid integration and cost of balancing.
vi. Power market interventions to support penetration of higher level of renewable power.
vii. Regulatory mechanism and incentives.

The report contains valuable inputs by members of the INAE Sectional Committee on Energy Engineering and especially by Dr. Ajay Mathur, Convener and Mr. B. Prasada Rao. Drafts of the Report prepared at different stages were circulated and discussed with Fellows for suggestions for improvement. The Draft Report was also discussed on October 26, 2016 on the occasion of the Meeting on Clean Coal Technologies. Subsequently, a presentation was made by Dr. Ajay Mathur at the INAE Annual Convention 2016 at Ahmedabad on December 10, 2016. The Final Draft Report was circulated to Members of the Sectional Committee on Energy Engineering and their views were invited by December 31, 2016. All the feedback and comments received at different meetings and discussions were considered and the Study Report was finalized.

Our grateful to Dr. B. Bandyopadhyay, former Director, Solar Energy Centre for providing crucial inputs to the report on the issues of policy, programme implementation, strategy, financing and regulation at the national level, and undertaking peer review of the Draft Report; Mr. J.K. Mehta, Regional Manager, (South Asia), World Energy Council for providing inputs on international experience under the World Energy Council and Mr. A.K. Saxena, Mr. NS Prasad and Mr. Shirish Garud from TERI for providing valuable inputs.

We are grateful to Mr. K.S. Popli, Chairman and Managing Director, Indian Renewable Energy Development Agency (IREDA) for providing important inputs to the study on the issues related to financing and providing support.

Our grateful thanks to the team from Deloitte India led by Mr. Shubhranshu Patnaik, Partner and Mr. Tushar Sud, Mr. Rajneesh Sharma, Mr. Prabhat Lakhera, Mr. Abhishek Dave who undertook the responsibility of collecting & collating the data and preparing the Report.

Brig. Rajan Minocha, Executive Director, INAE and his team provided excellent secretarial support and coordination for smooth conduct of the Study and the same is duly acknowledged.

The Sectional Committee on Energy Engineering is privileged to present INAE-Deloitte Study that focuses on actionable recommendations to develop strategies for achieving India’s target of 175 GW of Renewable Power by 2022.

Pradeep Chaturvedi
Coordinator,
INAE Research Study on
“Engineering Interventions Necessary for
Achieving 175 GW of Renewable
Power by 2022”

Contents

LIST OF TABLES

LIST OF FIGURES

1 Executive Summary

The unique challenge India faces today is to ensure economic development using sustainable pathways and addressing issues related to energy access, energy security and climate change. To meet this challenge, India is focusing on developing its rich renewable energy resources, mainly solar, wind, biomass, and small hydro energy. This will support India's efforts towards climate change mitigation and emphasize its commitment to global climate change mitigation efforts.

India's Intended Nationally Determined Contribution (INDC) submission to UNFCCC covers 175 GW of Renewable Energy (RE) target as an important factor of India's future energy plan. Achieving this target would put India at the forefront of economies transitioning towards low carbon growth. The target presents opportunities for improving electricity access, clean technology development, manufacturing, and job creation. India has to focus on multiple fronts to take advantage of this target. Engineering interventions in the following areas would be necessary for achieving the target:

- Indigenous manufacturing of RE components such as solar PV cells and modules will benefit through job creation, reduce reliance on imported technology, and strengthen India's position as a manufacturing hub in line with 'Make In India' initiative.
- Achieving high capacity target of RE in a short time scale requires innovation in technology and cost reduction of project execution, operations, and maintenance.
- Injecting large amounts of variable RE would require the Indian grid to adapt to new challenges related to RE grid integration.

A. Indigenous manufacturing of RE components can help in creating jobs, reduce reliance on imported technology, and assist in the 'Make in India' Initiative

Solar PV

Global production of PV modules reached 69 GW in 2015 with China dominating the supply market with 41 GW. India had a PV module manufacturing capacity of 5.64 GW and cell manufacturing capacity of 1.46 GW as of June 2016. The 100 GW solar target by year 2022 presents a great opportunity for indigenous manufacturing of PV components. Indian solar installations are currently catered mainly through imported cells and modules. Successful global PV players have cemented their market share owing to strong raw material ecosystem, low cost of finance, innovation in material and production technology, high economies of scale and extensive state support mechanisms.

Cost of finance is a major issue impeding the growth of PV manufacturing in India as it impacts ability of manufacturers to achieve economies of scale, keep pace with new production technology, and allocate resource to R&D activities. Indian manufacturers also lack control over the raw material ecosystem as compared to the more established players globally. These issues will need to be resolved for PV manufacturing in India to stay competitive and keep pace with capacity installation.

Wind Power

Global wind power capacity addition in 2015 was 63.5 GW with China dominating installation and supply. Wind turbine manufacturing in India has a strong base of 9.5 GW and has been able to supply most of the local demand and has also benefited from exports. Wind turbine manufacturers in India have been able to create a strong raw material ecosystem. Most of the wind manufacturers have vertically integrated their manufacturing process, except for few components such as gearbox and bearings. While India has already achieved almost half of the 60 GW target set for 2022, challenges related to new technology development and boosting of exports still remain.

As availability of wind sites of class I and II reduces, there is demand for efficient wind turbine technology for low wind regimes. Issues such as high logistic costs which has affected exports of wind turbine from India, as of recently, will also need to be resolved to maintain the competitive edge of local manufacturers. Further, India has yet to explore the offshore wind energy potential and lacks adequate ecosystem required for development of offshore wind projects.

Small Hydro

India has a potential of 20 GW for Small Hydro. As of December 2016, out of the target of 5 GW total SHP installed capacity had reached 4.33 GW. India has a manufacturing capacity of 1500 MW for small hydro power (SHP) components and can well meet the local requirement. As per MNRE, 70% of the manufacturing capacity has an export focus. In SHP, increased technology focus should be on micro-turbine technology which can cater to low heads such as canals, fall structures, dam outlets, and small streams.

Biomass

Out of the total target of 10 GW of biomass power capacity to be installed, India has already achieved 4.9 GW. As per MNRE, required indigenous manufacturing capacity exists for setting up biomass projects in the country. There is increased focus on improving boiler efficiencies for biomass cogeneration projects. Further, there are also opportunities in Waste-to-Energy (WTE) segment, where developing waste segregation and toxic management technologies are a priority, given the Government of India (GoI) efforts under Swachh Bharat Mission.

Various recommendations have been identified in the following areas for manufacturing in RE technologies with a time scale specifying actions that can be carried out over short and long term:

Area	Recommendation	Time Scale
Technology Focus	• In Solar PV, focus should be on next generation technologies i.e. third and fourth generation solar cells while enabling leapfrogging to new material production technologies. - Market competition (mainly from China) in first and second generation solar PV cell technology is very high – hence may be tough for Indian firms to compete in these segments currently.	LONG
	• Focus should be on implementation of cost reduction interventions in the existing PV manufacturing process to lower cost like improvement in cutting technology to reduce wastage.	SHORT
	• Strengthen local manufacturing in Solar PV BOS: Resolve bottlenecks in manufacturing of sophisticated electronic components such as Insulate-gate bipolar transistor (IGBT) and controllers in order to reach 100% indigenization of PV BOS component manufacturing, and strengthen export.	SHORT
	• In Biofuel, promote second generation biofuel technology to tap huge biomass available in the country	
	• In Small hydro, promote micro-turbine technology design and testing specific to low-head water sources (<3-5 Mtrs) across different geographies in India.	LONG
	• Incentivize storage technology manufacturing in India that can be aligned with promotion of electric vehicle market and requirement of storage for RE integration.	LONG
Ecosystem and Competitiveness	Solar PV • Ensure sustained demand for locally manufactured PV modules to support existing ecosystem and upcoming module manufacturing capacity in India.	SHORT
	• Improve visibility of indigenously manufactured PV modules in target geographies/segments through dedicated initiatives.	SHORT
	• Focused initiatives to ensure integrated ecosystem of raw material for manufacturing such as partnering with manufacturers in China for critical raw material components. Some of the	LONG

	focus areas for this could be third/fourth generation solar cells, energy storage technologies.	
	Wind • In offshore wind energy, develop ecosystem & supply chain capabilities locally required for developing offshore wind projects. • Reduce logistic costs to enhance competiveness of Indian wind turbine manufacturers in global markets.	LONG
R&D Focus	• Increase R&D budget allocation to promote programs for new technologies which can enhance production efficiency- (similar to SunShot program in the US) like 3D printing to reduce the cell thickness of Poly-Si, develop capabilities for 3D printing third generation solar cells	SHORT
	• Create platforms for collaboration between private, government institutions and Centers of Excellence focused on next generation technologies – concept to commercialization like collaboration with ISRO for commercialization of multi-junction space grade solar cells.	LONG
	• Promote breakthrough technologies developed in India at a global scale	LONG
Enhanced Capacity of Testing Centres/Lab	• For achieving solar installation targets, MNRE should increase the capacity of testing centers/labs to support rapid development and commercialization of indigenous technology - All testing labs to be accredited by National Accreditation Board for Testing and Calibration Laboratories (NABL) - Encourage PPP framework to tap such capabilities already established by industry, while ensuring the independent nature of operating such facilities.	SHORT

B. Use of Cost Effective Technology solutions, Standardization for Project Execution, Operations and Maintenance will be a key for rapid deployment

Solar PV

Developers in India usually procure main components such as modules and inverters while outsource civil, electrical, and O&M functions to Engineering and Procurement Contractors (EPCs). The market for EPC players in India is highly fragmented and competitive with a presence of over 40 players. Due to this reason the quality of project execution vary widely amongst EPCs and there is a need for standardization. The issue of standardization attains significance for rooftop solar installations where the consumer (especially residential) have limited technical know-how.

There is also a need for adopting new technologies and tools which can reduce cost, time for installation and improve quality of project execution and O&M. This will be a critical factor to achieve a steady growth rate in installed capacity and achieve 100 GW solar target by year 2022.

Wind power

Wind power has a long history of development in India and is a well-established sector. So far all wind power projects have come up on-shore and future challenges an opportunities are expected to come up in repowering of existing on-shore wind and new off-shore wind power projects. India has a potential of 6 GW for repowering; and has potential for off-shore wind energy on its large coastal area.

India has not done much in implementation of off-shore wind power projects and require overcoming challenges before attracting private investment in this segment. Demonstration of off-shore wind energy power projects will be important to provide inputs on financial and technical feasibility, followed by creation of project execution standards for off-shore wind energy in India.

Small hydro

Small Hydro Power (SHP) has a potential of 20 GW across India. India has already achieved 4.3 GW out of the 5 GW capacity target. However, improvements are required to make SHP project management more efficient. One of the key issues has been the availability of accurate hydrological data and flow of water, which impact the output of the SHP power plant. Delay in approval & clearances also resulted in delay of implementation of a number of SHP projects. This adds to the risks associated with proper design and operation of SHP power plants which are normally located in difficult terrain.

Biomass

One of the main issues related to biomass power project management is raw material. The segregated nature of resources and uncertainties in availability of fuel throughout the year increases the complexity of supply chain management. Many a times this results into unsustainable prices for biomass raw material. Waste-to-Energy projects also face difficulties related to segregation and processing of toxic waste material. Utilization of biomass through second generation biofuel technology can be a focus and can assist in India moving towards achievement of biofuel blending targets.

Various recommendations have been identified in the following areas for RE project development with a time scale specifying actions that can be carried out over short and long term:

Area	Recommendation	Time Scale
Standardization	• Develop National Standard Guidelines for Solar PV Projects - specific quality and reliability standards with a focus on the roof top projects. - Code should provide clear directions on quality standards for design and installation. - Customize design and detailing for Indian conditions (accounting aspects of temperature, humidity, soiling etc), since they are mainly based on European Standards currently. - Create standard operating procedures for O & M of PV power plants. This will help maintain a minimum level of quality benchmark across power plants in different regions of India. The focus should be on enhancing quality of the solar systems without creating hindrances in adoption of new methods/innovative designs.	SHORT
	• Create standard for smart inverter technology engineered to suit Indian condition	LONG
Adoption of new tools and technologies	• NISE/Centres of Excellence shall undertake demonstration projects on new tools and techniques. Leverage PPP and private investment to provide cost and efficiency benchmarks to industry based on demonstration projects. The focus areas can be : - Faster project implementation : Foundation ramming, robotic installation of modules - Water less module cleaning using airjet or special coating for enhanced module efficiency - Promote use of thermal imaging to better manage deficiencies in PV power plant operation.	SHORT
Operating efficiency	• Demonstrate use of data analytics in analyzing power plant operation to understand rating of performance against quality benchmarks.	SHORT

	• Promote processes such as predictive, preventive, and scheduled maintenance activities based on data analytics.	SHORT
Technology Focus for project execution	• MNRE should encourage demonstration projects with a focus on replication and scaling at a commercial level: - Demonstrate different battery storage solutions - Demonstrate Wind-Solar hybrid - Demonstrate off-shore wind energy projects by providing technical assistance to NIWE to identify specific offshore blocks for project development through competitive bidding. - Demonstrate technology solutions for Waste-to-Energy - supply chain management issues such as segregation and safe management of toxic compounds to be addressed through innovative models. - Building Integrated PV (BIPV) and Floating Solar PV solutions.	LONG
Skill Development	• Focus on certification programs to train workforce for skills required for suppliers and installers with a specific focus on rooftop program.	SHORT
	• Develop skill at local level to cater to O&M of distributed rooftop solar projects – 40 GW rooftop solar capacity shall have high skill requirement at local level	SHORT
	• Provide training to EPC players to help follow quality standards during implementation and operation	SHORT

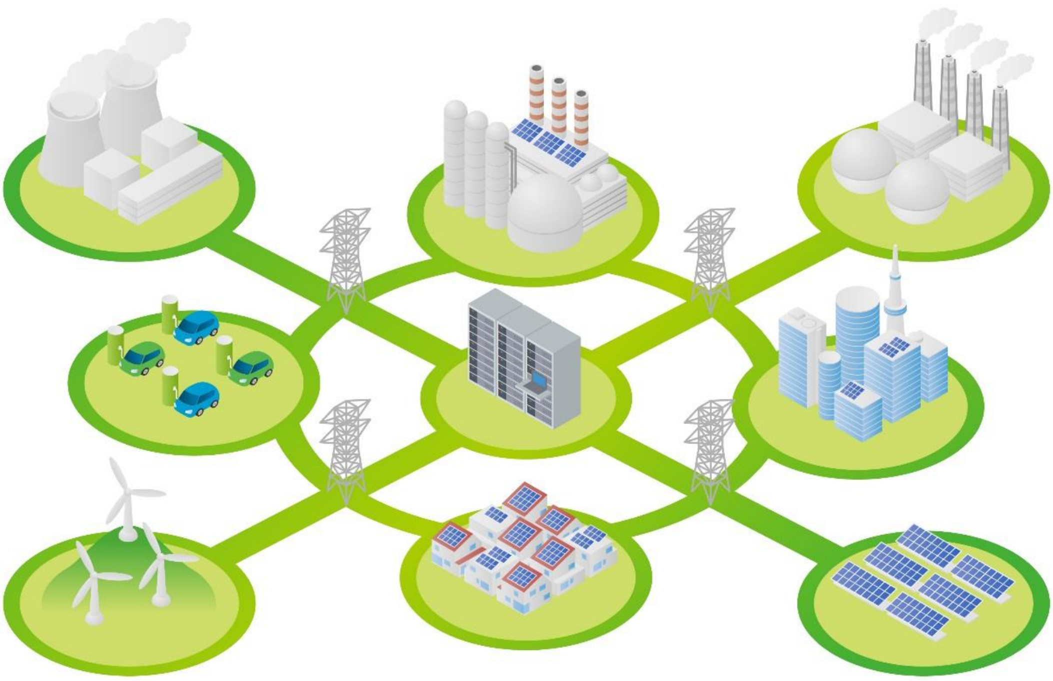
C. Grid Planning in India has to consider various measures to Integrate RE Capacity on a Large Scale

A 160 GW (wind & solar by 2022) of installed variable RE source would pose several challenges to the Indian grid. Issues related to evacuation and management of demand/supply schedules will be critical for long term security of the grid. Various technical issues such as managing intermittency in RE supply, spinning reserve requirement, accuracy in forecasting, and lack of adequate transmission infrastructure needs to be addressed. Initiatives are already under way such as the Reserve Regulation Ancillary Services (RRAS) implementation in Indian Grid by the National Load Dispatch Centre (POSOCO).

Following are the identified recommendation which can be considered to integrate 160 GW of variable renewable source in the grid:

Area	Recommendation	Time Scale
Forecasting capability	• Focus on enhancing the infrastructure - increase the number of monitoring stations and create data sharing framework between stakeholders such as distribution utilities, RE operators, data repositories and REMCs.	LONG
	• Provide access for real time data of RE generation from SLDCs and RLDCs – MNRE to provide funding to SLDC, RLDC, NLDC to set up adequate infrastructure required.	SHORT
	• Establish commercial framework for data sharing between developers and data providers to support accurate forecasting.	SHORT
Grid Integration	• Demonstrate using pilot projects capability of inter-regional balancing to manage variability- with support from CERC, SERCs, CEA and other state agencies.	LONG

	• Demonstrate smart grid projects to showcase new demand side management and decentralized grid connected generation technologies	LONG
	• Undertake pilot projects to review existing local distribution transformer (DTR) limits for rooftop solar installations – support SERCs through this initiative.	SHORT
Cost of Balancing	• Identify conventional capacity required for balancing activity based on analysis of variability on a regional and state level	SHORT
	• Quantify the cost of balancing for conventional power plant used for balancing, maintaining reserve power plants, managing errors of RE forecasting, retrofitting existing and new conventional power plants to increase backing and ramping capabilities.	SHORT
Ancillary markets	• Create markets for balancing capacity of conventional power plants used for managing variability of renewable energy. This shall complement the existing Reserve Regulation Ancillary Services (RRAS) being implemented by POSOCO in Indian grid.	SHORT
R&D Focus	• Use current available infrastructure of installed RE capacity to demonstrate large scale storage application using latest plug in battery solutions such as Li-ion, Hydrogen energy storage, and high power capacitors.	LONG



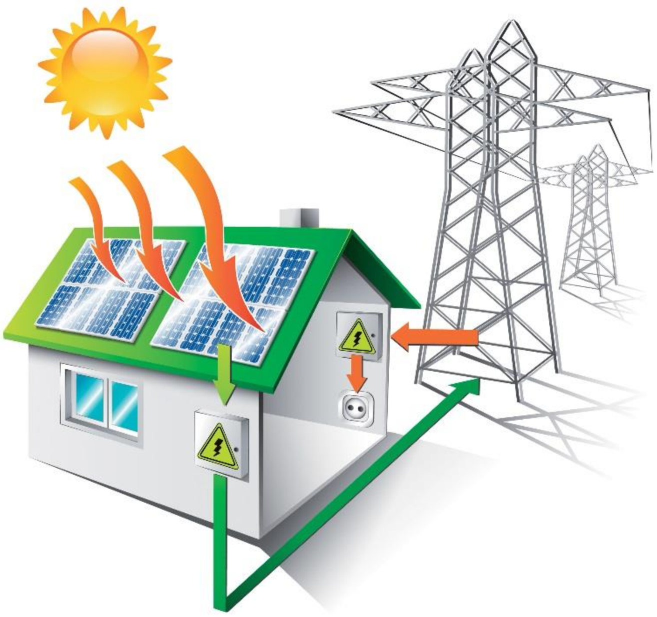
Conclusion

The RE target of 175 GW presents a great opportunity for India to transition to a low carbon economy. Overall benefits and successful achievement of the RE target can only be realized by focusing on multiple fronts of the RE ecosystem such as indigenous manufacturing, project management, and grid integration.

