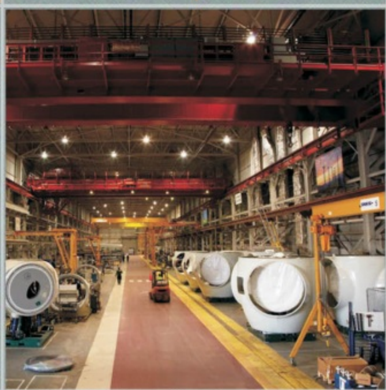
Addressing the Challenges of RE Manufacturing in India: Horizon 2032



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SHAKTI SUSTAINABLE ENERGY FOUNDATION

WISE WORLD INSTITUTE OF SUSTAINABLE ENERGY

CSTEP CENTER FOR STUDY OF SCIENCE, TECHNOLOGY & POLICY

Addressing the Challenges of RE Manufacturing in India: Horizon 2032

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Acknowledgements

CSTEP and WISE are grateful to all the experts and specialists for providing useful inputs and insights during the preparation and at various stages of this report. Special thanks are due to Shri Dilip Nigam, Director - Ministry of New and Renewable Energy, Shri Ashvini Kumar, MD (I/C) and Director (Solar), Solar Energy Corporation of India and Shri Gaurav Dave, Fmr. Chief (Joint Secretary), National Manufacturing Competitiveness Council for their useful insights and suggestions during the inception stage and drafting of the report. The project team would also like to acknowledge the support of officials from various Ministries and Departments of Government of India, particularly Ministry of New and Renewable Energy, Department of Industrial Policy and Promotion, Department of Electronics and Information Technology, Directorate General of Foreign Trade and Directorate General of Anti Dumping and National Manufacturing Competitiveness Council.

Further, we would like to thank industry professionals and experts in providing key inputs at various stages of the study. Special thanks are due to Mr. A.S Karanth (Executive Advisor, DEIF India), Mr. Chintan Shah (President and Head, Strategic Business Development), Mr. Hemkant Limaye (Commercial Director, LM Wind), Mr. K Bharathy (CEO, Windar Renewable Energy Pvt. Ltd.), Dr. Omprakash G Kulkarni (Scientist, Advisor, Indian Institute of Science), Mr. Ramesh Kymal (Managing Director, Gamesa Wind Turbines Ltd), Mr. R Bakul (President, Suzlon Energy Ltd), Mr. T. Pradeep Kumar (CEO, Kenersys Wind Energy), Mr. G. V. Balaram (MD, Karnataka Renewable Energy Development Limited), Dr. Arul Shanmugasundram (Executive VP (Projects) and CTO, Tata Power Solar Systems Ltd.), Mr. Rajesh Bhat (MD, Juwi India Renewable Energies Pvt. Ltd) and Mr. Srinath .T (Technical Director, EMMVEE Solar) for their valuable inputs and validation of the findings of this study.

In addition, we would like to profoundly thank Dr. V. S. Arunachalam (Chairman, CSTEP), Dr. Anshu Bhardwaj (Executive Director, CSTEP) and Mr. G. M. Pillai (Director General, WISE), whose insights and support gave the much-needed depth of perspective to the analysis and recommendations. Thanks are also due to various staff members of CSTEP and WISE who directly or indirectly contributed towards the study by means of organizing field trips and workshops, financial reporting, publishing and dissemination activities of the project.

Finally, a special thanks to Shakti Sustainable Energy Foundation (SSEF) for supporting this important project. In particular, we would like to thank Mr. Deepak Gupta, Senior Programme Manager (Power) and Ms. Disha Agrawal, Program Associate (Renewable Energy) for their patience and for providing valuable feedback and suggesting crucial course corrections at different phase of research.

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List of Acronyms

ABT: Availability Based Tariff

AC: Alternating current

AR: Anti reflective

ARRA: American Recovery and Reinvestment Act

a-Si : Amorphous Silicon

BCD: Basic Custom Duties

BESCOM: Bangalore Electricity Supply Company

BUs, MUs: Billion units, Million units

CAGR: Compound Annual Growth Rate

CAPEX: Capital Expenditure

CBDT: Central Board of Direct Taxes

CBEC: Central Board of Excise & Customs

CBGA: Centre for Budget and Governance Accountability

CDM: Clean Development Mechanism

CDR: Corporate Debt Restructuring

cdte: Cadmium telluride

CEA: Central Electricity Authority

CEEW: Council on Energy, Environment, and Water

CERC: Central Electricity Regulatory Commission

CIGS: Copper indium Gallium Selenide

CII: Confederation of Indian Industry

CIT: Corporate Income Tax

CNC: Computerized Numerical Control

CPUC: California Public Utilities Commission

CRGO: Cold Rolled Grain Oriented

CRNGO: Cold Rolled Non-Grain Oriented

c-Si: Crystalline silicon

CSIRO: Commonwealth Scientific and Industrial Research Organisation

CSP: Concentrated Solar Power

CST: Concentrated Solar Thermal

CUF: Capacity Utilization Factor

CVD: Counter Vailing Duty

CWET: Centre for Wind Energy Technology

DC: Direct current

DCR: Domestic Content Requirement

DD-PM: Direct Drive Permanent Magnet

DD-WT: Direct Drive Wind turbine

DEZ: Diethyl Zinc

DFIG: Double Fed Induction Generator

DGAD: Director General of Anti-dumping and Allied Duties

DISCOM: Distribution Company

DLC: District Level Committee

DNI: Direct Normal Irradiance

DoE: Department of Energy

DPO: Diphenyl oxide

DSIRE: Database of State Incentives for Renewable Energy

DSM: Demand-Side Management

DST: Department of Science and Technology

DSTI: Department of Science & Technology and innovation

DTU: Denmark Technical University

E&Y: Ernst & Young

ED: Excise Duty

EEG: Erneuerbare-Energien-Gesetz

EERE: Energy Efficiency and Renewable Energy

EEZ: Exclusive Economic Zone

EHV: Extra high voltage

EIA: Energy Information Administration

EIA: Environment Impact Assessment

EIT: Enterprise Income Tax

EO: Export Obligation

EOP: Export Obligation Period

EPC: Engineering, Procurement and Construction

EPCG: Export Promotion Capital Good

EPF: Employee Provident Fund

EPS: Electric Power Survey

EPS: Earnings per Share

EPZ: Export Processing Zones

ESCOM: Electricity Supply Company

ESI: Employees State Insurance

ETP: Energy Technology Perspective

EVA: Ethylene Vinyl Acetate

EXIM: Export-Import

FDI: Foreign direct investment

FICCI: Federation of Indian Chambers of Commerce and Industry

FiT: Feed in Tariff

FOB: Freight on Board

FY: Fiscal Year

FYP: Five year Plan

GBI: Generation-based Incentive

GBI: Green Building Initiative

GCF: Green Cess Fund

GDP: Gross Domestic Product

GERC: Gujarat Electricity Regulatory Commission

GESCOM: Gulbarga Electricity Supply Company Limited

GETCO: Gujarat Energy Transmission Corporation Limited

GHG: Green House Gas

GoI: Government of India

GRC: Glass-Reinforced Concrete

GST: Goods & Services Tax

Gt, KT, MT: Gigatonnes, Kilo tonnes, Metric Tonnes

GVW: Gross Vehicle Weight

GWEC: Global Wind Energy Council

HAL: Hindustan Aeronautics Limited

HAST: Highly Accelerated Stress Test

HDPE: High density poly ethylene

HE: Heat Exchanger

HESCOM: Hubli Electricity Supply Company Limited

HPTIV: High Performance Turbine Installation Vessel

HTF: Heat Transfer Fluid

HV: High Voltage

HVAC: High Voltage Alternating Current

HVDC: High Voltage Direct Current

ICB: International Competitive Bidding

IEC: International Electrotechnical Commission

IEP: Integrated Energy Policy

IMG: Inter-Ministerial Group

INCOIS: Indian National Centre for Ocean Information Service

IPPs: Independent Power Producers

IPRs: Intellectual Property Rights

IREDA: Indian Renewable Energy Development Agency

IT: Information technology

ITC: Investment tax credit

JERC: Joint Electricity Regulatory Commission

JNNSM: Jawaharlal Nehru National Solar Mission

JV: Joint Ventures

KAMM: Karlsruhe Atmospheric Meso Scale Model

KERC: Karnataka Electricity Regulatory Commission

KfW: Kreditanstalt für Wiederaufbau

KW, MW, GW: Kilowatt, Megawatt, Gigawatt

kWh: kilowatt-hour

LBNL: Lawrence Berkeley National Laboratory

LCR: Local Content Requirement

LEC: Levy Exemption Certificates

LP,HP: Low Pressure, High Pressure

M, Kg: Metre, Kilogram

MEDA: Maharashtra Energy Development Agency

MESCOM: Mangalore Electric Supply Company Limited

MNRE: Ministry of New and Renewable Energy

MoEF: Ministry of Environment and Forests

MoF: Ministry of Finance

MOST: Ministry of Science and Technology

MSEDCL: Maharashtra State Electricity Distribution Co. Ltd.