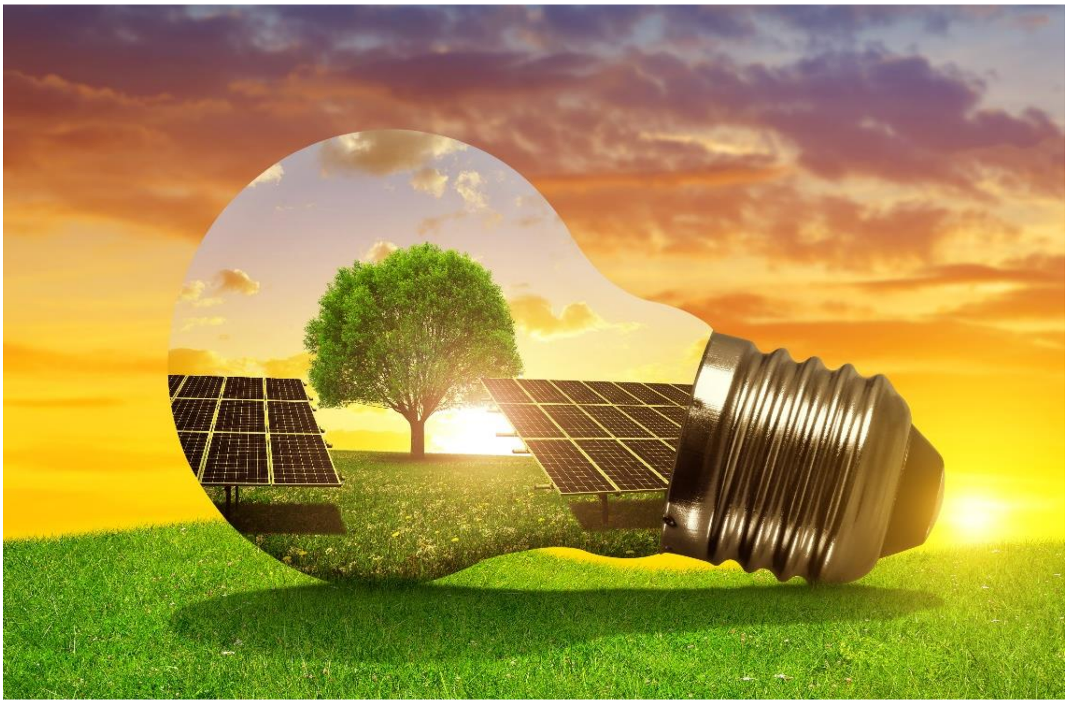
Growth in indigenous manufacturing of RE components can coincide with the growth in RE installations. The focus should be on increasing the competitiveness of Indian manufacturers at par with international players. This can be done by addressing issues on several fronts such as incentivizing development of new production technology which can reduce cost, lowering cost of finance, long tenured loans for RE production units, creating local raw material supply ecosystem, and higher allocation for R & D on RE technologies along with industry-wide collaboration for reducing time of commercialization.

Measures also need to be considered across the project planning, execution, and O&M phases with focus on cost reduction, faster project implementation and quality management. Process innovation which can reduce solar PV gestation period such as automated rammed foundation, standard operating procedures for PV module installation for fast scale-up, and modular and prefabrication housing for large electronic equipment can be considered. Incentivizing adoption of benchmark standards will also need to be considered along with more investment in R&D on project execution technologies.

The Indian grid will have to adapt to the new challenges of high installed base of variable RE source. Focus should be on developing more efficient evacuation infrastructure, forecasting infrastructure of RE, developing balancing capability, accounting for costs related to balancing, and introducing market mechanisms.



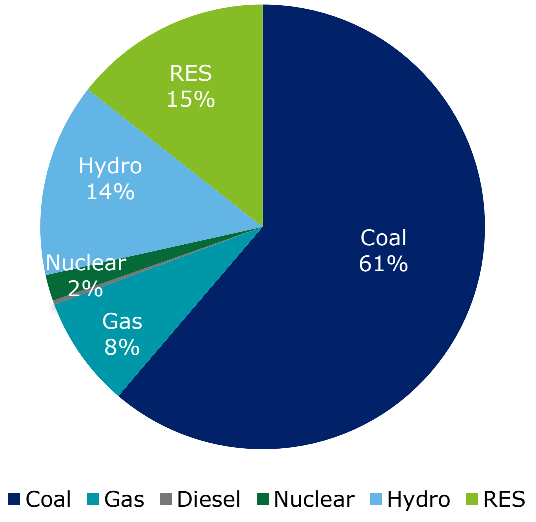
2. Introduction



2.1 India Energy Scenario

With a GDP growth of 7.1%[1] per annum, India is one of the fastest growing economies in the world. India relies heavily on conventional fuels to meet the energy demand. Out of the total installed capacity of 310 GW[2], the share of coal, gas and diesel power projects is close to 70% of the overall energy mix, while the share of renewable energy in the overall capacity is ~ 50 GW as of Dec 2016.

Figure 1 : Power Installed Capacity Mix (%) (Source: MNRE)



Ensuring adequate availability of energy is a crucial requirement for sustaining economic growth. The annual growth in total energy requirement is expected to be at 7.28% in the 13th plan[3] period (2017-2022). The restricted energy and demand deficit has been reducing over the years.

There have been significant investments in power generation in the last few years and has assisted the country in reducing the deficit to low levels - energy deficit of 2.1% and demand deficit of 3.2%[4] in FY 2015-16.

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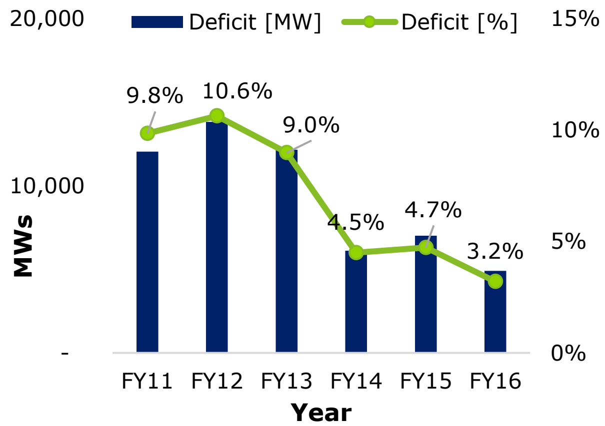
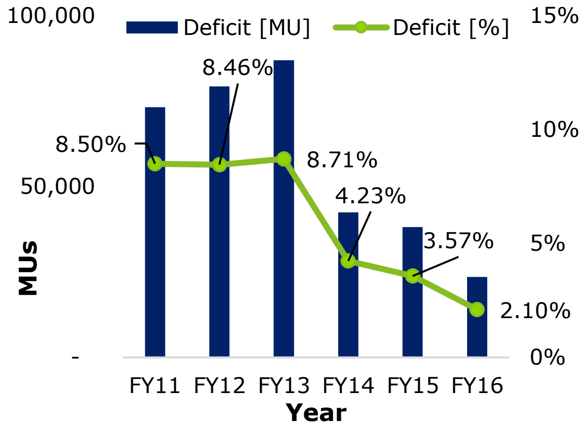
[1] GDP Forecast FY 2017, RBI - Dec 2016
[2] http://cea.nic.in/reports/monthly/executivesummary/2016
[3] http://www.cea.nic.in/reports/committee/nep/nep_dec.pdf
[4] http://cea.nic.in/reports/monthly/executivesummary/2016/exe_summary-04.pdf

Figure 2: Power supply scenario - Demand deficit



Power supply scenario – Energy deficit



Source: CEA, Monthly Report, April-2016

The per-capita electricity consumption in the country (1,010 kWh in 2014-15[5]) is less than half of the world average. More than 230 million[6] people in the country still do not have access to electricity. With concerted efforts in the last 2-3 years, the number of villages in the process of getting electrified has reduced to less than 7000.

2.2 Renewable Energy

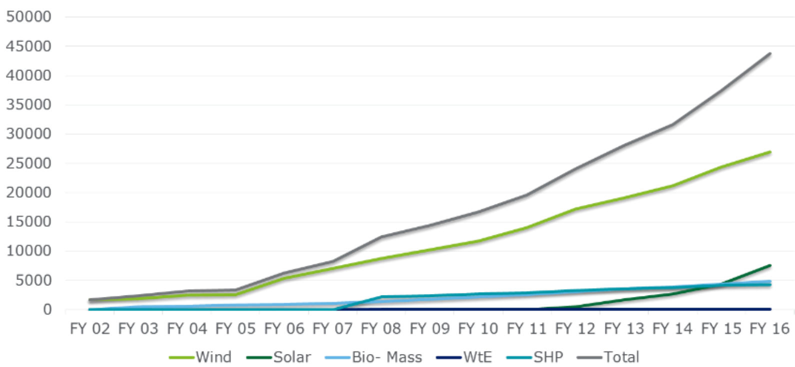
Since energy security and climate change concerns have taken center stage in the policy arena, Renewable Energy (RE) has become an important part of the energy policy in India. To this effect the government has set aggressive targets, and has put in place several incentives and policy initiatives at the Central and State levels for both grid connected and off-grid renewable energy.

The installed capacity mix for electricity generation has undergone significant change in recent years, with the share of RE capacity reaching 15% by December 2016. Growth of renewable energy across different technologies is given in the figure below:

It can be observed that growth of renewable energy technologies has been exponential mainly led by two technologies viz solar and wind power. Revised targets of MNRE for achieving 175 GW comprises 100 GW of solar power, 60 GW of wind power, 10 GW of biomass power, and 5 GW of small hydro power (SHP).

The current progress as mentioned of these targets are as below:

Figure 3: Renewable Capacity (MW) growth trend in India



Source: CEA / MNRE

[5] CEA, Growth of Electricity Sector in India From 1947-2015
[6] http://pib.nic.in/newsite/PrintRelease.aspx?relid=145200

Table 1: Achievement status of RE projects

Sr. No.	RE technology	Cumulative Achievement in MW (as on 31.12.2016)
1	Grid Interactive Solar Power	9,012
2	Grid Interactive Wind Power	28,700
3	Bio Power	7,856
4	Waste to Power	114
5	Small Hydro Power	4,333

Source: MNRE

As per the National Institute of Solar Energy (NISE) estimates, solar energy potential across country is approximately 750 GW out of which 9 GW has been harnessed to produce power to date[7]. Another 2 GW of solar capacity is under pipeline in different stages of implementation. Solar power target capacity of 100 GW by 2022 has been divided into two main parts with 40 GW for rooftop and 60 GW of ground mounted PV projects. The targets also specify the year wise targets as follows:

Table 2: Yearly target for achieving 100 GW of PV installation by 2022

Year	Target (Ground Mounted)	Target (Rooftop)	Total
2016-17	7200	4800	12000
2017-18	10000	5000	15000
2018-19	10000	6000	16000
2019-20	10000	7000	17000
2020-21	9500	8000	17500
2021-22	8500	9000	17500

Source: MNRE

2.2.1 Key Policy initiatives in renewable energy

It is well recognized globally that early commercialization of RE technologies is highly dependent on support from the government through a mix of policy and regulatory instruments. Over the years, the Government of India has introduced a number of policy and regulatory initiatives for promoting RE. Some of these initiatives have been illustrated in the table below:

Figure 4: Evolution of Policy & Regulatory framework for Renewable Energy

Year	Instrument/Initiative	Key Features and Impact on RE Development
1982	Creation of Department of Non-conventional Energy Sources	An independent department for development, demonstration and application of RE. RE sources were recognized as potential alternative energy sources and received special consideration.
1992	Creation of MNRE	The Department of Non-Conventional energy Sources was upgraded into a full-fledged ministry.

[7] Source: MNRE / NISE (Dec 2016)

Year	Instrument/Initiative	Key Features and Impact on RE Development
1993	MNRE Policy and Tariff Guidelines	Introduction of RE tariff guidelines by MNRE - states to purchase RE power at Rs 2.25/kWh with 5% annual escalation on 1993 as base year. Introduction of Tariff guidelines offered relatively higher price for RE than what was prevailing, and thus triggered development of RE sector, especially wind.
1993-94	Introduction of Accelerated Depreciation	Introduction of Accelerated Depreciation (100% AD) for promotion of wind projects (altered to 80% AD in 1999). This program led to the successful commercial development by involving the private sector in wind equipment manufacturing as well as its application.
1995-96	National Wind Resource Monitoring and Demonstration Program	This programme was intended to develop a GIS platform for presenting spatial data to prepare a meso-scale modelling and a comprehensive wind power density map of potential sites. This program helped in mapping the potential wind energy sites across India which in turn induced private sector participation for commercial applications.
1999	Establishment of Centre for Wind Energy Technology	The centre provided much needed technical support for wind resource assessment, testing, monitoring, certification and R&D. It also helped the Indian wind industry to develop large scale commercial wind farms.
2002-03	Electricity Act 2003	Recognizes the role of RETs for supplying power to the utility grid as well as in standalone systems. Provides an overall framework for preferential tariff and quotas for RE.
2004 onwards	Preferential Tariffs for RE from SERCs	Following the enactment of the EA-2003, states adopted preferential tariff mechanisms to promote RE. Since it provides differential tariffs for the development of different RETs, it brought in a balanced approach to RE development across states.
2005-06	National Tariff Policy	Directed SERCs to fix a minimum percentage of purchase of energy consumption from RE sources (RPO). This created a demand side stimulus for RE development.
2005-06	Integrated Energy Policy Report 2006	Suggested a path to meet energy needs in an integrated manner. Recommended special focus on RE development and set specific targets for capacity addition through RE sources.
2008-09	Introduction of Generation Based Incentives (GBI) for solar and wind energy	This scheme offers fiscal incentives along with tariff on power generation from solar and wind. It shifted investment interest from installation to generation.

Year	Instrument/Initiative	Key Features and Impact on RE Development
2008	National Action Plan on Climate Change (NAPCC)	NAPCC has advised that starting 2009-10, RPO be set at 5% of total grids purchase, and be increased by 1% each year for 10 years.
2010	Jawaharlal Nehru National Solar Mission (JNNSM)	Targets 20,000 MW of grid-connected solar power capacity and 2,000 MW of off-grid solar power capacity by 2022.
2010	REC regulation	Introduction of REC mechanism in which sale and purchase of solar and non-solar renewable energy certificates can be traded in an open market for meeting the RPO (renewable purchase obligations) by designated entities.
2015	Revision of National RE capacity addition targets till FY 2022	India is targeting very aggressive RE capacity additions – Target to achieve 175 GW by year 2022 • Solar power emerged as a focus area with a targeted capacity of 100 GW, followed by wind 60 GW, biomass 10 GW and SHP 5 GW by year 2022 • Year 2015-16 with RE capacity addition of more than 7 GW (158%) compared to target set
2015	Renewable Energy Act (Draft)/ Framework on RE forecasting and imbalance handling mechanism	• Provide a consolidated development model for renewable energy, creation of National Renewable Energy Fund, State Green Funds, National Renewable energy advisory group and National Renewable Energy Committee. • CERC notifies forecasting and imbalance handling (DSM) regulation for RE projects (covering solar and wind power projects).
2016	Amendment to National Electricity Tariff Policy 2016 / Ancillary market design introduction	• National Electricity Tariff Policy 2016 mandates solar RPO targets. • Introduction of ancillary markets concepts and general guidelines • No inter-state transmission charges for wind & solar power.

Source: MNRE

2.3 Specific interventions key for achieving 175 GW target

India has an estimated potential of 900 GW of renewable energy spread across the country which is reflected in the geographical dispersion of the 175 GW target. Understanding the necessities of achieving a target of 175 GW RE power in a time bound manner requires critical review of India's RE sector and identification of areas for improvement. An action plan based on such a review with short and long term action points can provide good insight for achieving this goal.

The Indian National Academy of Engineering (INAE) founded in 1987, comprises India's distinguished engineers, engineer-scientists and technologist covering the entire spectrum of engineering disciplines. The aims and objects of the Academy are to promote and advance the practice of engineering and technology, related sciences and

disciplines and their applications to problems of national importance. In this context, it was realized that the Fellows of the Academy should take up the issue of providing intellectual engineering inputs for achieving the goal set forth by the Prime Minister of 175 GW of electricity generation from renewable energy sources by the year 2022.

The INAE has partnered with Deloitte Touche Tohmatsu India LLP to undertake task of preparing this report on engineering interventions necessary for achieving 175 GW target of RE power by year 2022. The objective of the study is to bridge the gap of what is achievable and what India must achieve. This report encompasses a dialogue with key stakeholders so as to facilitate its release and circulation at the national and international levels. The need for circulation at national and international levels is to create awareness about the role INAE is playing in identifying engineering interventions necessary for national goal of 175 GW of renewable power to be achieved by year 2022.

2.4 Structure of the Report

This report is divided into five sections, Chapter 2 which is Introduction, describes Indian energy scenario, role of RE, key policy initiatives and drivers for renewable energy in the country. Chapter 3 focusses on providing global and Indian manufacturing overview, key issues in manufacturing capacities across complete value chain and way forward on the same. This section covers solar PV, wind and other RE segments.

Chapter 4 focuses upon project execution which includes project implementation phases, IPPs and EPC market scenario, execution, operation and maintenance. Identified issues are assessed across process innovation, technology innovation and operational model innovation. Chapter 5 provides insights into RE integration issues including need for grid integration, power evacuation, global experience mapping from developed countries, and RE balancing framework to enhance RE penetration levels.

3 . Manufacturing

3.1 Global RE Sector Overview

The year 2015 has been an eventful year for RE with an addition of 147 GW[8]. This has been the largest annual increase and is a step towards mainstreaming of RE as an economically viable power source. The historic climate agreement signed in Paris by 195 countries for limiting global warming to below 2 Degrees Celsius provided another boost to the RE sector globally[9]. Though the agreement had no bearing for RE investment in 2015, the investment in RE power was to the tune of USD 285.9[9] Bn. For the first time, developing countries were ahead of developed countries for total investment in renewable energy. China alone accounted for more than one third of the total RE investment in 2015[10].

Solar PV, wind power, biomass, and small hydro power witnessed large additions at GW scale, while geothermal and solar thermal Power capacity reached 13.2 GW and 4.8 GW respectively in 2015. Due to ease of deployment, scalability and commercialization accompanied by government incentives, solar PV and wind technologies attracted the maximum share in investments. Total installed PV capacity around the world reached 230 GW[11] with 55 GW being added in 2015 alone. More than 50% of this growth was seen in the Asia-Pacific region. Global addition in wind power capacity was 63.5 GW bringing total installed capacity to 433 GW in 2015. The demand of both these

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[8] REN 21 Annual Report 2016
[9] UNFCCC Paris 2015 Agreement
[10] REN 21
[11] IEA-PVPS Status Report -2015

technologies is expected to remain stable for the next few years. India was the 5th largest investment destination for solar PV and wind technologies adding 2 GW and 2.6 GW capacity respectively in 2015.