MSME: Micro, Small and Medium Enterprises

MTC: Manufacturing Tax Credit

NAL: National Aerospace Laboratory

NAPCC: National Action Plan on Climate Change

NCEF: National Clean Energy Fund

NCVT: National Council for Vocational Training

NEP: National Electricity Plan

NIMZ: National Investment and Manufacturing Zones

NLDC: National Load Despatch Centre

NMP: National Manufacturing Policy

NMZ: National Manufacturing Zone

NOWA: National Offshore Wind Energy Authority

NRDC: Natural Resources Defence Council

NREL: National Renewable Energy Laboratory

NSDC: National Skill Development Commission

NSM: National Solar Mission

NTP: National Tariff Policy

NTPC: National Thermal Power Corporation

NY-BEST: New York Battery and Energy Storage Technology

O&M: Operation& Management

OEMs: Original Equipment Manufacturers

OFTO: offshore transmission owner

OTC: Over the Counter

PDMS: Polydimethylsiloxane

PE: Polyethylene

PECVD: Plasma-enhanced chemical vapour deposition

PET: Polyethylene terephthalate

PGCIL: Power Grid Corporation of India

PGCIL: Power Grid Corporation of India Limited

PID: Potential Industrial Degradation

PMMA: Polymethylmethacrylate

PMSG: Permanent Magnet Synchronous Generators

PPA: Power Purchase Agreement

PPP: Public Private Partnership

PTC: Production tax credit

PV: Photovoltaic

PVB: Poly Vinyl Butyral

PVD: Physical vapour deposition

PVDF: Polyvinylidene Flouride

R&D: Research & Development

RE: Renewable Energy

REC: Renewable Energy Certificate

REE: Rare Earth Elements

RES: Renewable Energy Sources

RLMM: Revised List of Models and Manufacturers of Wind Turbines

RLMM: Revised List of Models and Manufacturers

ROC: Renewable Obligation Certificates

RPO: Renewable Purchase Obligation

RTI: Relative thermal index

SAN: Styrene acrylonitrile

SAR: Synthetic Aperture Radar

SCAT: Scatterometer

SCVT: State Council for Vocational Training

SD: Solar Driven

SECI: Solar Energy Corporation of India

SERC: State Electricity Regulatory Commission

SEZ: Special Economic Zone

SHP: Small Hydro Power

SIDBI: Small Industries Development Bank of India

SLDC: State Load Despatch Centre

SMEs: Small and medium enterprises

SNA: State Nodal Agencies

SPVs: Special Purpose Vehicles

SS: Stainless steel

SSC: Sector Skill Council

STU: State Transmission Utility

SWOT: Strength, Weakness, Opportunity, Threat

TCO: Transparent Conductive Oxide

TDB: Technology Development Board

TES: Thermal Energy Storage

TFE: Tetrafluoroethylene

TIFAC: Technology, Information, Forecasting and Assessment Council

TIFAC: Technology Information, Forecasting and Assessment Council

TIV: Turbine installation vessels

TPU: Thermoplastic Polyurethane

TSO: Transmission System Operator

UAE: United Arab Emirates

UI: Unscheduled Interchange

UL: Underwriters Laboratories

USIBC: United States-India Business Council

VAT: Value Added Tax

VGF: Viability Gap Funding

WAsP: Wind Atlas Analysis and Application Programme

WD: Wind Driven

Wp: Watt peak

WPD: Wind Power Density

WRIG: Wound Rotor Induction Generator

WTE: Waste to Energy

WTG: Wind Turbine Generator

Executive Summary

The manufacturing sector in India has been growing at a Compound Annual Growth Rate (CAGR) (constant prices) of 7.3% over the past decade. But, the manufacturing output growth rate declined in 2012 and 2013 (MOSPI, 2014a). Poor domestic and external demand, high interest rates and infrastructure bottlenecks are the primary reasons for the reduced growth rate (Das, 2014)(KPMG, 2015). In 2013-14, manufacturing's share in GDP was 14.9%, which was a 90 basis point decrease as compared to the previous fiscal year (MOSPI, 2014b).

Despite this business leaders, and the industry in general share, a positive outlook. The Index of Industrial Production exhibited a growth of 2.1% in 2014-15 (April–December), in addition to the 0.1% increase during the same period last year. Manufacturing output too increased by 3.9% and 0.4% respectively in the first and second quarters of 2014-15 (KPMG, 2015).

In 2011, the Government of India (GoI) announced the National Manufacturing Policy (NMP) which aims to increase the share of manufacturing in GDP to 25% by 2021, and in the process create 100 million jobs (PIB, 2011). NMP is considered as one of the most comprehensive and significant policy initiatives by the government for the manufacturing sector (PwC, 2012). Last year, GoI announced the 'Make in India' initiative to encourage companies to manufacture their products in India. The initiative focuses on job creation and skill enhancement in 25 sectors, including electronic systems and renewable energy.

The Modi government recently announced ambitious plans to scale-up Renewable Energy (RE) capacity, with targets of 100 GW for solar power and 60 GW for wind power. In this context, it becomes imperative to assess the challenges of domestic availability and manufacturing of different renewable components. An analysis of domestic manufacturing vs. import dependence and formulation of a suitable response for affecting an enabling policy and regulatory environment to address these challenges is also desirable.

India's current Wind Turbine Generator (WTG) manufacturing capacity stands at around 12 GW per annum. Twenty Original Equipment Manufacturers (OEMs) offer about 34 WTG models of rating in the range of 225–2500 kW. The wind industry has been experiencing low demand over the last 2-3 years (2011-13) and significant manufacturing capacity has remained underutilised. In the solar photovoltaic (PV) industry, as of March 2015, India had approximately 1,386 MW of cell and 2,756 MW of module manufacturing capacity. Although the cell and module manufacturing CAGR has been 63% and 66%, respectively during the years 2007-14, it still falls short of the 4-5 GW by 2017 targets set by the Ministry of New and Renewable Energy (MNRE).

Support for RE and the manufacture of renewable technology components has been growing in India. GoI, through its Jawaharlal Nehru National Solar Mission (JNNSM), Modified Special Incentive Package Scheme (MSIPS), NMP and Make in India, has announced several measures and incentives favouring renewable manufacturers. The National Wind Mission and Renewable Energy Law, which are expected to be announced soon, also include a variety of measures that would benefit domestic manufacturers.

This study comprehensively examines the manufacturing supply chain of different components used in RE systems, especially wind and solar technology, in India. Over the past one and half years, around 90 interviews were conducted across the solar and wind industry comprising manufacturers, developers, system integrators, academicians and policy makers. A sourcing strategy for these components has been identified based on macro-economic criteria, material and resource constraints, techno-economic feasibility and international market dynamics. The report also proposes necessary policy and regulatory interventions to expand the supply of RE and create a demand-side pull.

In wind technology, the study recommends that blades, generators and towers should be manufactured indigenously in the short-term. Due to dearth of casting and forging facilities, hub and rotor shafts are sometimes imported. These components can also be manufactured indigenously as the demand for casts of larger sizes and availability of forging facilities increases. Large bearings have low demand and can be imported in the short-term. However in the long-term, manufacture of all the components can be indigenised.

Offshore wind could be the future of the wind industry, as proclaimed by several wind industry experts. Currently, this sector is in its infancy in India, but is a mature industry in Europe and is exhibiting higher growth in countries such as China. Offshore wind presents an exciting supply chain opportunity for the already mature Indian wind industry. The study highlights salient aspects of the global offshore industry and the opportunities that are in store for India.

In PV technology, crystalline Silicon (c-Si) and amorphous Silicon (a-Si) technologies were evaluated. In c-Si technology, the analysis finds that India should focus on manufacturing glass, encapsulant and backsheet in the short-term. Whereas, cells should be both manufactured domestically as well as imported. In a-Si technology, in the near term, glass, encapsulant and backsheet should be manufactured indigenously, whereas, silane should be imported. In the long-term, the study recommends that all four components, in both c-Si and a-Si technologies, could be manufactured indigenously.

In Concentrated Solar Power (CSP) technology, Parabolic Trough (PT) and Solar Tower (ST) technologies have been examined. The analysis concludes that given the present manufacturing conditions prevalent in India, Parabolic Mirror and Power Block in the case of PT, and Heliostat and Power Block in the case of ST should be indigenously manufactured. Receivers for both technologies should be imported. In the case of PT, Heat Transfer Fluid (HTF) should also be imported. As recommended for wind technology, all the components for both the technologies could be domestically manufactured in the long-term. This largely assumes that sufficient demand for these technologies will exist in the future.

In conclusion, the study proposes several measures in finance, standards and benchmarking, materials and technology and research and development to promote and support domestic manufacturing in solar and wind technology. The study also suggests that measures and incentives proposed in JNNSM, NMP, MSIPS and other government policies should be actively pursued. In addition, interventions to address issues such as local content requirement, export promotion, auxiliary industry promotion and logistical challenges (in the case of wind technology) have also been proposed. A component-wise policy recommendation concludes the study.

1 Introduction

According to the World Energy Outlook 2012, renewables make up an increasing share of primary energy use, owing to government support, falling costs, CO_2 pricing in some regions, and rising fossil fuel prices. In the New Policies Scenario as highlighted in the report, electricity generation from renewables is shown to triple from 2010 to 2035, reaching 31% of total generation. By 2035, hydropower is shown to constitute 50% of renewables-based generation, wind almost 25% and solar Photovoltaic (PV) 7.5% (solar photovoltaic (PV) generation is shown to increase 26-fold from 2010-2035) (IEA, 2012).