As India aims to achieve high RE targets, it will be important that it focuses on building manufacturing capacity. Developing indigenous manufacturing capacity will decrease reliance on technology imports, create jobs and importantly put India on the leader board of clean technology production and innovation.

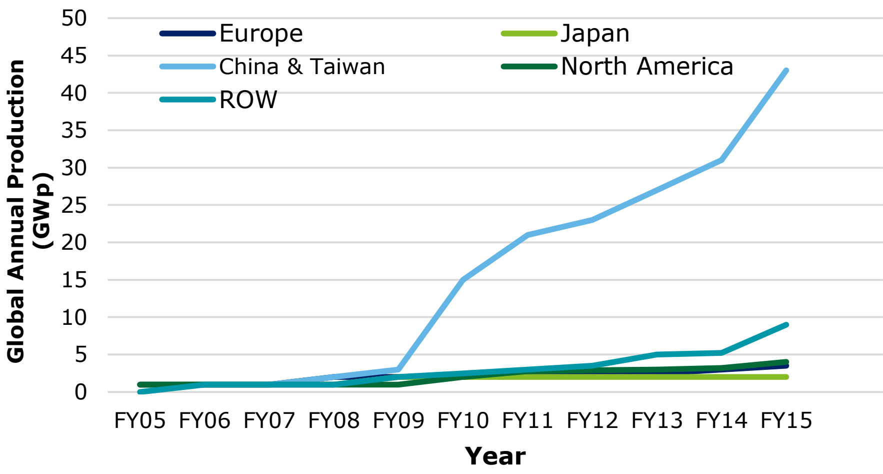
Considering these factors, it will benefit India to have policy focus on increasing manufacturing capacity for solar PV and wind power technologies. Focus should also be given to innovation in small hydro turbine and biomass technologies.

Wind turbine, small hydro, and biomass technology manufacturing in India has been successful in creating an indigenous ecosystem and supplied most of the demand up till now. Solar PV manufacturing in India on the other hand has so far been unable to capitalize on domestic opportunities. Considering India's RE targets, indigenous manufacturing of solar PV technology presents the largest opportunity. India has to focus on building competitiveness of RE manufacturers in India to achieve overall success.

3.2 Solar PV Manufacturing - Global

3.2.1 Global PV Cells and Module Manufacturing trends

Figure 5: Global PV production (GWp) by Region



Source: Fraunhofer ISE

The total manufacturing capacity for module assembly globally was 69 GW as of 2015 with global cell/module revenues reaching USD 32.1 Bn[12].

Countries from Asia mainly led by China have captured a majority market share in supply of PV modules. China is the largest manufacturer of PV modules in the world with a production of 41 GW in 2015 with 63.4% of this production being exported[5].

The worldwide polysilicon production grew by 12.6% to 340 Ktons in 2015 over 2014 with half of the production coming from China. Chinese manufacturing companies dominate the global PV module supply market with half of the leading producers in the world constituting companies from China while OCI, Canadian Solar, Wacker, and Hanwha represent USA, Canada, Germany, and Japan in the list respectively as shown in table below:

[12] http://www.renewableenergyworld.com/articles/2016/04/2015-top-ten-pv-cell-manufacturers.html

Table 3: Top PV manufacturers in 2015

Rank	1	2	3	4	5	6	7	8	9
Company	GCL	Trina Solar	Jinko Solar	JA Solar	Wacker	Hanwha Q-Cells	Canadian Solar	OCI	First Solar
Country	China	China	China	China	Germany	Japan	Canada	USA	USA

Source: PV Tech

The overall climate for PV manufacturing has been positive with PV manufacturing margins reaching 22% in 2015[13]. The main reasons behind favorable climate has been the low prices of poly silicon led by higher production, favorable module prices, and accelerating global demand. Along with these indicators, a strong local presence of raw material ecosystem can be considered as a factor responsible for success of module manufacturers in China. However, there are also companies which are under stress mainly due to mismanagement of debt taken for early aggressive expansion activities.

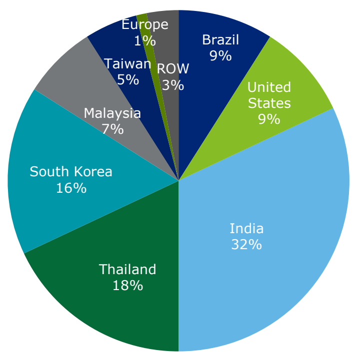
The momentum of global demand for PV modules is expected to remain stable considering lowering of prices and major countries announcing capacity addition targets for future. The average module price fell by 8% in 2015 over 2014 with spot prices for multi-crystalline silicon modules hitting USD 0.55/Watt[2]. This decline is likely to continue considering overproduction in China. Solar PV demand will mainly come from US, China, and India given country level targets.

Citing these opportunities, manufacturers from various countries have announced expansion targets for production capacity for the current year as shown in figure below. Multi-Crystalline PV technology is expected to dominate the module technology landscape with a 90% share.

The industry as a whole is focusing on developing new production technology and material which can reduce cost and increase efficiency. Manufacturers are focusing on increasing module production capacity around the world while developing in house capabilities to reduce outsourcing.

While these improvements assist in future project development costs, it will also become tougher for manufacturers in countries like India to function in an increasing competitive global PV manufacturing space.

Figure 6: Global share of new module manufacturing capacity announced



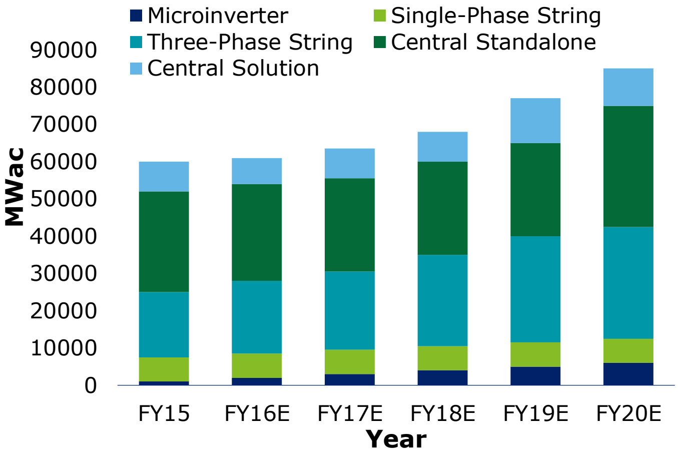
Source: GTM

[13] http://www.pv-magazine.com/news/details/beitrag/ihs--pv-manufacturing-margins-grew-to-22-in-2015_100023455/

3.2.2 Global PV Inverter Manufacturing

PV inverter shipments globally were close to 60 GW for the year 2015 and is projected to grow at a rate of 11% between 2016 and 2020. With three of its manufacturers, China dominated the number of companies which make it to the list of top 10 PV manufacturers by volume globally in 2015.

Figure 7: Inverter shipment forecast



Source: GTM

It is also expected that the global PV inverter market will be worth $7.1 Bn by 2020. Three phase and central standalone PV inverters had the majority market share in terms of installation in 2015 as shown in figure 7. It is expected that the share of micro inverters will gradually grow with proliferation of decentralized systems. PV inverters for decentralized systems will be a key market globally and in India considering India's target of installing 40 GW of rooftop PV by 2022.

Table 4: Top 10 PV inverter manufacturers by volume (MWac) in 2015

Rank	1	2	3	4	5	6	7	8	9	10
Company	Huawei	Sungrow	SMA	ABB	Sineng	TMEIC	TBEA	Schneider Electric	Power Electronics	SolarEdge
Country	China	China	Germany	Switzerland	China	Japan	China	France	Spain	Israel

Source: IHS

3.3 Solar PV Manufacturing - India

3.3.1 PV Cell and Module Manufacturing in India

India has come up with several initiatives such as the 'Make in India' which along with existing industry incentives provides financial, infrastructure, and R&D support for companies which plan to manufacture clean technology in India. Clean Energy Fund (CEF) also has a component of subsidy for PV modules and cells manufacturing in India. As per the Department of Electronics and Information Technology, 20% and 25% subsidy on capital expenditure has been announced for companies which establish PV module and cell manufacturing in Special Economic Zones (SEZ) and Non-SEZs respectively. Under Make in India, full exemption on excise duty is provided on round copper wire and tin alloys for use in the manufacture of solar PV ribbons. With conducive policy regime and support from government, Indian

PV manufacturing industry has seen new announcements for GW scale production capacity in 2016.

The PV manufacturing industry in India contains different players with varying degrees of installed production capacities. Figure below provides an overview of the top Indian manufacturers for PV cells and modules. India had a manufacturing capacity of 1.46 GW for cells and 5.64 GW for modules by the end of June 2016.

Figure 9: PV cell manufacturer market share India

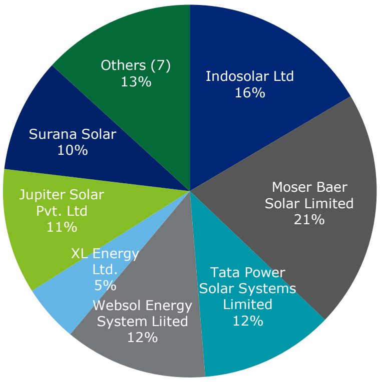
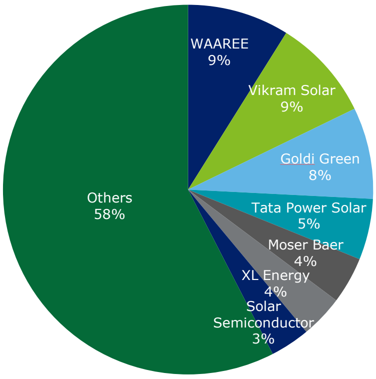


Figure 8: PV module manufacturer market share India



Source: MNRE (As on 01.04.2016)

Manufacturing of PV cells and modules in India has struggled due to high cost of manufacturing related to finance, raw material, technology and lack of infrastructure such as reliable low cost power and land.

Various market studies suggest that PV module price in India is around 54 UScents/Wp compared to module price in China which is 47 UScents/Wp. A difference of 7 cents USD/Wp which makes it harder for domestic manufacturers to compete. Given that India has planned for adding 15-17 GW of capacity annually to reach the target of 100GW by 2022, local module manufacturing in India has to keep pace in order to take maximum benefit of these targets.

The current installed capacity of module manufacturing in India is less than half of the 12 GW PV installation target set by MNRE for the year 2016-17. This means that in order to achieve the target for year 2016-17 most of the

Table 5: PV cells and module manufacturing capacity in India

PV Component	Capacity in 2016 (MW)
Cells	1468
Module	5648

Source: MNRE

NTPC Ltd has commissioned a 100 MW solar project making it the biggest solar project commissioned using domestically manufactured solar cells and modules. The plant shall generate approximately 160 million units of energy and save 110,000 tonnes of CO_2 annually. The success of this project indicates the capability of indigenous manufacturers in India to provide quality solar cells for large scale projects. The use of innovative design of balance of system (BoS) and cabling along with optimized selection of evacuation system indicates the high capabilities that EPC players in India have acquired over the years in PV power plant implementation.

modules will need to be imported. Considering the difficulty that domestic manufacturers face in terms of price competitiveness the imports required to meet this target would be even more than estimated.

Given the tough market competition for polysilicon modules supply, it will be important for India to continue creating large scale demand for locally manufactured PV modules. This shall help maintain current ecosystem and encourage the addition of manufacturing capacity locally in the future. While the competition in polysilicon module supply is projected to remain high, there is still considerable scope for India to pioneer large scale manufacturing of third and fourth generation solar cell. It will benefit India to invest in research and development of new solar cell technology with higher efficiency and lower costs, especially when China has invested heavily in first/second generation solar cell capacity.

Table 6: Types of Solar Cell Technology and their properties

Solar Cell Technology	Material	Properties
First-generation	• Crystalline Si	• Thick crystalline films • High efficiency • High cost
Second-generation	• A-Si, Poly-Si • CIGS • Cdte	• Low cost per watt due to lower material requirement • High surface area required compared to 1G to compensate for lower efficiency
Third-generation	• Nanocrystal solar cells • Photo-electrochemical cells • Graetzel cells • Dye sensitized hybrid solar cells • Polymer solar cells	• Higher energy capture within the solar spectrum • Polymer solar cells are lightweight, inexpensive, flexible, and disposable. • Better cost improvements on 1G and 2G cells
Fourth-generation	• Heterojunction solar cells	• Combines the low cost and flexibility of polymer films and the lifetime stability of novel nanostructures (inorganic material) • Better harvesting of solar energy and conversion to electricity
Next-generation	• Nanotube solar cells • Graphene solar cells	• Capability of transporting electrical charges 100 million times higher than previously measured. • Use of carbon nanotubes to enhance light absorption capabilities • Efficiency ratio improvement up to 95% • Graphene cells can perform in all weather conditions due to its capacity to split positive and negative ions from rain water.

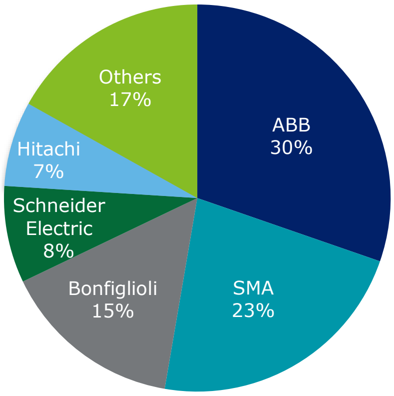
Source: Akshay Urja

3.3.2 PV Inverter Manufacturing in India

Majority of the PV inverters installed in India are manufactured in India by companies with local presence, while some have also been able to compete while importing given the demand for specialized products. Figure below provides market share of key inverter manufacturers in India. ABB, SMA, Bonfiglioli, and Schneider have significant market share of Solar PV inverters.

Most of these manufacturers have domestic manufacturing units to cater to the needs of the Indian environment. Given the nature of the Indian grid, there is a need for the design of PV inverter technology to be adapted to India conditions. Several inverter manufacturers in India have high capacity of production for non-solar inverters and need to focus on developing technology specific to PV inverters.

Figure 10: Market share by Global PV Inverter suppliers in India

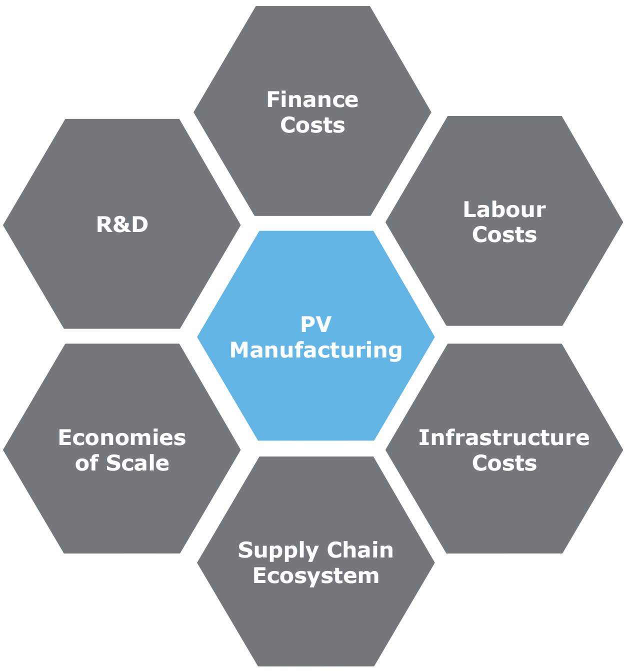


The PV inverter segment in India has high potential for growth in central, string, and micro inverter segment given the 100 GW solar target. As the demand increases, it is expected that more manufacturers will focus on local sourcing of PV inverter components to stay price competitive. Several companies have also introduced the new 1500 VDC technology for solar inverters in India. It is expected that advancement in technology will further reduce costs for PV inverters.

3.3.3 Key Issues Impacting PV Component Manufacturing in India

The current status analysis reveals that while PV inverter segment has been able to indigenously manufacture and supply the demand up till now, the same is not true for PV Cells and Modules. Most of the installed PV module capacity in India has been imported. At the same time, the PV inverter industry in India also has to focus on technology development to maintain its share in the growing market.

Figure 11: Important factors impacting PV manufacturing



There are various key factors which can be addressed in order for companies in India to compete at the global and domestic level. These key factors are identified as per figure 11 and comparison is drawn in table 7 below between India, China, and US depending on market performance of the key factors in these countries.

Table 7: Comparison of key factors impacting manufacturing for India, China, and US

	India	China	US
Cost of finance	High due to interest rates of 10-13%	Low due to state financing and longer repayment periods	Low due to interest rate of 5%
Land and Infrastructure	Land availability is an issue at competitive prices however new options such as National Investment and Manufacturing Zones under Make in India will help	State provided land	Land available at competitive price for setup
Machinery cost	High as mostly imported	Low due to local sourcing	Mix of local and imported components
Raw material cost	High as components such as cells are mostly imported with high supply time risk	Low due to local sourcing with low lead times	Combination of locally produced and imported components
Power	Highs costs and power supply related issues	Low cost of power	Reliable power supply
Labor	Low	Low	High
Technology and R&D	Low investment in R&D since most technology is imported	High investment in R&D to boost domestic manufacturing	High investment in R&D through programs such as SunShot
Logistics and Export	High	Low	Finance support for export and efficient logistics
Economies of scale	Low manufacturing capacities result into higher cost of production	High manufacturing capacities result in low cost	High manufacturing costs due to labour and local sourcing of certain products

Source: US CRS / FICCI

a) Cost of finance

Given the high capital requirements for PV manufacturing units, the cost of finance becomes very critical. High cost of finance creates restrictions for companies in India to setup and compete with the fast changing international PV manufacturing industry. Cost of finance in China and USA vary upto 5% compared to 10-13% in India, thereby making it easy for PV Industry in both these countries to not only invest new production technology but also create economies of scale. Providing accessibility to finance at globally competitive rates to manufacturers in new technology industries has become an important tool for countries to help their industry develop a competitive edge in international markets. Programs which focus on providing loan guarantees and low cost finance can help countries in providing an initial boost to their industry.

b) Labor

India benefits from the availability of low cost labor, however there is a need to invest in skill development. It is estimated that close to 1 mn[14] jobs will be created if India achieves the target of 100GW by 2022. Approximately 81,000 highly skilled, a quarter of a million skilled, while the rest will be semi-skilled and low-skill jobs that shall be created. Currently the solar industry in India provides close to 1,03,000 jobs[5]. India needs to quickly increase investment in training people across various institutions in order to achieve this goal. MNRE and MSDE (Ministry of Skill Development and Entrepreneurship) in India are funding various education and training programs across educational institutes in this direction and more efforts are required. China and US both allocate adequate investment for workforce skilling activities.

The Skill Council for Green Jobs began its operations on October 1, 2015. It has been jointly setup by Ministry of Skill Development and Entrepreneurship and Ministry of New and Renewable Energy (MNRE). Since its inception, it has affiliates over 70 training partners across the country. It has developed the national occupational standards and qualification pack in the solar domain. It has also recently released three handbooks on solar rooftop installation. It is in the process of producing national occupational standards for solar designers, ground mounted SPV power plants, solar proposal evaluators, and so on. Such initiatives will help in meeting the skilling the workforce for the demand of green jobs, which will emerge in RE, EE and waste treatment.

c) Infrastructure costs

One of the main operational challenges which the PV manufacturing industry in India faces today is issues related to adequate power infrastructure, logistics supply chain, raw materials procurement dependence on imports. With the 'Make In India' initiative, India is trying to resolve some of these issues by inviting investors to open plants in special zones wherein the government is responsible for providing adequate infrastructure.