In recent years, the growth of Renewable Energy (RE) in terms of capacity addition, technological development and cost reduction has been significant. The major bottlenecks for the development of RE have been identified as high capital costs, variable nature of resource and challenges with grid integration. But, RE is expected to achieve growth due to following market drivers:

- **Energy security:** Growing population and rising incomes will increase energy demand, thereby causing energy prices to go up. This will also pose the risk of higher dependency on the import a limited range of energy supplies.
- **Future strategic positioning:** The increase in oil prices since 2002 has put pressure on the balance of payments of several developing countries[1]. To reduce the current account deficit and corresponding fiscal deficit, a shift from conventional to non-conventional energy technologies is imminent.
- **Industrial development:** The global market in low-carbon and energy efficient technologies, which includes RE products among other technologies, is projected to triple to USD 2.2 trillion by 2020 (UNEP, 2013).
- **Quality of environment:** The shift from fossil fuels to RE sources can meet Greenhouse Gas (GHG) reduction targets. Emissions in 2012 increased by 58% above 1990 levels. Under a business-as-usual scenario, global GHG emissions are predicted to increase to 37 Gigatonnes (Gt) annually by 2035. Regeneration can limit carbon emissions from energy production and use, thereby potentially saving an equivalent of 220–560 Gt of CO_2 between 2010 and 2050 (UNEP, 2013).
- **Employment and skill development:** Investing in RE technologies also creates new employment opportunities. In 2012, about 5.7 million people worldwide were estimated to be working, either directly or indirectly, in the RE sector and another 16.7 million are expected to be added by 2030 (IRENA, 2013). Estimates suggest that by 2030, 9.7 million people could be employed in the bio-energy sector, 2.1 million in the wind sector and 2 million in the solar PV sector (IRENA, 2013).

Global investment in RE decreased in 2013 by USD 36 billion, to USD 214 billion, which was a decrease of 14% from USD 250 billion in 2012 and 23% from USD 279 billion in 2011 (a record year) (BNEF, 2014). In developing countries, the decrease in investment was significant, from USD 107 billion (2012) to USD 93 billion (2013). Investments in the RE sector decreased in developed countries too, from USD 142 billion (2012) to USD 122 billion (2013). Global investment decreased as a result of economic and policy-related uncertainty in some traditional markets, as well as reduction in technology costs. The drop in technology costs had a helpful effect on capacity

[1]Current account deficit forms a portion of the Balance of Payments (Capital Account, Errors and Omissions are other factors). Trade deficit, one of the major factors contributing towards India's current account deficit in 2012-13 was USD 191 billion of which USD 109 billion was accounted by oil imports. India imports approximately 80% of its oil consumption. These together with imports of coal contribute significantly towards negative balance of payment.

installations, especially in the case of solar. The top five countries in RE investment during 2013 were China, the United States of America, Japan, the United Kingdom and Germany. India attracted investments of USD 6.1 billion in 2013. Table 1.1 depicts India's technology-wise RE investment (in billions of USD) from 2008-13.

Table 1.1: RE Investment by Technology (in billion USD) (REN21, 2013)(BNEF, 2014)

RE Technology	2008	2009	2010	2011	2012	2013
Solar Power	59.3	62.3	99.9	158.1	142.9	113.7
Wind Power	69.9	73.7	96.2	89.3	80.9	80.1
Biomass and waste-to- energy	14.1	13.2	13.7	12.9	11.1	8.0
Hydro <50 MW	7.1	5.3	4.5	6.5	6.0	5.0
Bio Fuels	19.3	10.6	9.2	8.3	6.6	5.0
Geothermal Power	1.8	2.7	3.5	3.7	1.8	3.0
Ocean Energy	0.2	0.3	0.2	0.3	0.2	0.1
Total Investment	171.7	168.2	227.2	279.0	249.5	214.4

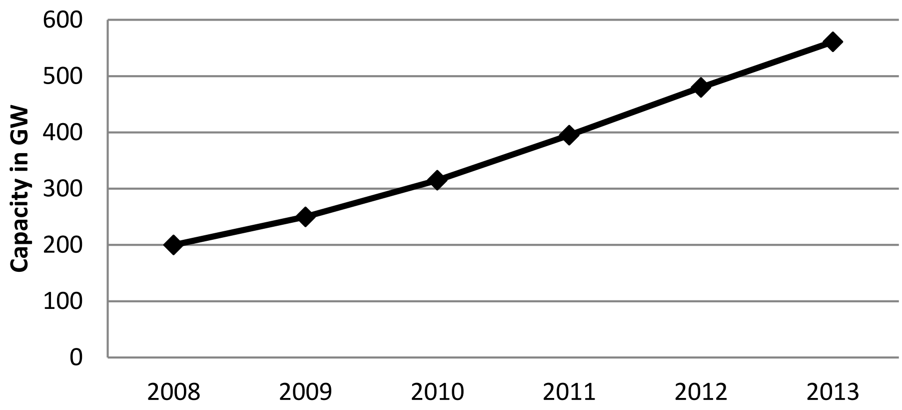

Figure 1.1: Cumulative Global RE installed Capacity (in GW) (REN21, 2013)(BNEF, 2014)

Figure 1.1 shows the cumulative RE installation across the globe. Various countries have increased their fuel subsidies by putting a strain on government budgets and underpinning the demand for fossil fuel imports (UNEP, 2011). Figure 1.2 shows the subsidies on fossil fuels and RE in industrial and developing countries. Subsidies on fossil fuel were approximately USD 451.2 billion in 2010 – which was close to 7 times more than that provided to renewables.

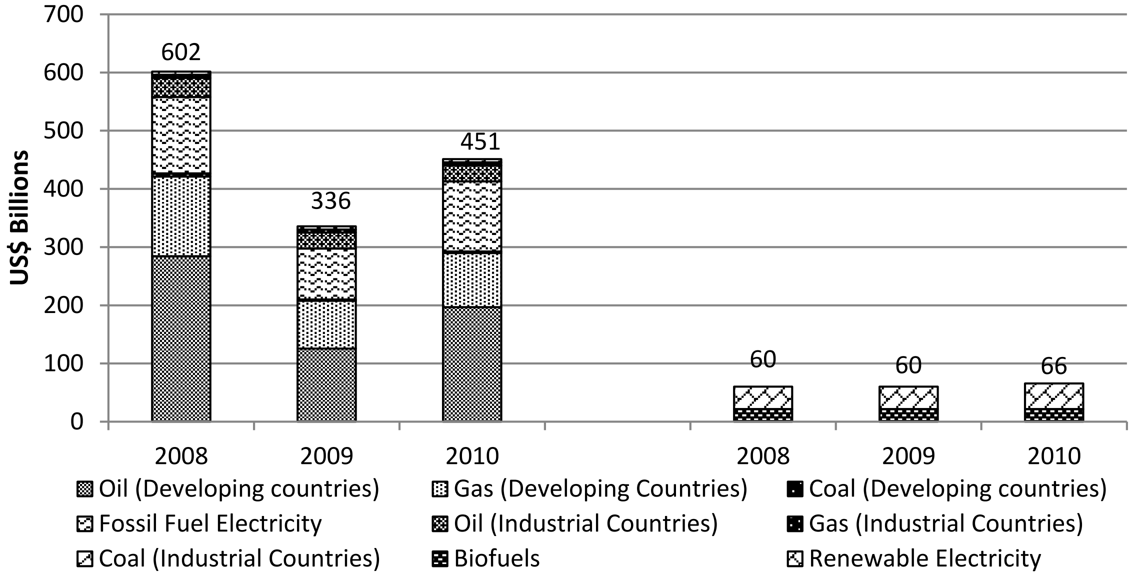

Figure 1.2: Estimated Global Subsidy for Fossil Fuels and Renewables in 2008-10 (UNEP, 2013)

RE subsidies increased to USD 88 billion in 2011, 24% higher than that in 2010. However the subsidies need to rise to almost USD 240 billion in 2035 to achieve the trends projected in the New Policies Scenario (IEA, 2012). The cumulative support to renewable power generation amounts to USD 3.5 trillion, of which, over one-quarter is already locked-in by commitments to existing capacity (and about 70% is set to be locked-in by 2020). While vital to growth of the industry, subsidies for new renewable capacity need to be reduced as costs fall to avoid them becoming an excessive burden on governments and end-users. (IEA, 2012)

Recent studies have observed that in order to encourage developing countries to adopt RE technologies in the local and regional context, the capacity to maintain and operate systems is not sufficient; innovative capabilities also need to be addressed. The required capabilities to undergo the process of adaptive innovation are considerable and depend on a knowledge infrastructure usually encompassing R&D and also requiring higher levels of education. As a result, the flow of technology and knowledge are of vital importance for technology transfer to developing countries (UNEP, 2011).

India has already adopted RE in its energy mix. But, for creating robust and growing domestic RE industries and delivering affordable domestic energy, the right policy and support mechanisms are required. Policy and support mechanisms are essential for both upstream as well as downstream value chain. It is identified that (Barua, Tawney, & Weischer, 2012):

- Domestic deployment is key to building both upstream (manufacturing) and downstream (domestic industries)
- Supportive policies for at least three to four years correlate with sustained annual deployment (of renewables) and growth of supporting upstream and downstream industries as well
- Most export opportunities emerge from a strong domestic manufacturing industry, supported by domestic deployment.