China is ahead of India in terms of providing these fiscal benefits in the form of cash grants, discounted silicon and aluminum necessary for production of solar panels, discounted land, power and water, export grants and insurance for the domestic Chinese PV manufacturers. Some of these issues related to transport and logistics have been taken well by Make in India and can further assist manufacturers reduce lead time for sourcing and control the timelines required for the PV modules to reach the market.

[14] https://www.nrdc.org/sites/default/files/india-renewable-energy-jobs-IR.pdf

d) Raw material supply ecosystem – polysilicon availability, cell manufacturing etc.

One of the key parameters which has played a part in competitiveness of global PV players has been presence of local raw material ecosystem. Solar grade Si cell requires the manufacturing process to achieve high levels of purity to a level of 1 part per billion. The focus should be on building capability, increase in manufacturing scale and control over entire manufacturing ecosystem including supply chain ecosystem of costly chemicals, gases and other components which will have indirect effect on reducing the cost of manufacturing of Si cells and overall module assemblies. Focus should also be on production of quality silicon wafer at par with global standards, which will ultimately improve capabilities & supply chain ecosystem in the country.

The table below shows the status of raw material ecosystem of PV components in India.

Table 8: Status of PV raw material eco system in India

Component	Main Raw material	Major Sources
Modules	Cells	Import/ Low level of local sourcing
	Low Iron Glass	Import/ Low levels of local sourcing
	EVA	Import
	Junction boxes	Local sourcing
	Al Frames	Local sourcing
	Back sheet	Import
	Chemicals used in module manufacturing	Import
Cells	Wafers	Import
	Ingots	Import
Inverters	IGBT	Import
	Other electronic components	Import/local sourcing
Solar Trackers	Steel Structures	Local Sourcing
	Technology	Imported

Source: FICCI Report

Indian manufacturers currently depend largely on imports for main raw material components for module manufacturing such as cells, EVA, back sheets, and low iron glass. China on the other hand has complete control on the supply chain of raw materials, e.g. large manufacturing set-ups related to back-sheets / glass etc. are available locally to meet the production deadlines of GW manufacturing orders. High dependence on imports raises the costs of domestically produced PV modules in India.

The price of modules produced in India has been consistently high as compared to modules from China and the USA. China is the largest producer of polysilicon in the world with the production of 165 KT, in 2015, while USA has the advantage of home grown technology which makes sourcing more streamlined in these countries.

There is an urgent need for India to create a manufacturing ecosystem of PV components focused on capacity expansion, price competitiveness and high quality to meet the rapidly growing demand. This also will create a platform for India to take lead in third or fourth generation solar cells. An efficient raw material ecosystem can provide better control into the hands of producers and can help them in responding to markets better.

e) Economies of scale

The US DOE estimated in a study that every doubling of manufacturing capacity correlates to 20%[15] decline in PV prices globally. An increase in manufacturing capacity can lead to various cost benefits resulting from lower cost of raw material and infrastructure requirements per sq. mtr of PV production. The top 10 PV producers have a capacity ranging from 2-4 GWp[16] of production which gives them a leverage over smaller players. Out of the 81 registered manufacturers with MNRE in India, only 4 have a capacity of close to 0.5 GWp, 20% have a capacity of between 0.1-0.35 GWp, and the rest are placed near the national average of 70 MW.

Low capacity of Indian manufacturers increases the cost at which they source raw material and restricts their ability to keep pace with upgrades in production technology. Increasing the capacity for investors in India to setup large scale manufacturing units will help manufacturing industry to be price competitive on a global scale and in the domestic market.

3.3.4 Key Measures to boost PV Manufacturing in India

Indian manufacturers lack in capacity to compete at a level playing field with international players. This is mainly due to i) various policy measures and support mechanisms that international manufacturers benefit from in their home countries, ii) Low cost of sourcing raw material, iii) Ease to upgrade to new and efficient production technology.

The policy initiatives in India have to be directed towards improvement of factors such as cost of finance and infrastructure. There are other infrastructure issues on which China and US score high as compared to India. China and US both have been leaders in development and commercialization of new technologies resulting from high R&D budgets. This further helps companies in these countries to take an early mover advantage. India needs to focus on increased R&D spending from current levels, specific to cell deposition and production technologies. A coordinated effort is required across industry and project implementation value chain to address technological barriers and faster implementation.

[15] U.S. Department of Energy, Revolution Now: The Future Arrives for Four Clean Energy Technologies – 2014 Update, October 2014, p. 6.
[16] http://www.pv-tech.org/editors-blog/43000

Considering the growth in PV segment globally, this presents an opportunity for India to push for an export agenda and capture greater global PV market share in future. India has a module manufacturing capacity of close to 5GW and has seen announcements of expansion plans which would double this capacity in the next few years. This can be achieved by increased focus on creating a sustainable and local raw material ecosystem, continued support from government schemes which boosts sourcing of domestically produced products along with proper infrastructure and financial support for manufacturing.

3.3.5 Enhanced R&D and focus on next generation solar technologies

The PV manufacturing industry landscape is in continuous change due to pressure on costs associated with PV modules. A new production process technology which can reduce production costs can increase the competitive ability of a company in the international market. Several countries provide subsidies to companies for upgrading their manufacturing infrastructure on these lines. US provides special financial assistance to PV manufacturing initiative to the tune of $112.5 Mn[17] in funding over five years to advance manufacturing techniques to lower the cost of producing PV panels. US also provides financial assistance to cross cutting technologies which can demonstrate capability to strengthen domestic PV industry.

India can also benefit from such initiative by leveraging a network between industry, government, education, and other institutions. Currently industry participation in India for R&D initiative undertaken by the government needs strengthening at the same time there is a need for increased spending on R&D. The financial outlay provided to the Ministry of New and Renewable Energy (MNRE) of India for year 2015-16 was $ 13.5 Mn[18] which is low when compared to China's and US's RE R&D spending of $2.8 Bn and $1.5 Bn[19] respectively. Corporate spending by top 12 PV module manufacturers globally was $ 540 Mn[20] for 2015, while producers in India are struggling to allocate resources for R&D due to low margins.

Market Potential for PV in Africa and South East Asia

Africa has a population of 1.1 Bn out of which approximately 60% do not have access to electricity. This has led to a growing off-grid solar lighting market which is expected to reach USD 1.4 Bn in 2024 from USD 355.28 Mn in 2015. Products such as solar lanterns are increasingly becoming popular for replacement of traditional lighting fuels such as kerosene lamps and candles. Various companies in India already have wide experience in manufacturing of components such as solar lanterns as well as managing rural markets. This experience can be extended to capture sizable market opportunity in Africa for small system applications using solar. Grid connected solar PV capacity in Africa was 1.5 GW as of 2015 mainly led by South Africa and is expected to reach 55 GW by 2030 while currently 14GW of PV projects are in pipeline. With growing utility scale solar PV, manufacturers of module and inverters should also focus on export opportunities in this region.

The total installed solar PV capacity in South East Asia was 2.2 GW at the end of 2016. Out of this Thailand had an installed capacity of 1.6 GW and Philippines came second with an installed capacity of 377 MW. Thailand has a target to install 6 GW to meet its 30% RE share target while Philippines aims to install a capacity of 2 GW in the near future. Most of the future demand for PV is expected to come from Thailand and Philippines for grid connected large scale projects since both countries have FiT incentives in place. It is further expected that demand will primarily be driven by government incentive based mechanisms.

[17] US congressional research service report on 'US Solar Photovoltaic Manufacturing'
[18] http://mnre.gov.in/file-manager/UserFiles/outcome-budget-mnre-2015-16.pdf
[19] REN21 'Global Status Report'
[20] http://www.pv-tech.org/editors-blog/leaders-and-laggards-of-rd-spending-for-12-key-pv-module-manufacturers-in-

MNRE has focused its R&D efforts[21] on activities such as development of CZTS (Copper Zinc Tin Sulfide) solar cells and modules – non vacuum process, development of stable and low cost solar spray, and development of 20% efficiency crystalline silicon solar cells. These initiatives cover innovation in production process to material technology and industry participation in these activities can enhance commercialization. Further, a competitive spending strategy by government and corporate on R&D and nation scale collaboration can help develop a sustainable PV manufacturing industry for third and fourth generation cells in India. R&D breakthroughs should be publicized in other countries. Considering low capacity and high cost of manufacturing that Indian producers face today, R&D needs to become an essential part as India aims to achieve its 100 GW of solar target by 2022. Some of the possible areas for focus can be:

a) R&D collaboration with Space agencies

Indian Space Research Organization (ISRO) makes use of multi junction solar cells for space applications. Solar cells used in space applications are multi junction cells designed for high surface area to weight ratio. PV cells used are of higher efficiency of 28% as compared to 17-18% multi-crystalline Si cells. Collaboration with Space agencies to create processes for manufacturing high efficiency solar cells at low cost can help achieve faster commercialization of multi junction solar cells in India. India can leapfrog to a mass production of next generation solar cell technologies.

b) R&D focus on Thin Film technologies

Due to versatility (application on various types of surfaces), flexibility, good performance in diffused irradiation and low temperature induced coefficient interest private sector investments, academia and researchers to focus on thin film based PV manufacturing. However, thin film modules are characterized by low efficiency, high cost of balance of systems, toxicity concerns across world. Thin film manufacturing process involves the use of toxic gases and various processes are energy intensive. Therefore, a careful choice of manufacturing investment in the thin film PV panels is required considering long terms market potential both in India as well as Africa, UAE and other tropic regions across world having high temperature and dusty environment[22].

c) 3D printing

3D printing has the potential to revolutionize the way we design, customize and produce. 3D printing of dye sensitized solar cells provides an attractive market opportunity which can be explored. The ability of 3D printing technology to deposit solar cell material on flexible material surfaces is expected to create large number of opportunities in small as well as BIPV system application. 3D printing will also find synergies with technologies on the horizon such as solar cells created out of graphene and bacteria.

d) Battery Manufacturing

Energy storage is a broad term encompassing a wide range of chemical technologies, mainly batteries, along with mechanical/thermal technologies, such as flywheels, compressed air, pumped hydro, and molten salt[23]. Currently lead acid batteries offer a wide variety of applications in solar PV projects. Globally deep discharge lead acid batteries are considered to be the highly cost effective solutions for PV applications. However, a recent publication from UNEP showed that lead acid batteries is not expected to be able to compete with newer chemistry, in cost, performance or environmental respects.

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[21] http://mnre.gov.in/file-manager/UserFiles/Ongoing-R%26D-projects-in-solar-PV.pdf
[22] https://www.greentechmedia.com/articles/read/what-governs-thin-film-module-prices
[23] Source : Alternative thinking 2016 | Five game-changers powering the future of renewable energy (Deloitte)

Lithium ion batteries are expected to dominate the markets and lot of efforts are being made globally in innovating the manufacturing process to make it suitable and cost effective solution for renewable applications. For example in USA, Tesla Motors is building a Gigafactory in Neveda to produce lithium ion batteries in greater volumes (35 GWh per year) with 30% lesser cost. Germany has introduced a battery storage program for distributed PV rooftop plants of size lesser than 30 kW. There are 27,000 system reported to be sold with a total market cap of 136 MWh[24].

Opportunities in Storage: The India Energy Storage Alliance estimates that over 35 GW of energy storage opportunity has been scheduled to come up in newer applications such as wind and solar integration, frequency regulation, peak management, T&D deferral, diesel usage optimization, and electric vehicles. Storage technology can mitigate the variation from renewable energy generation and ensure grid stability. A 10 MW storage system based on lithium ion battery powered platform is scheduled to be installed by a power distribution utility in Delhi to aid the penetration of rooftop solar. Solar Energy Corporation of India has recently received several bids for its tender of 5MW/2.5MWh battery energy storage for two separate projects of 50 MW each. The system is expected to have an output for 30 minutes, with a minimum cycle life of 5,000 with a response time of no more than a second. This will increase the tariff of these projects by 2% which can be considered as marginal given the benefits of grid stability. The demand for large scale storage technology for renewable energy integration presents a great opportunity for the battery industry in India.

e) Electric Vehicles & Solar charging stations

Due to lack of reserves for transport fuel and increasing demand for transport infrastructure, there are various initiatives that India is taking. The National Electric Mobility Mission is designed to stimulate growth in the electric and hybrid vehicles segment by 2022. The mission aims to achieve a demand target of 6-7 million electric vehicle annually by 2020 by focusing on demand and supply creation, technology, R&D projects, public charging infrastructure, and pilot projects. The Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) scheme which has a budget of INR 795 Crore under this mission has already shown results[25]. The mission also focuses on creation of strong indigenous manufacturing capacity within the next 10-15 years by undertaking implementation in four phases.

Electric vehicles and solar charging stations-cum-parking facility can become mutually beneficial cost-wise. There should be a focus on developing more affordable vehicles given the nature of demand in India along with creation of a reliable network of solar charging stations. This has to be backed with increased R&D spending on activities focused on battery storage technologies, efficient EV motors, design, and PV charging technology.

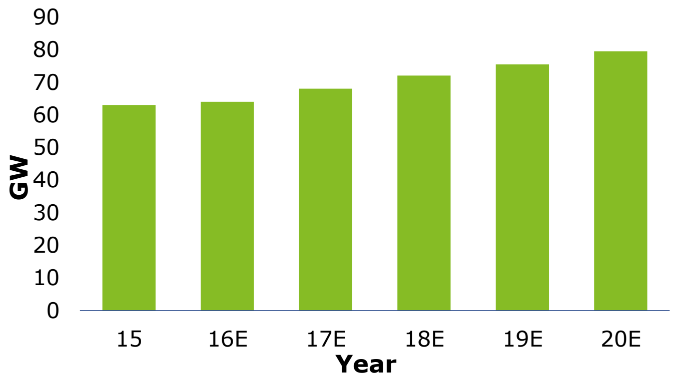
[24] Source: http://fs-unep centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf
[25] http://economictimes.indiatimes.com/industry/auto/news/industry/fame-india-scheme-puts-demand-for-hybrid-vehicles-in-top-gear/articleshow/52090824.cms

3.4 Wind Component Manufacturing

3.4.1 Global wind scenario

The total wind energy installation by the end of 2015 was 433 GW, with a record 63.5 GW being added in 2015. Half of the new installation in 2015 came up in China. The total offshore wind turbine installation reached 3.4 GW in 2015 bringing the total to 12 GW. Europe is leading in offshore installation with a share of 90% of the global installed capacity.

Figure 12: Annual installation and projected demand of wind globally



Source: GWEC

It is expected that wind energy installation will grow at an annual rate of 12% to reach an installed capacity of 792 GW by 2020. Asia is expected to dominate the demand in the world market for the period 2016-2020, with a 50% share with Europe maintaining a steady growth rate along with the Americas which are expected to maintain their steady growth rate.

Goldwind topped the list of wind turbine manufacturers in 2015 in terms of added capacity, along with four other companies from china making it to the top 10 list.

Table 9: Top 10 wind turbine manufacturers in 2015

Rank	1	2	3	4	5	6	7	8	9	10
Company	GoldWind	Vestas	GE	Siemens	Gamesa	Enercon	Guodian	MingYang	Envision	CSIC
Country	China	Denmark	US	Germany	Spain	Germany	China	China	China	China
Market Share (%)	12.50%	11.80%	9.50%	8%	5.40%	5%	4.90%	4.10%	4%	3.40%

Source: BNEF, REN21

Wind power is increasingly playing a key role in countries in EU leading the world with share of wind power at 11.4%[26]. On shore wind power has become directly competitive with fossil fuels due to wind turbine technology improvement related to increase in capacity factor. Wind turbine manufacturers are further trying to adapt to growing demand related to technology suitable for low wind speed regimes and new grid codes related to increased penetration of variable source. Wind turbines are getting bigger every year in terms of their hub height and blades. Off shore wind turbines are also getting upgraded to suit more deep waters in Europe.

3.4.2 India Wind Power Component Manufacturing

India installed a total of 2623 MW of wind turbine in 2015 and surpassed Spain for the fourth position globally with a cumulative installed capacity of 25 GW.

India has a total manufacturing capacity of 9500 MW. The top five players in the Indian market were Gamesa, Suzlon, Inox, Regen, and WindWorld. Gamesa and Suzlon held a market share of 60% in India. Inox, Regen, and WindWorld held a market share of

[26] European Wind Energy Association

37%[27] in 2015. With local sourcing of 63%, Gamesa has been able to leverage its industrial presence with a network of 1674 suppliers[28] in India. Indian manufacturer Suzlon also has a strong local sourcing and manufacturing infrastructure with a manufacturing capacity of 3600 MW[29].

Compared to solar PV, wind turbine manufacturing has sufficient domestic base to meet its capacity target of 60 GW by 2022. The wind industry in India employs 48,000[30] people as of 2015. Companies are focusing on bringing new variants of wind turbines with higher hub heights and longer blades which can cater to the low wind regimes of India. Considering the wind turbine manufacturing ecosystem in India there are also opportunities for India to become an export hub for wind turbines.

With a manufacturing capacity of 9500 MW, the wind manufacturing industry in India has proven and established capabilities for producing most of the wind turbine components. Components such as generator, tower, blade, and hub are the areas of expertise for Indian manufacturers.

Table 10: Status of wind turbine manufacturing in India

Component	Generator	Gearbox	Tower	Blade	Bearing	Hub	Main Shaft
Sourcing	Local	Import / local	Local	Local	Import	Local	Local

Source: Shakti Sustainable Energy Foundation Report

The wind turbine manufacturing industry in India has a strong supply chain network dependent on local sourcing and can be leveraged for export oriented production. Due to low manufacturing cost, India is capable of exporting domestically manufactured wind turbines and blades to Australia, Brazil, Europe, and USA. The exports of wind turbine components reached $1 Bn[31] in 2009-2010, however it has faced stagnation since then.

It is estimated that wind turbines from India cost 15% more than suppliers from Europe, with logistics cost being an important factor. Creating an efficient logistic infrastructure can cater to specific demand of the wind industry in India and create good opportunity for Indian wind turbine manufacturers to regain ground in the global market.

Table 11: Financial support for wind manufacturing

[27] http://www.thehindubusinessline.com/companies/gamesa-emerges-top-wind-turbine-seller-in-201516/article8482828.ece
[28] GAMESACORP Annual Report 2015
[29] http://www.suzlon.com/pdf/investor/QR/2016-17/Investor-and-Analyst-Presentation-2016-Final.pdf
[30] GWEC
[31] http://www.indianwindpower.com/pdf/Hindu_Business_Line_Delhi_13th_July16

India	China	Germany
High cost, shorter tenure for loans Low R&D support for new technologies and workforce skilling Customs duty exemption for critical wind turbine components	Government loans at low rates (<2%) for long term tenures (15-20 years) Subsidies for production Import tax exemption for critical raw material used in wind turbines Tax incentives for new technology enterprises Support for domestic content in project bidding	Various investment grants for new manufacturing units Long term low interest rate loans availability Various support mechanisms for R&D and skill development

Source: Shakti Sustainable Energy Foundation Report)

The cost of financing is higher for wind turbine manufacturers in India as compared to China and Germany. China and Germany also have a high allocation of R&D budget to activities related to RE technologies and skill development as compared to India. Improving on both of these parameters would further strengthen the position of wind turbine manufacturing in India.