1.1 Renewable Generation in India

The total installed capacity of renewable, as of March 2015 stood at 35.8 GW (MNRE, 2015a). Figure 1.3 highlights the technology-wise break up of installed capacity of renewables. Wind has the highest share (66%), followed by small hydro (11%) and solar (10%) in total the RE installations. During 2012-13, renewables accounted for 47 Billion Units (BUs) of generation, which was about 4.9% of India's total generation of 959 BUs (CEA, 2013a). According to CEA, from April to August 2013, wind and solar accounted for 80% and 2% of the total renewable generation, respectively (CEA, 2013b). In 2013-14, wind energy accounted for 2.7% of the total electricity generation (POSOCO, 2014). The wind sector (cumulative capacity installed) has been growing at CAGR of 23.68% over the past ten years, whereas the solar PV sector has grown at 389% over the past five years.

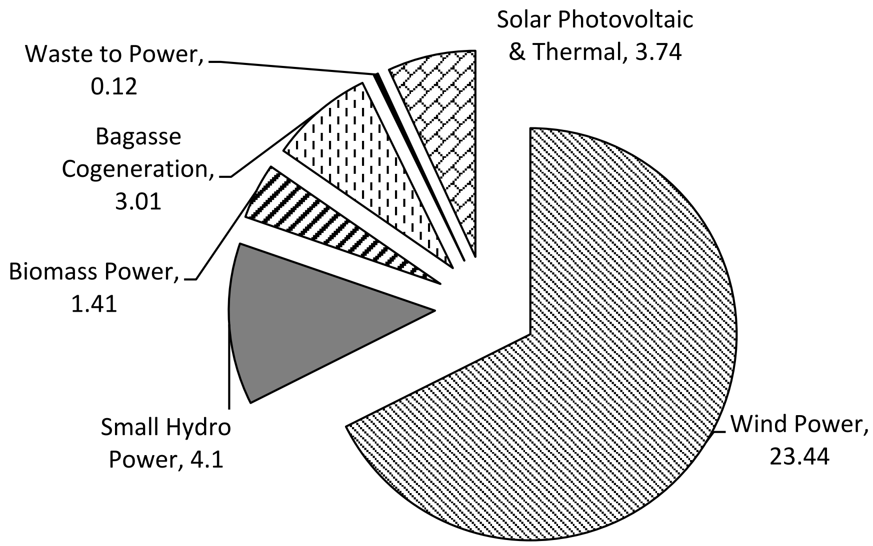

Figure 1.3: Source-Wise Renewable Installed Capacity (in GW) in India, March 2015 (MNRE, 2015a).

Table 1.2 shows the status of India's power sector at the end of the 11th Five Year Plan (FYP) (Planning Commission, 2013b)(Indiastat, 2013)(CEA, 2012d). The net RE penetration in the total electricity mix at the end of the 11th FYP reached 5.89%. In the absence of data availability of actual generation from renewable plants, corresponding capacity utilisation factors from the Central Electricity Regulatory Commission (CERC) and Karnataka Electricity Regulatory Commission (KERC) tariff guidelines were used to estimate renewable generation (CERC, 2011)(KERC, 2013). In addition, CERC guidelines were also used to determine the auxiliary consumption, using which the net renewable generation was estimated (CERC, 2011).

Table 1.2: Cumulative Installed and Generation Capacity in 2011-12

Energy Sources	Installed Capacity (GW)	Net Generation[2] (BU)	Net Generation (%)
Conventional	175.4	818.7	94.21
Renewable Energy Sources (RES)[3]	24.5	50.3	5.79[4]

[2]Net generation = Gross Generation – Auxiliary Consumption. Auxiliary consumption in 2010-11 has been considered for this analysis. The auxiliary consumption has been taken from CEA's *All India Electricity Statistics, General Review 2012*
[3]RES comprises of Wind, Solar, Biomass, Small Hydro and Waste to Power (Urban and Industrial waste).
[4]The gross generation from renewables is 5.89%, which has been considered in the projections.

Total	199.9	868.9	100

Table 1.3 shows the RE capacity addition in India for the 10th, 11th and 12th FYPs. The capacity addition for wind, small hydro and bio power was more than their respective targets in the 10th and 11thFYPs. This was achieved as a result of proactive government support through incentives like Accelerated Depreciation (AD) and Generation Based Incentives (GBI). Both AD and GBI were revoked for the wind sector at the end of the 11th FYP. Due to these revocations, RE installation, especially wind power saw a fall in the early years of the 12th FYP. GBI for wind power was reinstated in the 2013-14 budget, with effect from April 2012 and 100% AD was also reinstated in the 2014-15 budget.

Table 1.3: RE Capacity Addition (in MW) for 10th, 11th, 12th FYP (CRISIL, 2012)

Resource	10th Plan		11th Plan		12th Plan	
	Target	Achievement	Target	Achievement	Target	Achievement*
Wind Power	1,500	5,427	9,000	10,260	15,000	3,782.1
Small Hydro Power	600	538	1,400	1,420	2,100	408.3
Bio Power^	780	795	1,946	2,042	4,550	896.32
Solar Power	145	1	416	940	10,000	1,716.2
Total	3,025	6,761	12,762	14,662	31,650	6,802.92

*RE Capacity addition in 12th Plan period as on 31/03/2014

^Includes biomass power, bagasse cogeneration, urban and industrial waste to energy

The issue of examining the supply chain of wind energy is timely and relevant as the National Wind Energy Mission is on the anvil[5]. Through this Mission, India aims to achieve a generating capacity of 60 GW by 2022[6].This would provide an impetus to indigenous manufacturing. In solar, the government has introduced Domestic Content Requirement (DCR) in the National Solar Mission (NSM)[7]. In Phase I, for PV projects chosen in Batch I (during FY11), it was mandatory to use modules employing c-Si technology that were manufactured in India. For Phase I Batch II, the mandate was extended to crystalline Silicon cells (MNRE, 2010). In Phase II, DCR has been applied to 375 MW from the total allotment of 750 MW[8]. In addition, one of the objectives of NSM is to develop 4-5 GW of indigenous module manufacturing capacity (MNRE, 2012b).

Structure of the Report

This study is unique since no other study has comprehensively examined the manufacturing supply chain of the different components of wind and solar technology in India, identified challenges and proposed recommendations for addressing the same. Chapter 2 starts with an overview of original equipment manufacturers and Tier I and Tier II suppliers in wind and solar technology in India. It also compares the cost of components produced in India against China and the United States.

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[5]http://mnre.gov.in/file-manager/UserFiles/national-level-consultation-on-national-wind-energy-mission-09012014.htm (Retrieved on 27/03/2014)

[6]http://www.re-invest.in/Document/orginal/15.RE-Invest_2015_Investors_Guide.pdf (Retrieved on 24/07/2015)

[7]National Solar Mission is one of the eight national missions under the Prime Minister's National Action Plan on Climate Change. In addition to 'establish[ing] India as a global leader' in solar energy, NSM seeks to install 20 GW of grid-connected solar power and 2 GW of off-grid solar power by 2022.

[8]The bids were received on January 21, 2014 and winners were notified on February 25, 2014. On techo-commercial basis, 14 and 21 organisations were selected in the DCR and Open category. http://www.seci.gov.in/upload/uploadfiles/files/Final%20allocation%20list_750%20MW(1).pdf (Retrieved on27/03/2014)

Chapter 3 comprises of the methodology engaged to determine the critical components for wind[9], solar (PV and CSP) and storage[10] technologies. After determining the critical components, these are assessed based on their existing market position, current and upcoming technology and manufacturing and assembling processes. The chapter also highlights the challenges associated with raw material, manufacturing processes, R&D, design and testing etc.

The methodology for the short and long-term 'Make or Buy' matrix, along with a Strengths Weaknesses, Opportunities and Threats (SWOT) analysis for each of the critical components is highlighted in Chapter 4. The short-term 'Make or Buy' matrix gives a status of domestic manufacturing capacity, compares domestic vs. import prices, range of existing technology depth, current sourcing mix, raw material availability, major raw material requirement and jobs for each of the critical components. The long-term 'Make or Buy' matrix on the other hand examines material requirement for each of the critical components selected in wind, solar and storage technologies.

Chapter 5 provides an overview of RE policies and regulations in India. It also discusses the different supply and demand side policies across China, the United States, Germany and Spain. The chapter ends with the identification of policy gaps in the Indian context. Chapter 6 covers offshore wind technology, which presents an upcoming opportunity for the mature Indian wind turbine manufacturing industry.

Chapter 7 underscores sector-specific, technology-specific and term-wise recommendations. The recommendations are aimed to ease the constraints in the business environment of renewable manufacturing, which in turn will provide the much needed impetus to the renewable sector. The chapter ends with an action plan to implement the recommendations and achieve the milestones that have been set under the ambitious FYPs and the National Action Plan for Climate Change (NAPCC).

[9]The critical component analysis has not been carried out for offshore wind technology, which is an upcoming trend in the Indian market. It is however covered separately in Chapter 6.

[10]The study examines thermal storage technology which engages molten salt. The study doesn't look into electrochemical storage technology, i.e., utility-scale battery.

2 RE Manufacturing Supply Chain in India -Overview

The share of renewable sources in the total generation mix rose from 7.8% in FY08 to 12.9% in FY 14. Growing energy demand, energy security, government support, cost competitiveness of RE technology, favourable foreign investment policy and vast untapped potential are some of the key drivers for RE in India (EY, UBM & REI, 2013). The large demand for RE has also established players throughout the RE manufacturing supply chain. This chapter gives an overview of the existing wind and solar manufacturing supply chain in India.

2.1 India's Wind and Solar Market

According to the latest estimate, India has a commercially viable renewable potential of around 897 GW, which includes 103 GW of wind and 749 GW of solar power (MNRE, 2015b). Wind and solar technologies are developing at an unprecedented rate in India. India has been ranked 4th out of 40 countries in an all renewables index published by EY (EY, 2013). In the wind index it ranked 6th and in the overall solar index it ranked 2nd, with 3rd and 5th positions respectively for solar PV and CSP. The demand and supply side measures put forth by GoI are the prime reasons for India's good performance.

The country added around 14,660 MW of renewable capacity during the 11th FYP and has added 6,803 MW during first two years of the 12th Plan. The share of RE in the country's total energy mix increased from 5.86% in FY07 to 12.9% FY14 (CEA, 2014b) (MNRE, 2014b). This trend could continue for at least the next decade as the government is committed to increasing the share of RE in India's power generation mix due to energy security and environmental concerns. NAPCC has also set a target of 15% renewable in the total electricity mix by 2020. Moreover, the government has already established grid-connected RE targets of 175 GW by 2022.

Figure 2.1 and Figure 2.2 show the actual and targeted share of conventional and renewable power sources in the total installed power capacity (200 GW) in India at the end of 11th FYP and by the end of 12th FYP, respectively. While the share of thermal capacity is expected to reduce marginally, the share of renewable is expected to increase significantly by 50% (from 12% to approximately 18%) by the end of the 12thPlan.

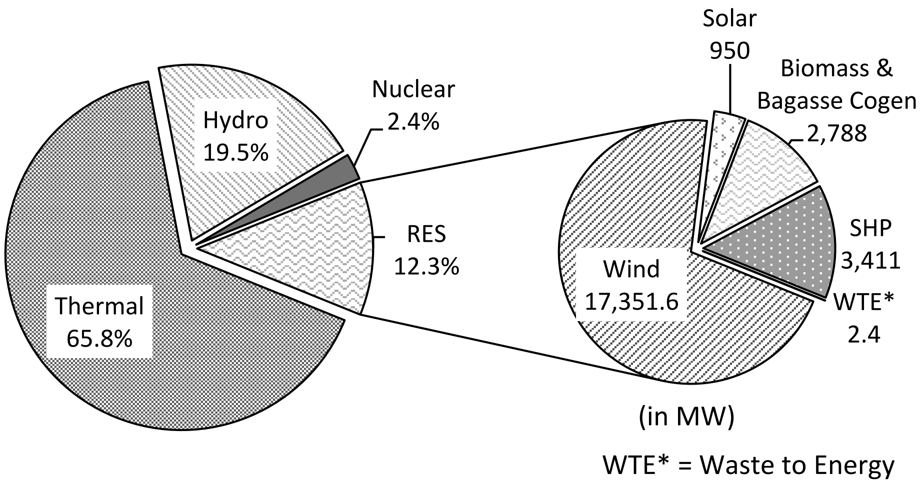

Figure 2.1: Share of RE in Total Installed Capacity by the End of 11thFYP

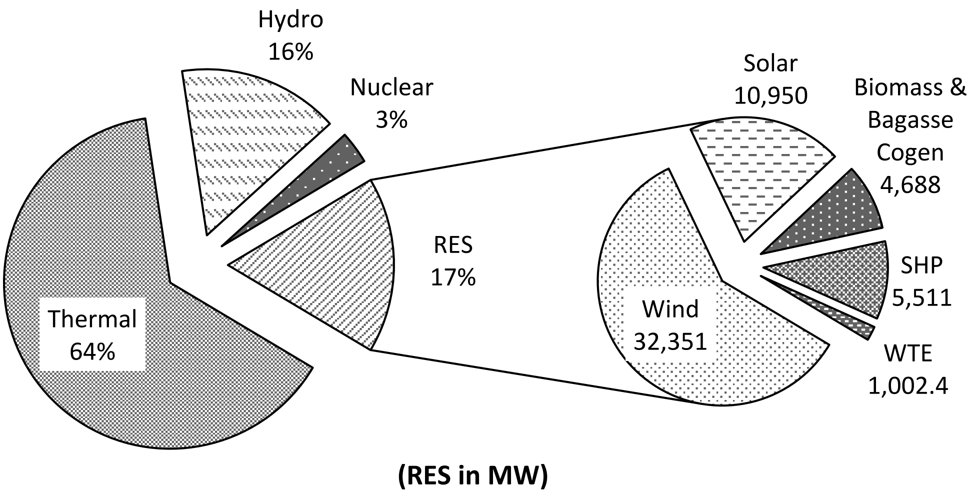

Figure 2.2: Expected Share of RE Capacity by the End of 12thFYP

2.2 Wind Power

Globally, wind energy has been growing at a good pace and captured more than 56% of RE till 2013 (BNEF, 2014)(GWEC, 2014). In 2013, wind energy achieved a cumulative installation of 318 GW with 35 GW installed in 2013 alone. Asia leads the global markets in annual wind installation with more than 18 GW, next to EU with about 12GW (GWEC, 2014).

India is one of the largest wind power markets in the world and provides great business opportunities for domestic and foreign investors. According to GWEC, in 2013, India ranked 5th in overall cumulative wind capacity and 4th in annual installed capacity added. As of March 31, 2014, India's cumulative wind power capacity was 21,136 MW with 1.5–3.2 GW of wind power installations being added annually over the past five years. The average capacity addition during last five years has been 2.2 GW per annum. Figure 2.3 shows the year-wise cumulative capacity and annual capacity addition of wind power in India since 1992.

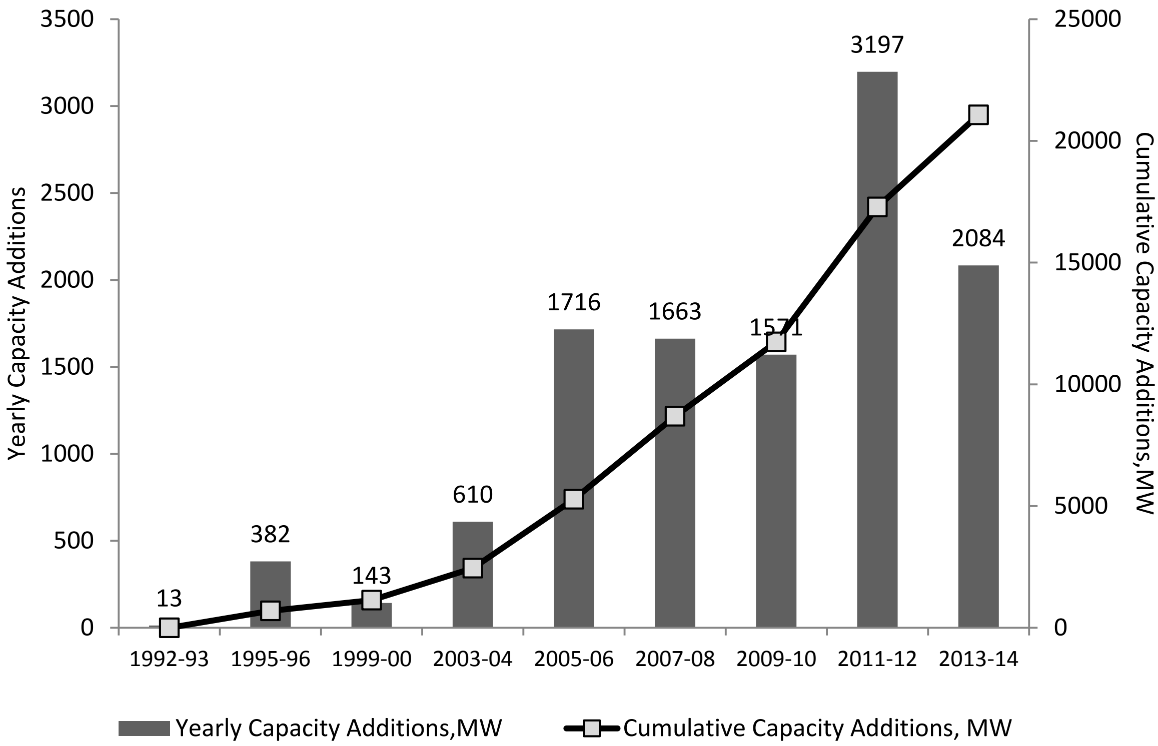

Figure 2.3: Wind Power Development in India (MNRE, 2014b)

Various organisations such as the Central Electricity Authority (CEA), Power Grid Corporation of India (PGCIL), and Global Wind Energy Council (GWEC) have estimated future wind installations for different time periods. CEA estimates indicate that India's cumulative wind capacity would range between 38 GW and 51 GW under different scenarios, namely low renewable and high renewable at the end of the 13thPlan period (CEA, 2012b). PGCIL envisaged India's cumulative RE capacity in 2030 to be 199 GW (164 GW from wind and 35 GW from solar) and has planned its power evacuation infrastructure based on this projection (PGCIL, 2012).GWEC estimated 66 GW to 191 GW of cumulative installed wind capacity by 2030 (GWEC, 2012a).