Since most of the wind sites across India fall under low wind regimes, the market is demanding turbines which are larger in size and are configured to class III wind regimes (low -medium speed wind regimes). The focus should be on creating an eco-system for wind turbine suitable for these low speed wind regimes. There is also a shortage of casting and forging facilities in India which can facilitate production of large size components for new wind turbine designs. Policies which focus on incentivizing support for wind turbine components down the supply chain can benefit wind industry in India in capitalizing future opportunities.

3.5 Small Hydro Power

The U.S. hydro subsector, which is dominated by European-owned manufacturing that targets western hemisphere markets, is not expanding actively except in the niche small-hydro subsector. China will account for the vast majority of the world's investment in large hydropower. Driven by increasing demand for new energy sources to reduce the carbon footprint of its power mix, China is aiming to reach 350 GW of large hydropower capacity by 2020. To cater to hydro installations demand, China relies on its domestic manufacturing of hydro equipment and its deep supply chain[32].

[32] Source: http://trade.gov/topmarkets/pdf/Renewable_Energy_Top_Markets_Report.pdf

3.5.1 Small Hydro in India

Small Hydro power has already reached an installed capacity of 4.3 GW. As per MNRE, the manufacturing capacity for SHP in India is close to 1500 MW[33] and close to 27 manufacturers which can supply the full range of SHP equipment are registered with MNRE. Around 70% of the manufacturing capacity in India is directed towards exports with most European companies in small hydro technology are present in India. There is a focus on turbine technology which can cater to geographies with low head such as canals, fall structures, dam outlets, and small streams. In 2014, Tata Power commissioned a 10 KW micro hydro project using low-head micro-hydro turbine installed in the tailrace of the 150 MW Bhira hydro power station in Maharashtra[34].

Figure 13: A 10 KW low head micro-hydro turbine

Source: Tata Power

New technology such as permanent magnet which can manage variability of discharge in streams has become available along with improvements in control system for SHP. The industry can also take direction from standard guidelines set up by AHEC of IIT Roorkee[35]. Further R&D effort in turbine technology can fast track development of micro turbines for small hydro projects. Considering that the potential for growth in small hydro is also high at a global level, policy measures can be implemented which enables SHP turbine manufacturing in India to aim for export opportunities.

3.6 Bioenergy

3.6.1 Bio-Power

Despite the large biomass resources in developing and emerging economies, the relative contribution of biomass is small, with the majority of biomass capacity located in Europe and North America[36]. As per MNRE, the required indigenous manufacturing capacity exists in the country for the machinery required for setting up biomass projects. Large manufacturers have capabilities to manufacture spreader stoker fired, traveling grate/dumping grate boilers, atmospheric pressure fluidized bed boilers, and circulating fluidized bed boilers.

With increasing interest in biomass power cogeneration, industry is focusing on manufacturing high efficiency boilers. Steam turbines which can match world standards are also being manufactured indigenously. Other equipment such as harvesters, balers, briquetting equipment, handling, and firing equipment is also available locally. The critical issue of biomass power ecosystem in India that is required to be addressed is the availability of biomass around the year. States with sugar cane industry have been able to create a decent biomass power capacity with cogeneration technology. Commercial biomass availability is good post the harvest season for a couple of months while it is uncertain rest of the year.

[33] http://www.indiaenvironmentportal.org.in/files/file/Draft-national-mission-on-SHP.pdf
[34] http://www.tata.com/company/releasesinside/Tata-Power-integrates-a-micro-hydro-turbine-at-its-Bhira-hydro-power-station-in-Maharashtra
[35] http://ahec.org.in/publ/standard/standards_for_small_hydropower_dev.html#A) Standards for Small Hydropower Development
[36] Source: https://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-BIOMASS.pdf

A focus on creating a supply chain infrastructure for biomass used as raw material for power generation is important. There is also a need for standard guidelines for biomass processing which can direct the industry better. With target to double the capacity, investment in raw material processing for biomass is expected to increase and focus should be on reducing cost for transportation and increasing availability around the year. Providing support mechanisms for creation of biomass supply chain infrastructure will also provide great opportunity for rural entrepreneurship.

3.6.2 Biomass Gasifier Programme

Biomass gasification uses a process which converts biomass into a combustible gas mixture using a thermal chemical conversion process. A gasifier comprises of a reactor which generates the gas followed by a cooling and cleaning train which produces clean combustible gas for power generation in diesel-gen-set or producer gas engines.

MNRE is promoting biomass gasifier based power plants which use locally available biomass resources such as saw-wood, chips, rice husk, arhar stalks, cotton stalks, and agro-residues in rural areas. The focus of the program is to meet captive electrical and thermal needs of rice mills and other industries to reduce their dependence on conventional fuels and provide unmet demand of electricity for villages for lighting, water pumping, and micro-enterprises. Small scale biomass gasifier based power plants up to 2 MW capacity connected at the tail-end of grid which can provide multiple benefits such as reduction in T&D losses, ensuring sustainable supply of biomass, and access to electricity in villages. The program is planned to be implemented in collaboration with various stakeholders such as Independent Power Producers (IPPs), Energy Service Companies (ESCOs), Industries, Co-operatives, Panchayats, SHGs, NGOs, manufacturers, entrepreneurs, and developers.

Second Generation Biofuels: Second generation (2G) bioconversion technology can help convert cellulose-based, non-edible biomass, and agricultural waste into clean and affordable high value fuels or chemicals. 2G biomass technology provides an alternative source both of energy and of chemical industry inputs unlike other renewable technologies. The first commercial scale 2G plant was inaugurated in 2013 while 8 more power plants have come up since then in North America, Brazil, and Europe. China, India, Indonesia, and Malaysia have also seen government initiatives to facilitate establishment of a 2G ethanol market. There is a trend which can be seen wherein this technology is accelerating in terms of development similar to initial trends seen wind and solar energy.

Similar to first generation biomass technology which processes edible waste, 2G plants should also be located near dependable and long term sources of biomass. The cost of sourcing and a supply chain infrastructure will be a key factor for 2G plant operation. Leading players will need to create and coordinate teams comprising feedstock suppliers, government agencies, technology owners, and investors. By collaborating, these partners can structure complex 2G projects from beginning to end and collectively assemble all the capabilities needed to complete them.

One such project is in the works in the Malaysian province of Sarawak. A consortium of local companies, international partners, and the government plans to invest in a new biomass hub, and a 2G plant is scheduled to open in coming years. The Hock Lee Group, based in Malaysia, will grant access to the biomass and operates a local network of petrol stations. Biochemtex (based in Italy) will provide expertise in running large capital-investment projects; its subsidiary, Beta Renewables, will contribute conversion know-how. Another firm will offer enzyme technology. The hope is that by using by-products from the area’s palm-oil plantations and other feedstock, these efforts will create new, high-value industries in the region.

3.6.3 Waste to Energy as a focus area

With increasing affluence of population, the amount of waste production will also increase which provides opportunities for business to contribute in sustainable waste management by using it to produce energy. Waste to energy infrastructure can be deployed for off-grid as well as on-grid application.

A total of 62 million T[37] of waste is generated annually in India and is expected to increase to 165 million T by 2030. Waste management will become a challenge in the country and waste to energy infrastructure presents a good solution to address this issue. Proper waste management is also essential for minimizing impact on the environment.

Currently, most of the waste goes into landfills which is unsustainable considering the rate at which landfill areas will need to be increased in-order to manage disposal in future. According to a report by then Planning Commission of India, waste has a potential to generate 439 MW of power from 32,980 TPD of combustible wastes including refused derived fuel and 72 MW of electricity from biogas. The Government of India has come up with various incentive mechanisms to support waste to energy production which are as mentioned below:

Table 12 : Government Incentives for Waste-to-Energy technology

Waste/Processes/ technologies	Capital Subsidy	Project type
Power generation and/or production of Bio CNG at sewage treatment plants	Subsidy - INR 2 Crore/MW or Bio CNG from 12000 Cub.Mtr biogas/day Max. Incentive - INR 5 crore/project or 40% of project cost whichever is lower	Utilization of biogas produced at sewage treatment plants
Power generation and/or production of Bio CNG from urban wastes and agricultural waste/residues	Subsidy - INR 2 Crore/MW or Bio CNG from 12000 Cub.Mtr biogas/day Max. Incentive - INR 5 crore/project or 20% of project cost whichever is lower	Utilization of biogas from Biomethanation of Urban and agricultural waste
Biogas generation from Urban, Industrial, and Agricultural wastes/residue	Subsidy - INR .5 Crore/MW or Bio CNG from 12000 Cub.Mtr biogas/day Max. Incentive - INR 5 crore/project or 20% of project cost whichever is lower	Biogas generation from urban waste, industrial waste/effluents, and agricultural wastes/residues.

[37] http://pib.nic.in/newsite/PrintRelease.aspx?relid=138591

Waste/Processes/ technologies	Capital Subsidy	Project type
Power generation from Biogas and/or production of Bio CNG from Biogas from Industrial Wastes	Subsidy - INR 1 Crore/MW or bio-CNG from 12000 Cub.Mtr biogas/day Max. Incentive -INR 5 Crore/project or 20% of project cost whichever is lower	Biogas generated at industrial waste/effluent used to power generation though engine/gas turbine route/production of Bio CNG
Power generation from Biogas, Solid Industrial waste and agricultural waste/residues excluding bagasse	Subsidy - INR 0.2 Crore/MW Max. Incentive - INR 1 Crore/project or 20% of the project cost whichever is lower	Projects on power generation or cogeneration through boiler and steam turbine configuration for utilization of biogas or solid waste

Source: MNRE

These incentives are expected to boost the installation of waste to energy plants in India. The government has also planned to commission waste to energy plants to produce a total of 73.6 MW[38] in the near future. A project done by BMUB of Germany in cooperation with MoEF in India and Nashik Municipal Corporation uses co-fermentation of organic waste and septage for energy production. The technology provider is Hamburg Wasser and according to its estimate the system yields 2,100 cub.Mtr of biogas each day which can be used to generate upto 3,200KWH of electricity on a daily basis.

Availability of waste may prove more reliable unlike in biomass since many state governments such as the one of Odisha have directed urban local bodies to provide municipal waste to project developers for free. However, India needs proper mechanism which can take care of segregation of waste at source which will make its supply chain more efficient. The Solid Waste Management Rules have recently been revised by the Environment Ministry and are designed to address some of these issues. A study on implementation of waste-to-energy supply chain for circular economic system looked at various waste-to-energy operating mechanisms around the world. It concluded that in-order to effectively implement the WTE supply chain policies should focus on addressing barriers related to regulation, institution, finance, and technology. Few recommended measures are to establish policy and government responsibility, increase social acceptance by internalizing externalities, focus on investor mobilization, provide financial support such as economic incentive and minimum support prices, and implement performance based evaluation program[39].

[38] http://indianexpress.com/article/india/india-news-india/six-waste-to-energy-plants-to-be-set-up-under-swachch-bharat-mission/
[39] https://www.researchgate.net/publication/282628146_Strategies_on_implementation_of_waste-to-energy_WTE_supply_chain_for_circular_economy_system_A_review

3.7 Solar Thermal

Solar thermal power generation works on similar principle as that of fossil fuel based power generation. The only difference being the steam required to run a solar thermal power plant is created using heat collected from solar radiation. Solar thermal power plants use concentrator systems to heat fluids to high temperatures needed to produce steam. India has several locations such as in Gujarat and Rajasthan wherein the direct normal irradiance is of the order of 1800 kWh per annum, ideally feasible for solar thermal power plants. The four main types of technologies used for solar thermal power generation are parabolic trough, linear Fresnel, solar dish, and solar power tower.

There are various advantages of using solar thermal technology to generate power. Solar thermal power plants can store energy in the form of molten salts and other such systems. The stored heat can be utilized to generate continuous power for longer duration. The electricity supply from solar thermal power plants can be uniform and reliable at low costs. Solar thermal power plants also have long life span as compared to other PV and wind technologies.

Constructing a solar thermal power plant requires equipment such as solar mirrors and turbines. In India, work carried out on heliostat design and construction has shown that cost of such construction in the country with all precisions required is much less than available internationally. All solar concentrating collectors and other components essentially belong to precision engineering where Indian market can provide cost effective solution. An expansion of concentrating solar thermal would also contribute in generation of employment and solar thermal market.

There are, however, several constraints which have impacted the rapid development of solar thermal power. Constraints such as high cost, water requirement, locations and size limitations, and long gestation period. There are ample opportunities for addressing these constraints such as cost reduction in components through indigenous manufacturing which will also create jobs and introducing cooling technologies which do not require water.

New application such as solar thermal hybrid systems should also be taken up under pilot programs in India. Solar thermal power plants can be combined with conventional fuel powered back-up systems to provide required heat for start-up, maintaining the desired level of temperature and thus power production. This can increase the reliability of existing conventional power plants for dispatching electricity. This would help in reducing coal consumption and save emissions.

Solar thermal technology can also be applied for high temperature thermochemical processes to produce solar fuels. Considerable scope exists for developing cost effective solar thermochemical hybrid technologies involving solar reforming of natural gas. The hydrogen economy can also benefit from solar thermal applications. Cost projection of these innovative solar fuel routes using solar concentrating thermal technologies show that these processes are eventually economical.

3.8 Recommendations

A set of recommendations across identified gaps in the RE manufacturing is given with the help of table.

Table 13: Recommendations on key identified gaps and recommendations

Manufacturing Parameter	Identified Gap	Action Suggested / Timeline impact	Key stakeholder
Finance cost	Long term low cost loans / Currency hedging	State backed financing / Loan guarantee programs	IREDA / MNRE
Financial incentives	Lack of incentives, import duty exemption on PV and other RE technologies	Levels of incentives / incentive types framework to be prepared and implementation arrangement to be finalized	MNRE/GoI
Infrastructure support	Low cost power and land availability	Land lease / low cost power arrangement	MNRE/MoP/ State Govt.
Labour and skill set mapping	Capacity building on skills / training needs	Institutional capacity building / Standards and manuals in Manufacturing	NISE / NIWE / SNAs/Skill Council
Raw material supply eco system	Complete value chain of supply raw materials / Capacity building across complete procurement raw materials	Incentives for domestic raw materials for PV / Wind and other RE technologies	MNRE
R&D and process innovations	R&D gap/ Budget allocation	Higher budget allocation for RE R&D efforts / incentives for Indigenous improved processes / mass commercialization of innovative processes	NCPRE / NISE / NIWE / MNRE/ Ministry of Science and Technology
Economies of Scale	Low Production capacities leading to higher cost of production	Adapt new technologies and processes for capacity enhancement on RE manufacturing / Create local demand in the domestic market through fiscal benefits based upon finished product volume	MNRE/ Ministry of Science and Technology
Data Repository	Limited data availability	Country wide DNI real time measurement need to be made available	MNRE

Goods and Service Tax (GST) and its impact on Renewable Energy

In a bid to promote renewable energy systems the government of India has provided various tax exemptions for setting up of renewable energy power plants. Exemptions such as of customs duty on import of PV cells and modules, excise duty on mounting structures and wind turbine generators, and VAT exemption on sale of RE components are examples.

Implementation of GST is expected to directly impact these critical tax benefits that the RE industry has been receiving which shall result in higher costs and higher tariff rates for RE development. It will also impact the competitiveness of RE technology when compared to conventional power technology.

GST is aimed at providing a common tax structure with a single rate for goods and services. Assuming a rate of GST of 20% against the current concessions in excise duty that RE components receive would substantially raise project development cost. A GST of 20% against a current service tax of 14.5% on procurement of services would have the same effect. The same shall apply to situations when VAT exemptions are replaced with flat rates of GST.

The effects of GST implementation on renewable energy systems should be carefully assessed. The goods and services that had a status of tax exemption needs to continue in the GST regime. In cases when exemptions are not available proper concessional rates of GST must apply. The current VAT exemption regulation as it varies across states needs to be replicated with SGST. Current process of tax refunds for RE system components must continue under the GST regime.

The GST regime is certainly a game changer for how tax is implemented in India and shall certainly help business. At the same time the RE industry in India is at a nascent stage and the ecosystem has been created carefully under various policy measures and is now ready to achieve India's 175 GW RE target. Any change in the RE ecosystem may adversely affect the sector and India's plan to become a green economy hence it is important that along with implementation of GST framework the RE sector ecosystem is preserved by not putting it under burden of extra costs.

Source: MNRE published reports, Secondary research

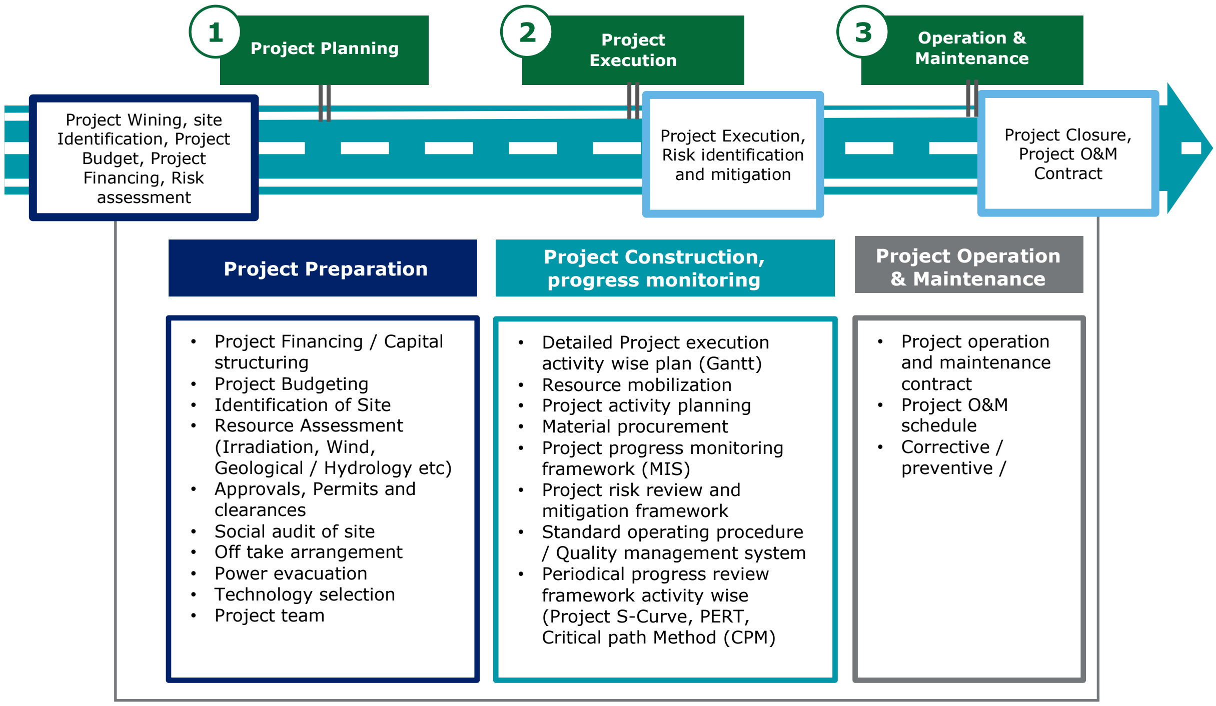
4 . Project Execution

RE Capacity addition in 2015 reached a record breaking share of 77% in the total new installations[40] globally. Some of the developed countries such as Germany, USA and Japan have been leading the growth in RE capacity addition. Key success factor for high growth has been the innovation in project execution methods. Main focus has been on products and processes that aim to achieve high levels of efficiency in terms of time, cost, and quality in project delivery.

Project execution can be divided into three main phases namely pre construction, construction, and post construction. The planning phase or pre-construction phase covers site preparation, planning, approvals, permits, and compliances. The project execution or construction phase covers the civil, mechanical, and the electrical works of the power plant. The post construction phase covers the operations and maintenance of the power plant. The following chart provides more information on these three phases:

[40] REN 21, Renewable 2016, Global Status Report

Figure 14: Project Execution Phases

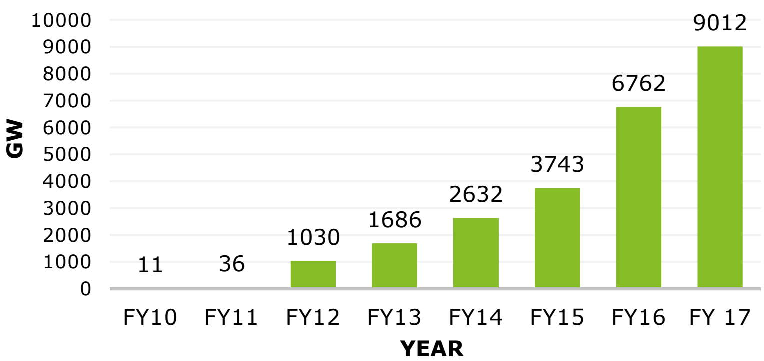


4.1 Solar PV Project Execution

India has witnessed high growth in the renewable project segments over the past few years. Grid connected Solar PV capacity had reached 9012 MW by December 2016.

This high growth in project installation capacity is the result of government policy support, regulatory initiatives and private sector participation in the segment.

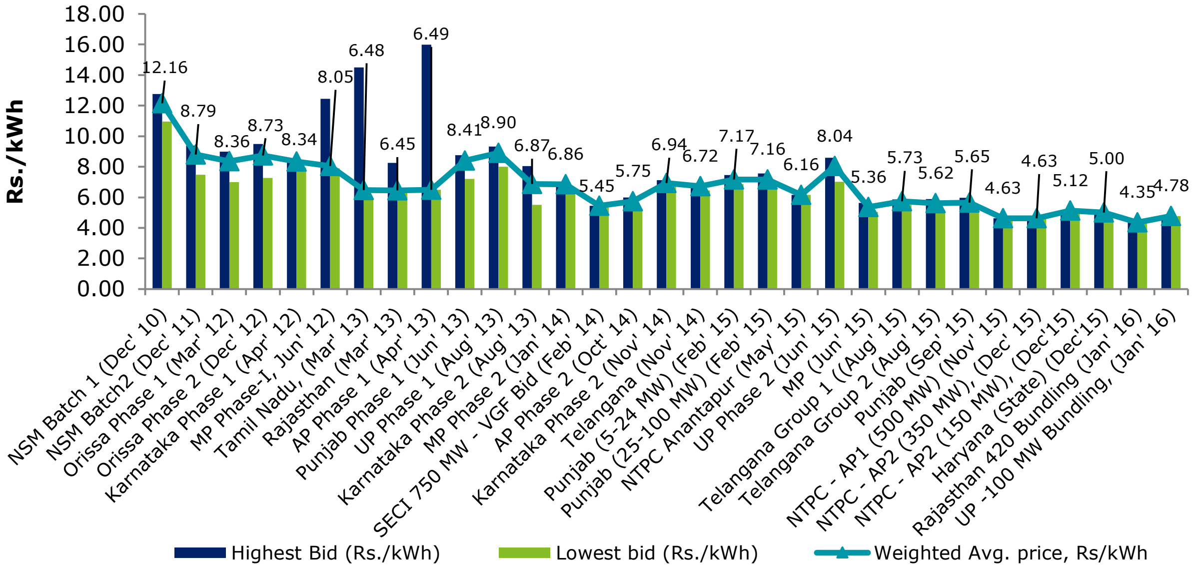
Figure 15: Growth of Solar PV installation in India



Source: MNRE (FY 17 till Dec 2016)

Various improvements in the project execution process by EPC players has facilitated the rapid rise in installation of PV power plants across India. This has also led to a decrease in the bidding prices for grid connected PV power. Reduction of cost of procurement for PV modules, inverters, and BOS has also played a part. Solar bidding price for the past few years in India are represented in the figure below:

Figure 16: Tariff rate for PV project across different states

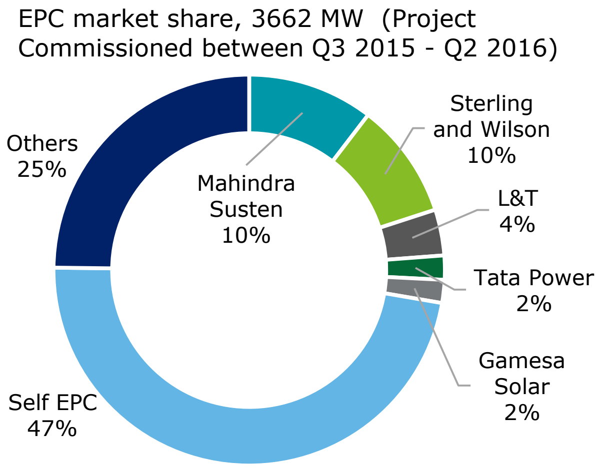


Source: Deloitte Analysis

Market share of key players in solar EPC[41] is represented as shown in figure. Solar EPC segment is highly fragmented with top four players in the market cover 25.8% market share.

Recent trends in solar EPC has been to make use of latest imported technologies (automation) in the project execution and monitoring so as to achieve reduction in the cost of project construction in lieu of achieving competitive prices expected by market.

Figure 17: Market share for Solar EPC Companies



The Government of India has set a target of 100 GW of solar power capacity addition by 2022. In order to achieve this target, it will be important that more efficient methods of project execution across the phases of pre-construction, construction, and post construction of solar PV projects are adopted. The role of Engineering Procurement and Construction (EPC) contractors will become critical here.

4.1.1 Project Execution Issues/Considerations

Various issues related to project management phase are as follows:

a) Data availability and reliability for resource assessment

MNRE has taken initiative is setting meteorological stations across different locations in India but still a large scale data availability framework is required to be built in the

[41] Source: Bridge to India Report

country to strengthen the efforts on accurate solar resource data modeling and forecasting.

b) Selection of turnkey EPC contractor
EPC contracts are the most common form of contract used to undertake construction works by the private sector on large-scale and complex solar construction projects. There are various types of contracts i.e. LSTK, i-LSTK (involving land development integrated part of turnkey contract) with or without a guaranteed period of plant operation and maintenance in Indian Market. An EPC contractor takes the responsibility on a turn-key basis for commissioning the project on behalf of the developer.

Indian solar Industry is fragmented with more than 30 players in the market having varied levels of skill sets. With expected growth in rooftop solar & small capacity solar projects, it is important to enhance awareness amongst consumers towards selection of right EPC and contracting arrangement. This attains significance for rooftop solar projects.

c) Approvals and clearances
Given the short time lines in which PV projects have to be commissioned, there is a need to simplify the process of approvals, permits, and clearances. Scope of approvals and clearances varies across states while state nodal agencies act as facilitators in states for approvals. A single window clearance mechanism needs to be implemented along with online availability for clear information on the scope of nodal agencies, central government, and MNRE.

d) Procurement specification is not standardized for all components
Product standards are available for most PV components such as PV panel, Inverters, Junction boxes, DC and AC Cables, Inverter duty transformers, Auxiliary power transformer, and Switchgears etc. Procurement specifications, however, for certain components of PV plant are not standardized across the complete component range. This has led to variation in the quality of project performance. For example, low quality back sheet of PV modules leads to unexpected PV degradation and may affect the bankability along with other issues such as potential induced degradation – PID in crystalline PV panels. There is a need for a uniform procurement specification and standards covering these factors to maintain long term performance of the PV plant.

e) Technical design and detailing needs to be customized for India
A national code for quality standards specific to Indian conditions which can direct the industry in design and development of PV power plant can become an important tool to maintain long term quality and performance of PV power in India. The following are the areas which can be considered for same:

- Design specifications
- Design of structures; drawings (latest revision)
- Design calculations
- Execution plan; risk assessment ; vendor specific design and integrated plant design

f) Limited technical laboratories for testing
There is a need to improve the testing laboratory infrastructure in India to keep pace with indigenous technology development. Currently, there are very few labs equipped to test PV components such as cells, modules, inverters, and balance of system as per standards suitable for Indian conditions. Testing laboratories should also be capable of scaling up to meet the challenge of new technology development to achieve the 100 GW of solar power by 2022. An implementation framework for licensing testing labs, testing equipment technology sourcing, and standardization is required.

g) Operation & Maintenance (O&M) for PV power plants

Efficient O&M practices can be characterized by efficient water management, rectifying faults in the PV modules or system, maintaining minimum downtime, and security of the overall power plant. Module cleaning can consume up to 1.6 Ltrs/Sq.Mtr of water creating resource constraints in dry regions and also impact maintenance costs which can wary between INR 3 to 12 Lacs across different regions of India.

Water can constitute up-to 60% of the annual maintenance cost as per Deloitte's consultation with several subject matter experts. There are a range of opportunities in cost reduction which can be explored for efficient O&M of projects.

h) Reactive power controls and smart inverter regulation

Reactive power is a critical and complex feature of modern electrical network. Careful localized management of reactive power is a key to smooth-operating grid. Mismanagement of reactive power can lead to catastrophic failures of electrical circuits such as blackouts in Northern & North-Eastern India in the year 2012[42]. One of the opportunities for localized management is use of smart inverters coupled with distributed PV systems to provide reactive power adjacent to the point of load. Smart Inverter features provide system operators to control the output characteristics of PV generated power, provisioning or withholding reactive power as per necessity.

In order to maintain grid power quality (voltage control), it requires that low voltage grid be capable of supplying reactive power during normal operations. In order to take advantage of reactive power control from inverters, these inverters require retrofits in the controls and instrumentation requiring a small incremental in capital cost of the conventional PV inverter.

Smart inverters are commercially available in different geographies across world such as Germany and USA where these regulations are in place. However, India currently does not have any regulation on smart inverters. In case of very high penetration from solar PV in grid, utility will limited visibility on these distributed systems spread across different grid networks. Having smart inverters which interact with utility through GSM / other communication means based commands solves the problem to an extent and can lead to a better power operation management of the grid. Upon command from the utility inverters may control the power output functionality in terms of active and reactive power feed in capability and could facilitate grid in abnormal grid operation conditions.

A focus on creating smart inverter standard suited to Indian conditions will prove beneficial over a long term in a high variable RE resource scenario:

Smart Inverter Regulation in Germany: Germany's new grid code effective VDE-AR-N 4105 dated 1 Aug 2011 mandates that generators connected to LT grid provide grid voltage support via reactive power control during normal operation. Meeting these new grid codes is largely expected to be facilitated by advanced inverter functionality that allows distributed PV systems to be more flexible in providing services that promote grid stability and power quality. Government is also providing support for the retrofits that may require for conventional inverters to be able to change into Advance / Smart inverters specifications. These conversion process is designed in phases with distribution area wise planning and implementation framework.

[42] http://www.cercind.gov.in/2012/orders/Final_Report_Grid_Disturbance.pdf

i) Skill set required for Solar PV Project Execution

A total of 1,116,400 total workforce would be required in solar sector by FY 2022 for achieving a target of 100 GW of Solar PV projects across utility and rooftop PV segment. Type and number of jobs required at various skill levels for solar sector by 2022 is represented in the below table:

Table 14: Type and composition of workforce required to achieve solar targets by 2022 in India[43]

Function	Skill Set	Key skills	Number of Trained Personnel to Achieve 40 GW of Rooftop Solar	Number of Trained Personnel to Achieve 60 GW of Utility Scale Solar	Training and/or Degrees Required
Business Development	Highly Skilled	Tracking the market, Drafting bids, Land selection, Project Finance	15,200	2,400	Master's degree or diploma in business administration
Design & Pre Construction	Highly Skilled	Plant design engineering	18,400	10,200	Engineering degree in civil, mechanical or electrical engineering
Construction & Commissioning	Highly Skilled	Site engineering	154,000	28,200	Engineering degree in civil, mechanical or electrical engineering
	Semi and Low Skilled	Electricals training and PV installing	338,400	286,200	-
Operation & Maintenance	Highly Skilled	Performance data monitoring	48,000	33,000	Engineering in electrical systems
	Semi and Low Skilled	-	92,400	90,000	-

Institutions such as NISE / academic institutions having renewable energy courses will play a key role in skilling the solar workforce of the future. MNRE in association with various authorized academic institutions / agencies has initiated Suryamitra and set forth a target of 50000 Suryamitra for next three years in the country. Close to 310 training programmes have been conducted since 2009 and 12,443 people have been trained. Roles and responsibilities of such institutions can be further mapped on a national level to prepare a plan which can be implemented in a time bound manner.

[43] Council on Energy Environment and Water & Natural Resources Defense Council published report titled filling the Gaps in India's clean energy market

4.1.2 Possible Interventions in Solar PV project execution

Enhancing efficiency and reducing cost for project execution and O&M shall require efforts on multiple fronts. Some of the possible areas for intervention are indicated below:

Area	Recommendation
Standardization	• Develop National Code for Solar PV Projects - specific quality and reliability standards. - Code should provide clear directions on quality standards guidelines to follow for procurement, design, and installation. - Customize design and detailing for Indian Conditions (Temperature, Humidity, and Soiling) since they are mainly based on European Standards currently. - Create standard operating procedures for O & M of PV power plants. This will help maintain a minimum level of quality benchmark across power plants in different geographies of India. • Create a standard for smart inverter technology engineered to suit Indian conditions.
Adoption of new tools and technologies for project maintenance	• NISE/Centres of Excellence shall undertake demonstration projects on new tools and techniques. Areas for focus : - Faster project implementation : Foundation ramming, robotic installation of modules - Water less module cleaning using airjet or special coating for enhanced module efficiency - Promote use of thermal imaging to better manage deficiencies in PV power plant operation. Provide input to the industry on costs and scalability of technology based on such demonstration projects
Operating Efficiency	• Demonstrate use of data analytics in analyzing power plant operation to understand rating of performance against quality benchmarks. • Promote processes such as predictive, preventive, and scheduled maintenance activities based on data analytics.
Technology Focus for project execution	MNRE should encourage demonstration projects with a focus on replication and scaling at a commercial level: • Demonstrate Wind-Solar hybrid and off-shore wind energy projects • Demonstrate technology solutions for Waste-to-Energy - supply chain management issues such as segregation and safe management of toxic compounds to be addressed through innovative models • Building Integrated PV(BIPV) and floating solar PV solutions.
Large scale power Project execution	• Scale of economies will bring down the cost of project execution and procurement cost of PV module and BOS components as well requirements of specific plant and machineries for project execution.
Skill Development	• Develop skill at local level to cater to installation and O&M of distributed rooftop solar projects – 40 GW rooftop solar capacity shall require high skill requirement at local level

4.2 Wind Power Project Execution

Wind power has the largest share (28.7 GW)[44] in the total installed capacity of renewable energy in India. Wind power has a potential of 102 GW & 302 GW at 80 and 100 meter hub height[45] respectively. India ranks fourth in terms of global wind installation after China, USA and Germany. In the wind sector, Government has initiated various policy initiatives like GBI (generation based incentive), Accelerated Depreciation (AD) benefits, exemption from electricity duty etc. that provided thrust for wind power projects deployment in the country.

4.2.1 Key issues/considerations

Wind power project is characterized by all necessary background planning work including permitting requirements, compliances, and detailed technical design which needs to be completed before the start of project construction. Various issues which need to be addressed for timely execution of wind power projects are as follows:

a) Land Acquisition

Wind power projects usually require large parcels of land for development and are usually located in remote or rural areas where land may serve multiple purposes such as for farming or forest land. Proper land acquisition framework for wind power projects needs to be implemented to include all stakeholders in the process, given the site specific nature of wind energy potential. Further, introducing transparency and simplifying the process would facilitate rapid deployment of wind power to meet the 60 GW target by 2022.

b) Resource Assessment

National Institute of Wind Energy (NIWE) has estimated a potential of 302 GW at 100 meter hub height while 102 GW potential at 80 meter hub height. Most Wind Resource Assessment (WRA) stations have installed equipment at 50 meter or 80 meter hub height and MNRE has already initiated to have more robust wind resource assessment for 100 meter and 120 meter of hub height, which would be more suitable for modern wind turbine designs.

[44] MNRE- December 2016
[45] Source: NIWE

c) Technical design and standardization
Several improvements have come up in the design of wind power plants such as improved site array layouts supported by mathematical models for wind turbine performance[46]. New aero-foils have been developed to enhance the capacity of wind turbines for energy capture. Further, modular concept for rapid deployment of wind turbines has proved efficient in many part of the geographies such as Germany, USA and China. Wind turbine designs customized for Indian low speed regimes could provide excellent opportunity for increased operational efficiency and overall performance of power plants. Low wind regimes require considerable changes in the design of turbine components and generator configuration in order to reduce the cost of energy as much as possible. This can be done either by cost reduction approach or maximizing power capture. Cost reduction approach include designs for low fatigue loads, horizontal loading, using gearless machines, passive generator cooling etc. while maximizing power capture is done by taller designed towers, rotor diameter optimization, modern electronics and better controls measures.

d) Technical Efficiency
Though there has been a constant improvement in the Capacity Utilization Factor (CUF) over the years (the average CUF has increased from 7-12% in 1988 to 22-25%) there exists significant scope for improvement. For the Indian wind power market, one of the reasons attributed for such low efficiency levels is the AD policy regime, which incentivized capacity addition, but not necessarily, maximizing generation.

e) O&M for Wind Power Projects
Large scale capacity addition necessitates the requirements of highly specialized and customized techniques which need to be adopted as per the requirements across geographies in the country. For example in Rajasthan due to heavy wind gust storms, a comprehensive O&M plan for turbine may differ from a O&M project in southern states such as Tamil Nadu.

4.2.2 Possible interventions in wind power project development

a) Repower the old wind power projects

It is estimated that a large capacity in the country is having turbines that are of 500 kW or lower capacity, with hub heights of 25 to 50 m installed from 1994 till 2000, at sites that are classified as premium wind zones. Most of these wind turbines have crossed their service life time and have lower operating efficiencies compared to current turbine models in the market[47].

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[46] http://iceeot.org/papers/OR0030.pdf
[47] Source: http://www.indianwindpower.com/pdf/Indian%20Wind%20Power%20Magazine%20-%20Feb.-March%202015%20Issue.pdf

The Government of India recently released the policy for repowering of wind power projects. Wind turbines with capacity of 1 MW and below are eligible for schemes under this policy. It focuses on promoting optimum utilization of wind energy resources by creating a facilitative framework. Under the scheme power plant developers can access an additional interest rate rebate of 0.25% over and above the interest rate rebate available for new wind power projects under Indian Renewable Energy Development Agency (IREDA) scheme.