During the initial years, the primary driver for the industry was investment-linked incentives like AD and sales tax benefits. Hence, the major focus was on capacity addition and not specifically on the performance of wind turbines. During this phase of development, a majority of installed wind turbines were of lower capacity, i.e., up to 500 kW ratings. As the technology and market matured over the years, the share of smaller machines (less than 500 kW) in total cumulative installations decreased from 98% in FY2000 to 6.27% in FY13. Till 2002, sub-MW turbines had a major share and larger turbines were virtually non-existent. Later, especially after 2002, due to advancements in technology, larger sized machines were introduced in the Indian market with larger rotor diameters, higher hub heights and sophisticated control mechanisms which were more efficient in energy generation as compared to the older machines. Megawatt-scale turbine installations increased from 11% in FY03 to 53% in FY13. The year-wise change in share of smaller (<500 kW), sub-megawatt (500 to 1000 kW), and megawatt scale (> 1000kW) machines in cumulative capacity is shown in Figure 2.4.

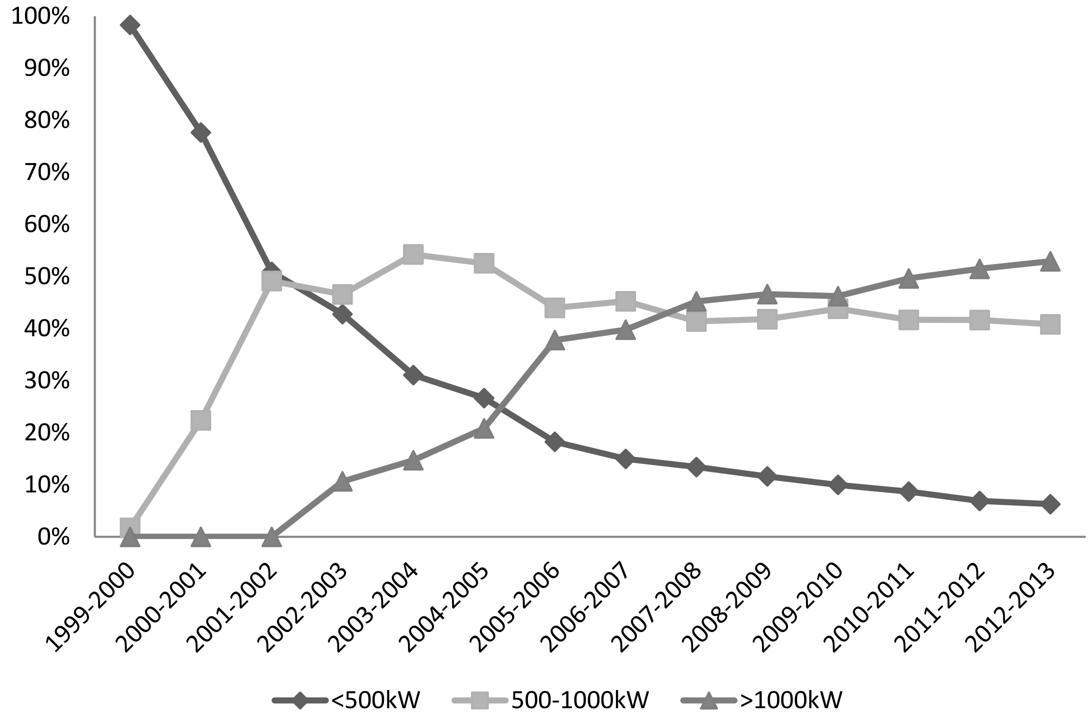

Figure 2.4: Percentage Cumulative Share of Various Ratings of Wind Turbines

2.2.1 Technology Trends in Onshore Wind

With the emergence of Independent Power Producers (IPPs) in the wind sector, the industry's focus has shifted towards utilising higher efficiency technologies to maximise returns on investment. The present trends show that megawatt-scale turbines are becoming more popular as compared to smaller capacity turbines. The average WTG size for annual installations has increased gradually, touching 1.33 MW during FY14 (BTM WIND Report, 2014). At the same time, with the focus now being laid on developing low wind speed sites, WTGs suited to such conditions are being preferred.

A wind turbine has three major components – rotor, nacelle, and tower. The rotor and nacelle comprise of various mechanical, electrical and electronic subcomponents. A rotor comprises of a blade, rotor hub, pitching system and lighting protection. A nacelle comprises of a shaft, bearing, gearbox, coupling and dampers, generator, cooling system, hydraulic system, nacelle main frame and enclosure, yaw system, wind sensor assembly and control system. Latest turbine technologies indicate a shift towards direct drives which eliminate the need of a gearbox, but need larger sized and variable speed synchronous generators. The tower is a stand-alone component. Finally, a transformer is used to step-up the low voltage power produced by the turbine. Wind turbines are connected in clusters (onshore and offshore) for power generation.

Increasing rotor sizes need technological breakthroughs in drive trains as the load path is longer in the case of a geared turbine; in larger rotor turbines, direct/gearless drive trains or hybrid drive trains are being increasingly preferred. Figure 2.5 shows the increasing share of direct drive technology in India over the past five years, except in 2013-14. The average market share of gearless turbines has been around 35% over the past five years.

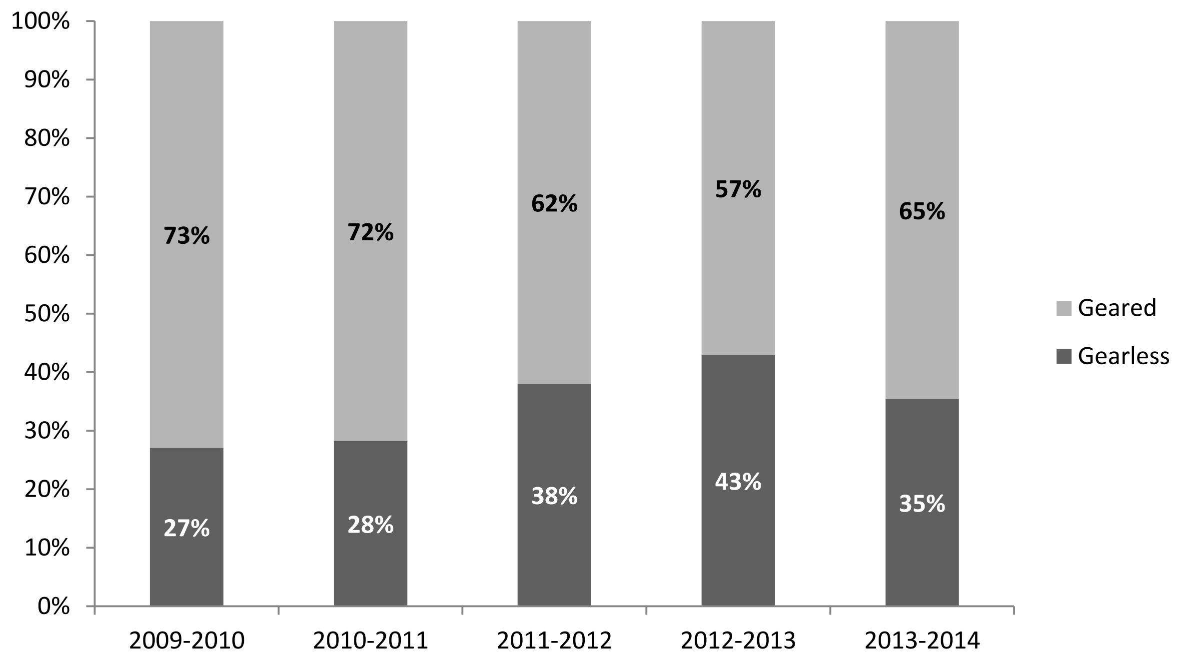

Figure 2.5: Gear and Gearless Turbine Contribution in WT Installation in India, 2009-14

In India, traditionally all WTG manufacturers, except Wind World (earlier Enercon), offered induction generators. However in the recent years, variable speed synchronous generators are also being offered by a few players such as Regen Powertech and Leitwind Shriram. WinWind has introduced a hybrid technology with a single-stage gearbox integrated with a synchronous generator. Globally, the developments in drive train concepts are moving towards hydraulic drive trains which have better cost efficiency per kWh and less top head mass for wind turbines of comparable capacities. These newer generators have better fault ride through capability and lesser power factor issues than that seen in induction generators. Therefore they may perform better under weak grid conditions that prevail in India.

In terms of power regulation, Indian wind turbines initially had passive stall turbines. Now, active stall and pitching mechanism have been introduced which have reduced the reduction in power capture due to stall effect.

In support structures, lattice towers were used in earlier in most of the wind turbine installations (usually sub-MW WTGs). Now the trend has unanimously shifted towards tubular towers. This change is shown in Figure 2.6.

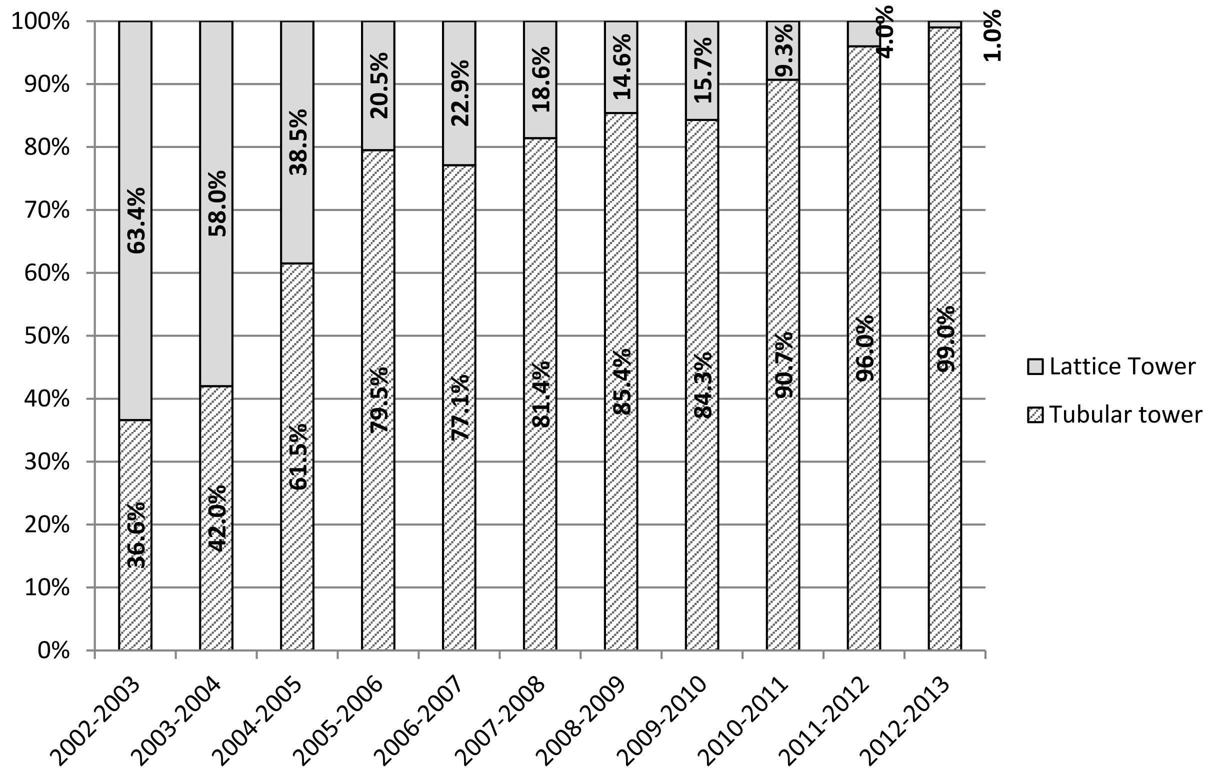

Figure 2.6: Percentage Share of Tubular and Lattice Towers in the Indian Market, 2002-13

Lately, hybrid towers (a combination of lattice and tubular) have been introduced by Suzlon, one of the major manufacturers in India for 2 MW wind turbine. This development may have positive implications for material and cost reductions in the future.

2.3 Solar Power

Globally, solar PV technology grew at the second fastest rate among all other renewable technologies during 2006-2013 – CAGR of 59% (Clean Technica, 2014)(BNEF, 2014). CSP technology grew the fastest at 87% during the same time period (REN21, 2012)(Helios CSP, 2014). The year 2013 saw an addition of 39 GW (BNEF, 2014) of solar PV capacity bringing the cumulative global capacity to approximately 136 GW (IEA-PVPS, 2014)and 946 MW of CSP (Helios CSP, 2014)bringing the total installed capacity to 3.4 GW (REN21, 2013). In solar PV, India ranked 6th globally with around 1.1 GW of annual installed capacity (IEA-PVPS, 2014).

PV installations in India are driven by a mix of national targets and support mechanisms at the central and state levels. JNNSM (henceforth referred to as NSM) aims to install 20 GW of grid-connected PV systems by 2022 and 2 GW of off-grid systems, including 20 million solar lights. In the union budget for 2015-16 the targets have been further raised to 100 GW (The Hindu, 2015). The mandatory compliance of Solar Renewable Purchase Obligations (RPOs) by obligated entities is also leading to increased installations under the Renewable Energy Certificate (REC) mechanism. As of March 2014, the total solar power installed capacity in India stood at 2.65 GW, an increase from 46 MW at the end of 2010. Figure 2.7 shows the cumulative and annual addition of solar PV in India from 2010 to 2015.

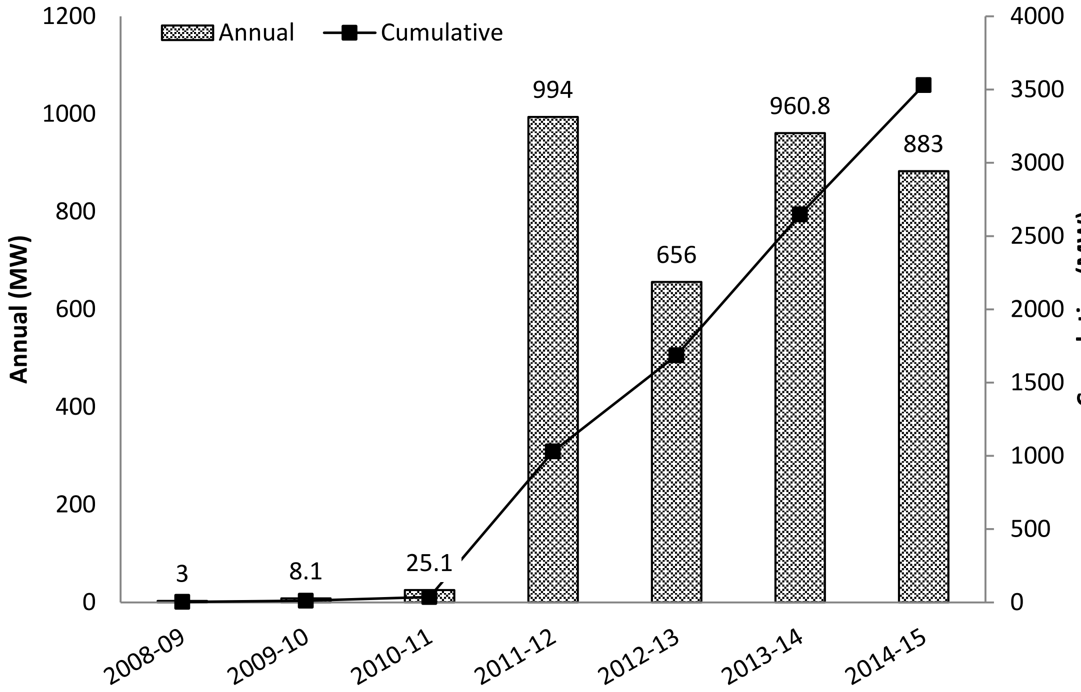

Figure 2.7: Cumulative and Annual PV Installed Capacity in India, 2008-15 (Mercom Capital, 2015)

PV cells can be distinguished into crystalline PV cells and thin film PV cells. In a crystalline PV module (or c-Si technology), cells are assembled together, while in thin film technology (or a-Si technology), cells are laser scribed after the deposition of a semi-conducting thin film on a substrate. The major components of a c-Si cell include crystalline Silicon cell (high purity – 6N), Silver paste or a typical conducting material, gases (Aluminium nitride, Boron nitride etc.), low Iron glass, encapsulant, backsheet, Aluminium frame, junction box and cable. The major components in a-Si technology are Tin or Zinc oxide (transparent conductive oxide), gases (Silane, Argon, Diborane, and Phosphine), low Iron glass or stainless steel (substrate), encapsulant, backsheet, Aluminium frame, junction box and cable.

As of September 2014, c-Si modules had a major share in the utility-scale PV installations in India (96%)(Bridge to India, 2014) and the cumulative capacity of installed PV systems stood at 2.633 GW (MNRE, 2013a). Out of the 0.87 GW of the installed thin film capacity, 52.5% corresponded to Cadmium telluride (CdTe) technology. Copper Indium Gallium Selenide (CIGS) and a-Si technology were used in cumulative installations of 0.32 GW and 0.1 GW respectively (Bridge to India, 2013a). Figure 2.8 highlights the installed PV capacity in India based on the type of technology.

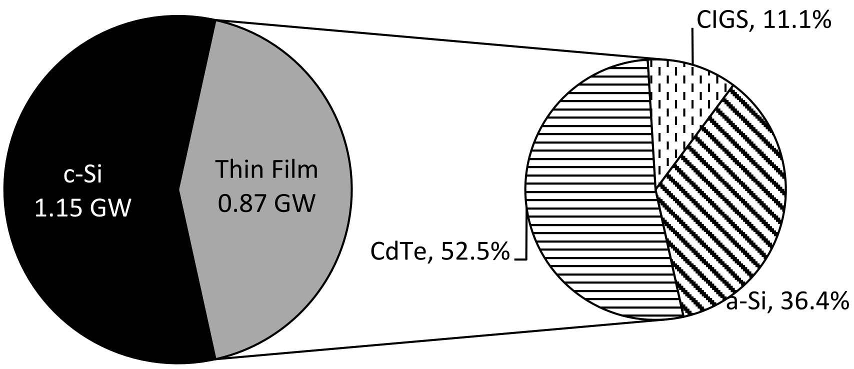

Figure 2.8: Technology-Wise Breakdown of Utility-scale PV Installed Capacity (in GW)

A CSP plant mainly consists of a solar field, storage system and power block. Receiver, mirrors, support structure, HTF and solar trackers are part of the solar field. The storage system consists of a storage tank and molten salt. Heat exchangers, steam turbine, generators, pumps, condensers and fossil boiler (optional) are components of a power block.