Currently maximum capacity of turbines that are available in the domestic Indian market is up to 3 MW. Modern Turbines have high efficient operation characteristics with advance controls and systems. Generally the increase in installed capacities for most repowered projects around the world is typically below 25% while net power generation can go up by more than 300% given the higher hub heights and the higher turbine efficiencies.

The role of State government is very important in implementation of repowering project given the leasing and PPA related issues. Hence, it is important for states to adopt adequate policy & regulatory framework for promoting wind repowering projects.

International Experience on Re-Powering Wind Farms in Germany: Repowering is expected to constitute a major part of the wind market in Germany. Repowering was considered at a policy level in 2004, and the first policy had issues including local government restriction on hub height, and requirements between installation and residential areas. With amendments in 2009, more attractive conditions for repowering projects were brought in by the policy makers, including additional increase in initial tariff for wind turbines by 0.5 cents/ unit above the initial feed in tariff of 9.1 cents/ unit. This resulted in the huge expansion of the repowering market in Germany, including conversion of 59.3 MW of old turbines into 168.5 MW with a repowering factor of 2.84. The main learning from Germany re-powering wind projects is that spacing requirements and height limits result in the loss of enormous economic potential for wind energy. Also if yields cannot be increased by a factor of 2.5, then repowering turbines before their technical service life ends (usually 20 years), no longer offers an economic advantage to wind farm operators.

b) Digital Wind farms Solutions

Digital wind farm solution is a dynamic, connected and adaptable wind energy ecosystem that leverages big data and analytics[48]. Digital wind farms are considered to be the next step in evolution of wind power plants which can be characterized by increments in efficiency through data analytics. For example, the Digital Wind Farm optimizes turbine performance and equipment life through the use of Predix, a predictive analytics software platform. Predix provides a digital infrastructure for wind farm, enabling to collect, visualize and analyze unit & site level data.

With the help of real time data i.e. weather, component alerts, service reports and performance, a predictive model is built and the data collected is turned into actionable insights. This model can perform advanced planning, such as forecasting a ‘plan of the day’ for turbine operation. This facilitates in determining a highly efficient strategy to execute planned maintenance activities. It also helps in providing warnings about upcoming unplanned maintenance events, all of which ultimately generates more output and revenue for the customer.

[48] GE, Digital Wind Farm Solution Publication

Table 15: Latest Wind Projects O&M Innovation trends

Type	Parameter	Innovation
Process Innovation	Turbine Performance	• Continuous monitoring of Turbine performance compared to standard conditions • Use of sensors for monitoring turbine different crevices
Technology Innovation	Efficient SCADA / VSAT	Use of high efficient SCADA / VSAT system
Operational Model Innovation	Substation components, inventory management	Predictive/Preventive/Scheduled
		O & M data analysis

c) Wind Solar Hybrid solutions

MNRE has released a draft National Wind-Solar Hybrid Policy. The policy is aimed at reducing the variability in renewable power generation and thus achieving better grid operation. Government is also promoting wind-solar hybrid solutions to achieve optimal and efficient utilization of transmission infrastructure and land. Solar and wind power resource map superimposition reveals large areas where both wind and solar have high to moderate potential. Existing wind farms have scope of adding solar PV capacity and similarly there may be wind potential in the vicinity of existing solar PV plant.

A comprehensive framework also needs to be prepared for implementation to achieve a 10 GW target by 2022 as provided in the wind-solar hybrid policy[49]. Some of the key focus areas are as follows:

- **R&D:** There is a need to develop standards and specifications for wind-solar hybrid projects. NISE / NIWE can play an important role for the same
- **Regulatory Intervention:** The Central Electricity Regulatory Commission should lay down the guidelines for tariff determination estimation approach and methodology
- **Forecasting and Scheduling framework**: State Regulatory Electricity Regulatory Commission required to frame forecasting and scheduling framework for combined wind-solar hybrid projects.
- **Bidding framework**: Parameters for bidding for wind-solar hybrid projects such as based on total capacity delivered at grid interface point, CUF, or on basis of unit price of electricity etc. need to be framed.

d) Explore Offshore Wind capacity addition

MNRE has issued an Off-shore Wind Energy Policy. It is estimated that there is potential of about 1 GW off shore wind power at 80 m hub height in Tamil Nadu itself. Rated capacities of offshore wind turbines are higher than on shore and fall typically between 3 to 5 MW. Globally Off shore wind project development installed base is of the order of more than 12 GW with high installed base in Europe followed by China and Japan. India is at a very nascent stage and has planned some pilot projects on off shore wind projects. NIWE has put up off shore wind data monitoring stations at around 54 locations along the coast[50]. Key considerations for large scale deployment of off shore wind projects are as follows.

[49] Wind-Solar Hybrid Policy, MNRE
[50] Offshore Wind Policy, MNRE

- Standards for foundation design and implementation for offshore wind projects
- High cost of offshore wind farms almost 1.5-2 times than that of on shore wind projects.
- Off shore resource characterization is required for confirming potential of particular sites.
- Development of a policy/ regulatory framework for development of off shore wind projects at State level.
- Capability demonstration of execution of off shore wind projects of commercial scale to understand nuances of turbine, array design consideration, grid integration.
- Developing ecosystem and adequate supply chain for off-shore wind projects

4.3 Small Hydro Power Project Execution

Hydro projects with a total installed capacity less than 25 MW are termed as small hydro projects. MNRE has been vested with the responsibility to develop small hydro power in the country. Total potential for the small hydro power projects in India is estimated to be 19749.44 MW out of which 4333 MW[51] has already been achieved.

The average annual capacity addition of 55 MW per year during the 9th plan had increased to about 284 MW per year during the 11th Plan. However, this capacity addition rate has declined to 170 MW in the year 2013-14. The main reasons affecting the growth rate have been the financial feasibility of projects owing to the difficult nature of project execution in SHP.

4.3.1 Project Execution issues and Interventions

The GoI targets an installed capacity of 5000 MW of installed base by FY 2022 of which 4333 MW has been achieved. The mission aims at developing technology and set up SHP projects on canal, dam outlets, and run of river. The following issues have been identified which are needed to be addressed for successful implementation and achievement of SHP mission targets.

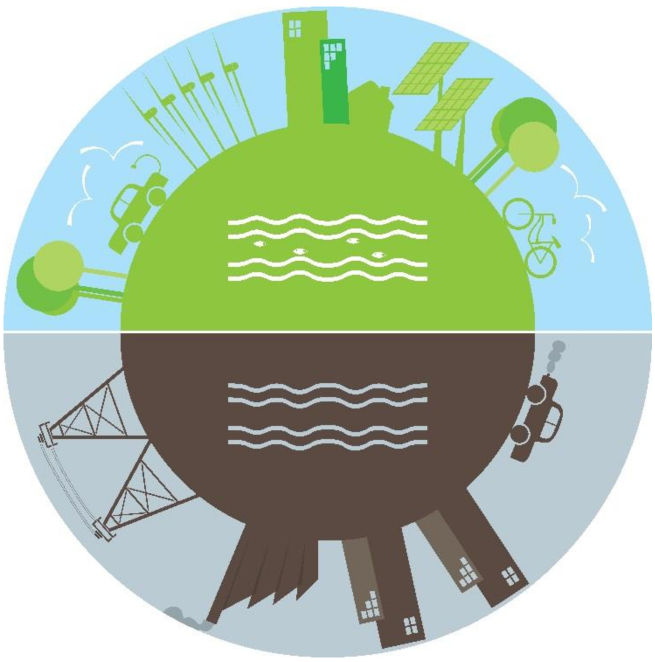
[51] MNRE

Table 16: SHP Issues & Interventions

Issues	Interventions
Resource assessment for SHP	• Strengthen hydrology data accumulation and availability
Land Acquisition	• States and Centre to review land acquisition process together and chalk out a framework to facilitate rapid deployment of SHP projects
Renovation of Old SHP projects	• Evaluate existing Government sector SHP with a view to renovate, modernize and uprate (RMU) to improve efficiency and further capacity addition possibilities. • Review and implementation of data collection framework, SHP projects review, site investigation
Old Turbines running at low load factor	• Develop new technology and engineering solutions to set up low / ultralow head (below 3 m) SHP projects.
Policy Interventions	• Enable framework for States to participate in the National mission on SHP by reviewing incentive framework.

4.4 Waste to Energy Project Execution

Increasing industrialization, urbanization, which accompany the process of economic growth, give rise to generation of increasing quantities of waste leading to increased threat to the environment and human settlements. In recent years, technologies have been developed that not only help in generating substantial quantity of decentralized energy but also in reducing the quantity of waste for its safe disposal. MNRE is promoting all technology options for setting up waste to energy projects.



4.4.1 MNRE Programme on Energy from Urban, Industrial, and Agricultural Waste / Residue

The Ministry of New and Renewable Energy (MNRE) is promoting urban waste to energy conversion technologies based projects. Energy in the form of biogas, heat or power is advantageous apart from the disposal of waste for such waste to energy projects in India. Presently bio-methanation and incineration are the preferred technologies but other technologies such as pyrolysis and gasification is also gearing up.

Setting up of waste to energy projects faces several execution issues that need to be addressed to meet the targets. MNRE is providing support provisions through State

SNA's. For example, Maharashtra State is providing fiscal benefits such as by way of 100% electricity banking free for first year, preferential FIT regime, concessional wheeling, and free supply of solid waste at site[52]. Various project execution issues and interventions in Waste to Energy projects are described as below:

Table 17: Waste to Energy Issues and Interventions

Issues	Interventions
Resource assessment for Waste to Energy & ensuring supply chain	• Coordination among various departments, Municipal Corporations, City planning for collection of data for waste generation
Varied technology options	• Standardization of waste to energy technology projects • Need empanelment of key technology suppliers, clarity on cost benchmarks
Project Risks	• Need clarity in ensuring waste supply chain for WTE projects • Land should be earmarked in the vicinity to encourage such projects
Lack of Skilled Workforce	• Capacity building, training institutes and role of various academic institutions

[52]http://www.bombaychamber.com/admin/images/upload/committee/141423133058Govt.%20incentives%20for%20indl.waste%20-%20Dr.Bharat%20B.%20Nagar.pdf

5. RE Integration

5.1 Grid integration challenges in Indian Context

As India plans to connect 175 GW of RE capacity by year 2022, a framework for large scale grid integration which addresses long term grid security has become a necessity. Issues such as evacuation of RE power from remote locations and managing high amount of variability from generation in the grid needs to be resolved for the success of India's RE targets.

As per the draft National Electricity Plan 2016 by CEA, electrical energy requirement by 2022 is forecasted to cross 16.11 Lakh MUs in the country. With targeted capacity of 175 GW by 2022, renewable energy shall be comfortably placed to provide more than 17% of the national energy requirement. This shall however be contingent to efficient grid integration of renewable energy capacity by resolving the various issues as discussed below:

a) Technical Issues

Managing the intermittent nature of RE

Managing intermittency in power generation from various RE technologies poses a major technical challenge and existing grid issues shall further impede smooth grid integration of RE. India's solar PV target also involves 40 GW of distributed rooftop PV which would require the grid to function under complex environment. High variability can alter the normal grid behavior and may lead to grid breakdown under certain conditions.

Technical issues such as voltage level which could exceed grid equipment tolerance, sudden ramps in generation, power generation from RE systems exceeding demand for long duration, reverse power flows towards upstream voltage levels, low quality of AC power from rooftop solar systems may impact grid stability.

Variability and intermittency of RE generation can be addressed by varying output of conventional power generation plants or using large scale storage. With increased penetration of RE generation there is a need of balancing services and reserve capacities to balance supply and demand in the grid.

Non-Uniform Distribution of RE sources
Certain parts of regional grids could come under high stress due to the nature of resource distribution i.e. high supply of variable source from states like Gujarat, Tamil Nadu, Rajasthan and Maharashtra, which have high potential, may make the regional grid more vulnerable. Thus, in addition to robust grid infrastructure for transmission of RE power from resource rich sites to load centers, profitable inter-state trade shall be necessary to ensure off-take of RE power. This shall require efficient grid infrastructure which can reduce losses and smart devices which can manage variability.

Spinning reserve requirements
Spinning reserves can be used to manage intermittency / variability in RE production across time blocks. However, it would incur additional cost of production per unit of electricity as these plants run for short periods of time. In absence of spinning reserves, UI (unscheduled Interchange) charges would be incident on state utility on account of variation in renewable energy production due to imports from other states during changes in production levels.

Accurate Forecasting
Large scale penetration of RE accentuates the need of accurate forecasting to maintain grid stability, especially in Indian context, which has synchronously connected national grid operating at same frequency. As discussed, high variability of RE sources poses grid balancing problem which can be tackled by accurate generation forecasting and scheduling. However, deviation in RE generation and forecast can lead to grid instabilities.

There is a need for developing a forecasting infrastructure both at an overall system and power plant level. This shall aid the regulatory framework for accurate scheduling and forecasting of RE and conventional power supply managed by state load dispatch centers. Accurate forecasting can also reduce balancing costs associated with variable RE source.

Dedicated Renewable Energy Management Centers (REMCs) have been recently proposed as information centers for managing data related activities of RE power generation in its area of responsibility which could be SLDCS, RLDCs, or NLDCs. REMCs can provide better foresight to load dispatch centers and other players in the energy system by providing real time data of RE generation. An initial estimate of cost for one REMC is EURO 2.2Mn[53] with a capability to monitor and control 200 pooling stations. The main scope of an REMC is as follows:

- Forecasting of RE generation
- Online geospatial monitoring of RE generation
- Ensuring quality and reliability of data
- Share data and coordinate with various load dispatch centers for forecasting, scheduling, and balancing activities
- Central repository and commercial entity for RE generation data

[53] http://mnre.gov.in/file-manager/UserFiles/draft-dpr-rmcs.pdf

- Coordinating agency on behalf of LDCs with RE developers
- Training and skill building for RE integration into the grid

REMCs can become an important tool in maintaining grid stability and managing variability of RE power. Availability of real time data can help load dispatch centers in providing clear directions to conventional and RE power generators for scheduling. REMCs can also assist generators in adhering to forecasting regulations[54] as set up by the Central Electricity Regulatory Commission (CERC) of India such as penalties related to forecasting errors.

b) Transmission Infrastructure

RE potential is specifically concentrated in some resource rich states which essentially requires high energy transmission corridors for evacuation to remote load centers. Inability to export electricity during periods of surplus has persistently plagued states such as Tamil Nadu, which has high wind installed capacity. Wind power plant operators in Tamil Nadu have to often back down their generation due to inadequate transmission capacity.

The Power Grid Corporation of India Ltd. (PGCIL) has planned to address these issues by establishing a country wide RE transmission and management network. The Green Corridor report identified that a strong grid interconnection network based on intra-state and inter-state transmission network for RE should be planned. PGCIL estimated the cost of the scheme at INR 43,300 Cr, which includes intra & Inter-state transmission system strengthening, dynamic reactive compensation, real time monitoring system, energy storage, and establishment of renewable energy management centers.

Based on India's Renewable Electricity Roadmap released by NITI Aayog, RE developers have reported that connection to the Interstate Transmission System could take three years to complete, whereas intrastate lead-times are closer to one year. Wind/Solar Plants generally have low gestation period as compared to implementation of dedicated transmission system. This lead time slows deployment and potential increase in finance risk leading to higher costs.

The implementation of such new transmission networks will need to keep pace with RE installations and future targets. A strong transmission network will resolve issues related to curtailment of power through regional and inter-regional balancing of RE power and reduce loses for RE generators.

[54] http://www.cercind.gov.in/2015/regulation/SOR7.pdf

Table 18: Progress of Inter-regional Transmission capacity*

End of 10th Plan	14050 MW
End of 11th Plan	27750 MW
12th Plan Up to Dec'15	30300 MW
Capacity actual (Dec '15)	57450 MW
Capacity as on Dec'16	63,650 MW
Capacity expected (Mar'17)	68,050 MW

*Inter-regional transmission Capacity at end of 12th Plan excludes 600 MW of 132 /110 kV lines operated in radial mode time to time. Source: Ministry of Power, Govt. of India

c) Financial & Market aspects

Cost of inter-connection to DISCOMS
The Electricity Act of 2003 states that the respective State Transmission Utility (STU) or the distribution utility is responsible for additional intra-state grid infrastructure to manage evacuation of electricity from renewable power plants. It is also responsible for extending the grid up to the wind farm pooling station. However, given the financial health of distribution utilities and some STUs, this may not be the case in practice, with states adopting a number of ad hoc arrangements. This has further made it difficult for these DISCOMs to secure investments for grid expansion. India has recently launched the UDAY scheme to improve the financial health of the distribution utilities.

Lack of Markets for balancing
Power sale and purchase in the Indian market is majorly done under long term power purchase/sale agreements. Power trading through exchanges still form a miniscule part of the power market. However, developing ancillary services market has great significance for large scale integration of renewables into grid. Basic ancillary markets like automatic governor control, reactive power support, black start capability, reserves have great potential. Efforts are being taken by POSOCO through the Reserve Regulation

Ancillary Services (RRAS). These can further be complemented by proper institutional, policy, pricing, and regulatory mechanisms to support grid balancing. There is a need to develop a market mechanism to meet the requirement of ancillary services in the Indian power system.

Ancillary & Operational Services in Germany

For the integration of high shares of RE sources, ancillary services for frequency/voltage control and system restoration after faults is managed through:

- Conventional power plants
- Flexible controllable loads
- Balancing energy pools including RE systems and large-scale batteries
- Operating equipment (e.g. reactive power compensator, FACT)
- Pumped storage power plants
- Black start capable thermal power plants
- Network control units directing operating equipment and conventional plants

d) Balancing Costs

Currently, there are very few studies that are available which look into the cost of balancing that a utility incurs in order to integrate RE power. A study[55] on load serving entities in US found that utilities adjust production cost model assumption to account for solar integration costs.

The parameters that are considered are the cost of operating reserve requirement to account for sub-hourly variability and uncertainty, day ahead forecast errors, and costs associated with additional ancillary services. The integration cost thus derived was between USD 2.5 to 10/MWH for the US market. Similarly, the National Load Dispatch Center (POSOCO) has calculated the cost of balancing of INR 0.5 per unit provided as markup over fixed and variable cost of electricity for the power plants registered under the Reserve Regulation Ancillary Services (RRAS) being implemented in India grid.

Since large scale storage technologies are still under development, the primary method that states across India use to manage RE supply is balance it by backing down conventional power plants. The share of conventional power plant which can be used for balancing will need to increase as India starts adding more variable source such as solar PV and wind power. As per POSOCO, the power plants scheduled to provide ancillary services during 15/1/2017 to 15/2/2017 are as follows:

[55] Mills, Andrew D. "An evaluation of solar valuation methods used in utility planning and procurement processes." American Solar Energy Society (ASES) Annual Meeting, Baltimore, MD, April 16-20, 2013. 2014.

Table 19: Capacity scheduled to provide ancillary services during Jan-Feb 2017

Region	Capacity (MW)	Available for balancing (MW)	Ramp up capacity (MW/15 Mins)	Ramp down capacity (MW/15 Mins)
Western	24,709	13,237	2,991	3,141
Southern	10,490	3,625	651	678
Northern	15,106	5,147	2,049	2261
Eastern	6,260	2,003	461	461
Total(MW)	**56,565**	**24,102**	**6,152**	**6,541**

Source: POSOCO

High amounts of installed renewable energy capacity needs to coincide with increasing amount of conventional power capacity that can be used for balancing RE generation. As per a GIZ study, the balancing capacity of thermal power plants as communicated by SLDCs in India is 30% of the rated capacity i.e. thermal power plants are able to reduce their generation to 70% of rated capacity at any given point. Based on this, theoretical balancing potential of thermal as of June'16 for all the regions in India is calculated and shown in figure below.

Figure 19: Theoretical Thermal Balancing Potential in India as of June'16

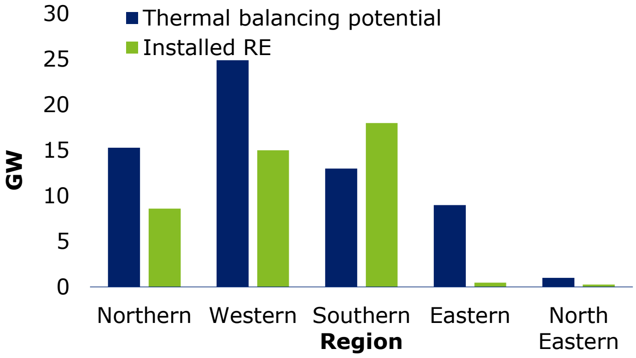
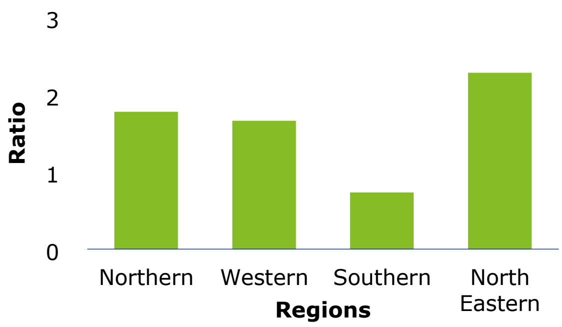


Figure Ratio of Balancing Potential/Installed RE in India



Source: CEA, IGEN-GIZ

As of June'16, all regions except the southern had a more than 1 ratio of balancing capacity to installed renewable energy. The southern region has a higher installed RE capacity compared to its balancing potential. The ratio of balancing potential to installed RE capacity indicates the potential to integrate RE in the system.

The ratio for northern, western, and southern region for India is 1.8, 1.65, and .75 respectively. More than 85% of the target solar PV capacity and 100% of wind power capacity is planned in these three regions. Further within each of these regions, while each region has 6-9 states, 90% of total capacity will come up in just 3-4 states. This is mainly due to potential and feasibility of installing RE projects. Though southern region is the only one with ratio of below 1 of thermal balancing potential to RE capacity, all regions will also need to rapidly increase balancing potential in-order to meet targets. E.g. Gujarat has a balancing potential of 8 GW compared to installed RE of 4.5 GW, it will have to double its balancing potential to integrate 16GW solar and wind power capacity target by 2022. Similar cases can be made of states in other regions as well.

In-order to take advantage of geographical dispersion of variable RE and balancing capacity, there should be a focus on developing inter-state and inter-regional balancing potential to reduce burden on individual states. Various regions and states can be integrated into a larger balancing framework to make good use of different types of balancing potential that they may have such as thermal and hydro.

Hydro power plants provide the best source for RE balancing as they have high flexibility and cost effectiveness. However, as per POSOCO, very low hydro capacity has been registered under ancillary services. Hydro stations are subject to limitations/constraints in terms of water flow and uses other than power generation. This is specific to run of river and pondage based stations. However, reservoir based stations can still be used to provide ancillary services. The estimated cost of balancing of hydro power plants is INR 0.25 per unit markup as per POSOCO.

Pumped hydro can also be considered as an option. Of the 96.5 GW[56] potential only 2.7% of it is realized as of today, however feasibility studies on specific sites will be required for exact potential assessment. There should be a focus on targeting capacities for pumped hydro in the near future along with RE targets.

Cost of updating existing power plant infrastructure for balancing capability
Retrofitting existing power plants can increase their capacity of balancing in terms of capacity to lower generation to minimum loads, higher gradient for faster ramping, and improving start up time for plants. Costing of these parameters can be plant specific and more study is required to evaluate a general framework, however NREL provides certain cost estimates for gas based power plants which are as follows:

Table 20: Cost of retrofitting natural gas turbines

Parameter	Improvement	Cost
Turndown Capability	5-10%	INR 1.06-2.35 Lacs/MW
Ramp Rate	100%	INR 1.3-1.8 Lacs/MW Plant Size ~ 300 MW
Start-Up Time (Single Cycle)	50-60%	INR 160-535 Lacs Plant Size: 50 – 300 MW
Start-Up Time (Combined Cycle)	50-60%	Upto INR 1,335 Lacs Plant Size >300 MW

USD: INR 67.36/-

Table 21: Cost of retrofitting coal power plants

Parameter	Improvement in Ramp Rate, Minimum Load, and Star-Up and Shut-Down time	Cost Range (USD Millions) Sub-Critical[200MW] / Large Sub-Critical[500MW] / Supercritical[750MW]
Boiler Retrofit	30-50%	0.3-3/0.5-5/1-7
Coal Mill Retrofits	~30%	0.5-10/1-12/1.5-16
Emission Control Retrofits	50%	0.5-2/1-3/1.8-4
Balance of Plant Retrofits	30-50%	0.57-4/1.5-7.5/2.25-8

[56] Central Electricity Authority

Turbine Retrofits	30-100%	0.25-1/0.75-2/1-4
Chemistry Related Improvements	50-100%	0.3-1.5/0.5-3/3-4

Similarly, the cost of retrofitting coal power plants compiled by IGEN-GIZ as per NREL is as provided in the table above. These cost estimates can be used to evaluate the investment that will be required in existing natural gas and coal fired power plants to balance RE.

5.2 Global Experience

As per the World Energy Outlook of 2015, the International Energy Agency made a momentous prediction: "Driven by continued policy support, renewables will account for half of additional global generation, overtaking coal around 2030 to become the largest power source." This bold projection is supported by the tremendous advancements that have been made in integrating renewables into the grid. As little as five years ago, it was widely believed that intermittent sources of electricity generation would threaten grid reliability and stability once they surpassed 10% penetration[57].

Grid planning in developed countries such as Germany, USA and Japan has shown that long term commitment towards integration of RE sources can pay off. Current penetration of RE sources in India constitute a relatively smaller portfolio (15%)[58] in overall power capacity mix, however grid planning India can take lessons from developed countries to make grid integration smoother of RE capacities in the future.

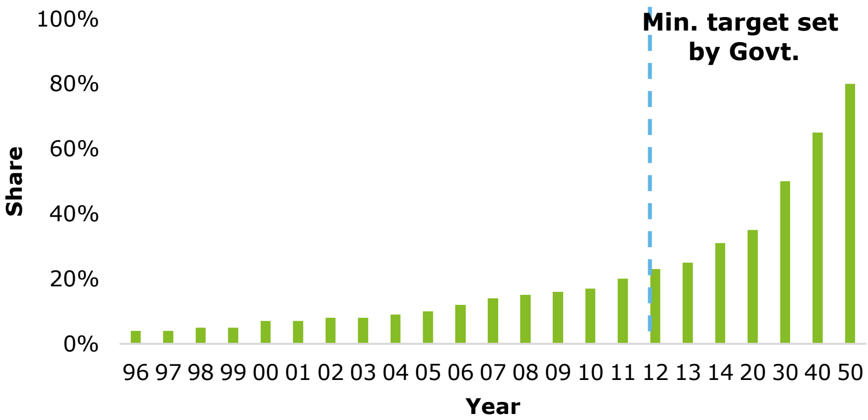
[57] Source : Alternative thinking 2016 | Five game-changers powering the future of renewable energy (Deloitte)
[58] Source: Ministry of Power, India

5.2.1 Experience from Germany

In 2014, Renewable energy totaled approx. **31%** of Germany's net electricity consumption. Nearly 7% of Germany's net electricity consumption was met from Solar PV. On sunny weekdays, PV power at times covered 35 percent of the momentary electricity demand, and on weekends and holidays up to 50 percent[59].

One of the main factors that supported such high levels of consumption from variable renewable generation was Germany's efficient grid infrastructure which also required fewer upgrades to accommodate RE power.

Figure 20: Percentage share of RE in gross power consumption & minimum targets set by German Govt.



Also, Germany has farsightedly planned its transmission infrastructure keeping in view increasing penetration of RE power. Despite sound grid infrastructure, Germany undertook technical improvement activities in local level distribution systems especially to cope with two-way power flows in rooftop solar PV systems.

In addition, high flexibility of operation of coal and nuclear plants has helped Germany to balance the surplus RE power generated. Better design of balancing (ancillary) power markets, to make them more effective, faster and open also helped German power system to integrate variable RE sources. These markets have been designed to provide additional power in short time frames to handle demand supply imbalances. 50 Hz transmission GmbH is one of the four TSOs in Germany. A number of factors and challenges that Germany faced to overcome high penetration of RE resources are highlighted as below:

- Transmission of excess wind capacity during high generation and low demand hours to neighboring TSOs (Transmission system operators) in EU region
- Close coordination between 50 Hz and neighboring TSOs in and outside of Germany
- 50 Hz control room and data centre for accurate wind forecasting using indigenously designed softwares / data measurement tools enabled accurate forecasting framework in Germany
- Enactment and amendment of RES Act "Renewable Energy Sources Act" introducing a new mechanism for wind power balancing, requiring each system operator to contribute to balancing requirements of whole country through wind power output in proportion to the size of its regional grid. The four TSOs in Germany have developed a real time wind power monitoring system for the wind power capacity and

[59] (Source: Fraunhofer Institute for Solar Energy Systems ISE)

associated cost that every system operator should be responsible for. In turn regional grids were acted like a single big grid with more absorption potential for wind power balancing in Germany[60].

5.2.2 Experience from USA

USA has a different set of wind scheduling, dispatch and operational mechanism across various regional grids on account of different grid composition, rules and wind power penetrations levels. One example from California Independent System Operator (CAISO) - has developed a Participating Intermittent Resource Program (PIRP) that allows individual wind facilities to self-schedule according to shared forecasting technologies. New York Independent System Operator (NYISO) requires wind farms to behave like conventional power in order to participate in real-time electricity markets. In certain circumstances, wind farms must reduce power output or be fined if it exceeds the value specified in scheduling instructions.

One of the initiatives in USA is the introduction of ancillary markets for balancing power. There are currently four types of ancillary markets - regulation up, regulation down, spinning reserve, and non-spinning reserve. Regulation energy is used to control system frequency that can vary as generators access the system and must be maintained very narrowly around 60 Hz. Units and system resources providing regulation are certified by ISO and must respond to automatic generation control signals to increase or decrease their operating levels depending upon the service being provided, regulation up or regulation down.

5.2.3 Experience from Japan

Japan power system consist of two parts, one 50 Hz on the eastern side and another 60 Hz power systems on the west side. Both power systems are connected through frequency converter stations. Most wind generation resources are located in eastern belt where demand of electricity is relatively less (of the order of 5 to 15 GW) while western region including Tokyo Metropolitan city demand of electricity is 60 GW. This situation pose a challenge for wind power integration since the low demand areas with high wind power production need to be connected with high demand areas but low levels of wind power generation. One option which Japan leveraged to expand integration of wind power capacities is by intertying utilities which can efficiently balance the generation between themselves or by reducing thermal power output to low levels to match the wind power generation while matching the load. Japan successfully integrated eastern region which accounts for rich wind generation zone with the western region which accounts for high demand through regional ties of power systems.

[60] CEA: Report on RE grid Integration

5.3 Suggested Interventions

To successfully integrate RE power at large scale, it is required that power generation and power consumption is always in equilibrium ensuring grid safety. There is a requirement to design the market and regulatory framework that shall guarantee a secure, cost-effective and environmentally sound power supply system taking into account an increased RE penetration.

Moving forward, as learned through domestic experience and international practices, some key interventions essential for large scale integration are as follows:

a) Investment in Infrastructure & Technology

Investment in transmission to mitigate congestion and removal of barriers to free flow of inter and intra state power is essential for large scale integration. Transmission infrastructure should be developed in advance of steep rise in renewable energy production. Investment in smart grid technology which incorporates information and communication into every function of power system shall support large scale integration through efficient grid balancing. Govt. has initiated steps to develop smart grids but the implementation process needs to be enhanced to match RE installations.

b) Increase flexibility of generation

Having flexible power source at disposal will become a key parameter for integration of variable source. Increasing the balancing capacity of current and upcoming power plants through faster ramp up/down ability and shorter startup/shutdown times will help electricity utilities manage supply/demand more efficiently. Reducing the wear and tear of power plants due to more frequent use in balancing will be essential in reducing overall costs. Improving emission efficiency from operation of conventional power plant during balancing activity will maximize the benefits from wind and solar energy. As per PGCIL, with a 30% penetration of renewable energy at the national level in 2019, India will need balancing reserves of 48 GW, which can be ramped up in four hours[61]. India is expected to have a balancing reserve of 43 GW and a shortfall of 5 GW of balancing reserve in 2019 to manage 30% RE penetration levels.

Further, scaling up large scale storage infrastructure (e.g. pumped hydro, Li-Ion battery) will also help in providing control over generation and supply from variable renewable energy systems. As per PGCIL, pumped hydro shall play a key role in RE integration for the Indian grid. It estimates that by 2019, close to 15 GW of pumped hydro capacity can be assumed as available for balancing requirements.

c) Coordination with all stakeholders

Planning is critical to all aspects of power systems, especially in Indian context, where it is governed by many bodies at central and state level. In addition, there are various other stakeholders-project developers and operators, equipment manufacturers, service providers etc. This inter-dependence calls for a coordination at national level by government and inter-governmental organizations for uniting all stakeholders. Developing a coordinated framework with connection rules, operational standards, infrastructure development cost, and incentives shall smoothen the integration in the synchronized national grid.

d) Disperse RE power plants to smoothen variability

Geographically dispersing renewable energy generation and diversifying the type of renewable technologies shall help in reducing vulnerability. However, given the concentration of RE potential in specific states this cannot happen unless it is planned in advance or developers are given incentive to do so.

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[61] PGCIL Report - Renewable Energy Integration - Transmission an Enabler, Nov 2016

e) Policy & Regulatory push

Significant policy and regulatory push shall be required to support seamless integration of RE power. Some of the essential steps which need immediate actions include:

- **Forecasting and Scheduling-** Significant effort into developing and deploying forecasting tools and techniques is essential. Forecasting and scheduling is essential not just for large scale plant but also for small scale plants under gross-metered or net-metered arrangements (in the long term). This shall become increasingly essential as rooftop solar proliferates in the low voltage distribution grid, which is weaker in comparison to the transmission grid.
- **Uniform regulations at State level-** With enhanced targets the government should push for faster roll out of forecasting and scheduling regulations at State level. This should be mandatory in order to induce accountability at the intra-state level as well.
- **Balancing markets-** As discussed, flexibility in power system operation becomes increasingly important with greater share of variable RE. However, this shall entail additional costs for the power plant operators. Development of innovative models to create balancing power markets shall help achieve operational efficiency in a cost effective way. Approaches to market and system flexibility from countries as Denmark which have large share of RE power can be adopted/modified to suit Indian power system. India already has regulations for ancillary services being used for various purposes like frequency changes, extreme weather conditions, load following, overloading of certain transmission lines and others. The same is being leveraged currently to accommodate for RE balancing activities as well.

f) Registry/ database for renewable generation

Target of 100 GW of solar capacity addition is one of the biggest targets set globally. Given the potential and increasing cost-economic favorability, RE generation is posed to increase rapidly in the near future. Under such scenario, a database for power generation from largely proliferated (small, medium and large) RE plants shall be necessary to plan grid infrastructure as well as to make other policy/regulatory amendments for management.

g) Research and Development focus

Large scale battery storage is an effective way to manage the vulnerabilities arising from variability in renewable energy. At the same time, the pace of development of grid scale storage technologies is also accelerating. India should focus on R&D of plug-in batteries by testing new technologies using existing installed infrastructure of renewable energy.

6. Way Forward

Energy policy in India is focused on increasing the RE share in future to take a sustainable pathway. This will become an important step towards reducing India's annual greenhouse gases. India's commitment is further emphasized by its INDC submission to UNFCCC which mentions a target of 175 GW of renewable energy. The target constitutes 100 GW of solar, 60 GW of wind, 15 GW of biomass, and 5 GW of SHP based renewable power. Achieving this target would help the Indian economy become one of the leaders in economy's transitioning towards carbon neutrality. This target shall create great opportunities across the value chain of RE power in manufacturing, project management, and RE integration.

Opportunities shall emerge in areas such as indigenous production, production technology development, innovation in material technology, technology related to efficient development of projects, and grid integration technologies for RE capacity. Most importantly achieving the target of 175 GW by 2022 shall create more than a million new jobs in India. Therefore, it becomes important to address the challenges that India faces in tapping into these opportunities. Improving competitiveness of RE component manufacturing in India by focusing on new PV module technology, integrating local raw material eco-system, and continuous the policy support for locally produced modules can be a first step. The more established wind, small hydro, and biomass component manufacturing sector in India should focus on design and testing newer technologies, micro-turbine technology development, and waste segregation and toxin management technologies respectively.

A parallel step should be creation of national code which can standardize PV project implementation across geographies and focus on reducing cost, timescale, and improving quality. Demonstration projects on financial and technical feasibility of offshore wind power generation should be carried out to guide the market. A framework for SHP resource data collection and sharing should be created to accurately map potential across India. Proper guidelines and standards on collection and segregation of biomass and waste should be created to help industry.

More efficient RE integration will need focus to strengthen ancillary market, enhanced balancing capacity similar to countries which have been successful in integrating high RE capacity. Deployment of RE forecasting infrastructure should be accelerated along with creation of a data sharing framework. Clear directions should be provided to utility and power plant operators on updating operational models, to accommodate cost of balancing such as balancing reserves, errors in forecasting and cost of retrofitting of existing conventional power plants.

RE ecosystem in India has the experience and potential to resolve the challenges that India will face on the path towards 175 GW, given existing gaps are addressed through policy and engineering technology interventions. These interventions should be carried out parallel at multiple points such as manufacturing, project execution and grid integration as parts of the RE value chain. Effective actions on these areas will help India build the capacity to support achievement of its RE target.

From the long term perspective of achieving India's INDC target to install non-fossil based power capacity of about 40 percent by 2030, will require formulating a clear roadmap. MNRE should prepare a detailed roadmap with clear action points for meeting the 2030 target. Based on MNRE's roadmap, each state shall prepare its own action plan and launch initiatives to achieve the 2030 targets. Some of the focus areas will include: (i) create framework for quick diffusion of cutting-edge clean technology in India through collaborative and indigenous efforts; (ii) enhance institutional capacity of power sector institutions to manage huge RE capacities and ensure compliance of the regulatory interventions for supporting RE power; and (i) mobilize domestic and new funds from developed countries to implement specific initiatives to build capacities.

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