The primary difference between the PT and ST technology lies in the solar field technology. Mirror, receiver and HTF are the primary components of a solar field. **Annexure 1** lists the components of solar field for both PT and ST technologies.

The installed capacity of CSP technology as of September 2015 stood at 227.5 MW of which 100 MW corresponds to the PT based plant located in Rajasthan (Godawari Green Energy, 2013)[11] and Andhra Pradesh (NREL, 2015). The remaining 127.5 MW is based on Linear Fresnel Receiver and ST[12] technology[13]. Figure 2.9 highlights the share of different CSP technology commissioned in India for generating power. **Annexure 1** provides a brief overview of the different technologies.

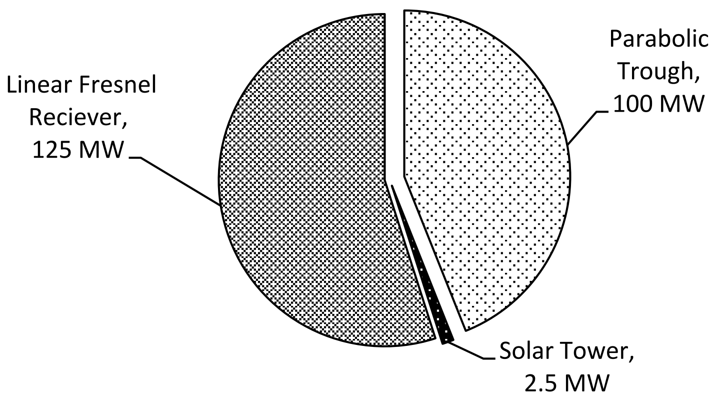

Figure 2.9: Technology-Wise Breakdown of Utility-Scale CSP Installed Capacity (in MW)

[11] A 0.6 MW PT plant has been installed in Ramanathapuram, Tamil Nadu for desalination http://solar.kgisl.com/ (Accessed on 29/05/2014).

[12] The 2.5 MW ST plant is currently not in operation and is in the process of being moved to a different location with a higher Direct Normal Irradiance.

[13] Information obtained from- http://www.nrel.gov/csp/solarpaces/by_technology.cfm

2.4 Wind and Solar Manufacturing Supply Chain in India

The relationship between manufacturers and suppliers has come under stress in the last three to four years because of higher demand variability, larger investment and greater agility to capture value in a rapidly growing sector. Supply chain issues have dictated the delivery capacity, timeline, product strategy and pricing for RE component suppliers. Manufacturers have sought to strike a sustainable and competitive balance between vertical integration of component supply and complete component outsourcing to fit their product design.

Procurement of materials has given rise to a unique market structure for each component, underlining the complexities of wind turbine and solar module design and manufacturing. The critical components in the wind turbine supply have high entry barriers based on the size of investment and require longer time to ramp up. At the same time, a few components such as generators and towers have lower entry barriers with a large number of players in the market.

The entry barriers in the case of solar components are based on the stream of supply chain (at the upstream level barriers are low, while at the lower end barriers are high), production scale and the size of investment. For instance, supply of raw materials has a low barrier, while the production line for float glass requires significant investment. In addition, access to low cost energy is essential (Green Rhino Energy, 2013a).

The wind and solar industry supply chains are mainly composed of developers or IPPs, OEMs, Tier I and Tier II suppliers. The overall supply chain of manufacturers is shown in Table 2.9.

Tier-II Suppliers: Raw material and small component suppliers represent this segment. These suppliers do not produce raw materials or components only for the renewable industry; they have a large industrial consumer base. Wind turbine and solar module manufacturers or Tier-I suppliers are their customer segment.

Tier-I Suppliers: Tier-I companies are direct suppliers to OEMs. Hence, major component manufacturers are Tier-I suppliers. However, a single company may be a Tier-I supplier to one company and a Tier-II supplier to another company or may be a Tier-I supplier for one product and a Tier-II supplier for a different product line. In this study, major components cumulatively contribute more than 90% of the wind turbine cost and these components are manufactured by Tier-I suppliers.

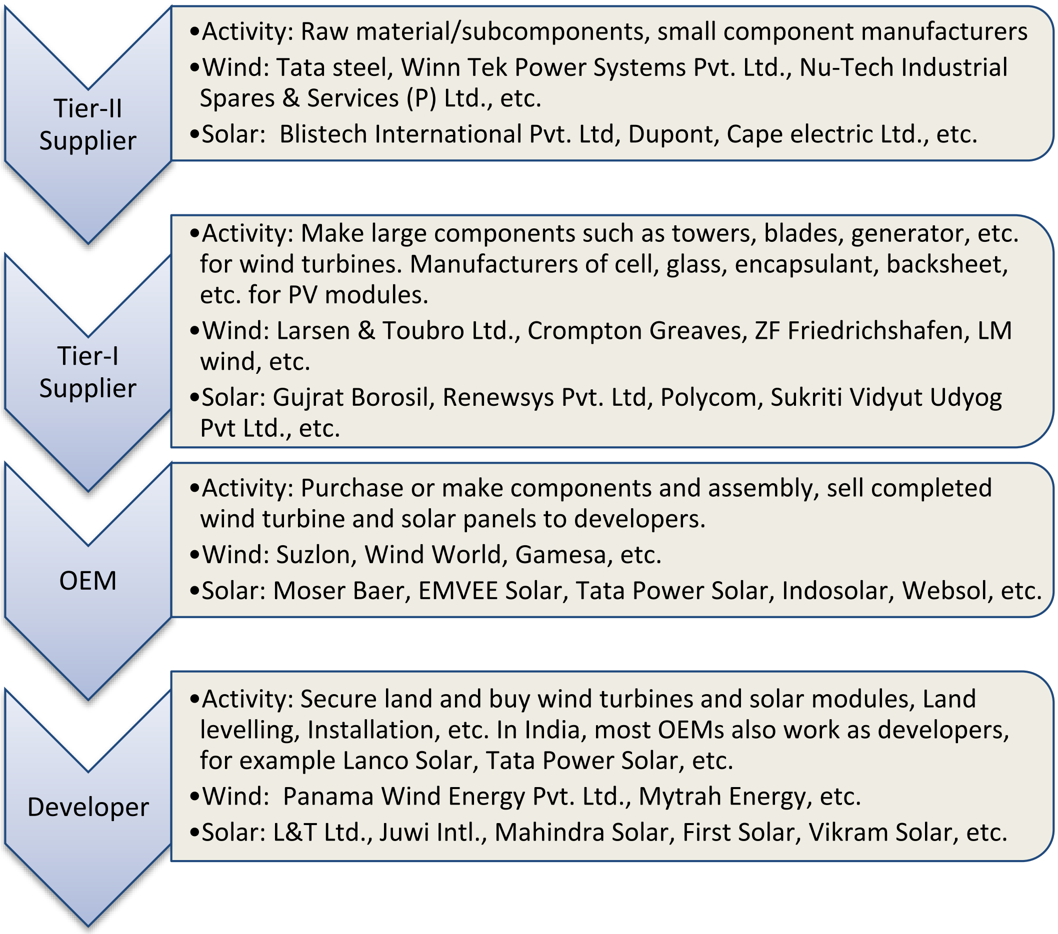

Figure 2.10: Wind and Solar Industry Supply Chain

Original Equipment Manufacturer (OEM): These companies primarily engage in designing the wind turbine and solar modules or CSP components. In case of wind, the companies obtain licenses of wind turbine from foreign WTG manufacturing companies or design their own turbines with assistance from foreign design and manufacturing teams, assemble the turbine/module parts, test and ship the finished WTGs. In India, most OEMs (in wind) provide turnkey solutions whereas in solar this is restricted to a few large manufacturers such as Moser Baer, Tata Power Solar and Vikram Solar.

Developers/IPP's: Wind and solar developers develop and sometimes own and operate RE generation farms. This involves purchasing or leasing land, installing meteorological equipment to quantify the wind and solar resource, securing transmission and power sales and turbine and module supply, construction and financing agreements.

Shift towards project development mode: Most IPPs engage OEMs or independent developers for developing wind and solar farms on a turnkey basis. However, some IPPs have started developing projects on their own. This strategy involves a closer involvement with the project and direct control of project execution, which may prove to be cost effective in the long run.

The subsequent sections examine the wind and solar manufacturing supply chain in greater detail.

2.4.1 Wind OEM Overview

In the Indian wind power industry, the role of OEMs is primarily to assemble major WTG components and not to manufacture all the components and sub-components at their facility. This study is aimed at understanding the contribution of Tier-I suppliers and original equipment manufacturers/assemblers.

As per the latest Revised List of Models and Manufacturers of Wind Turbines (RLMM), dated October 2013, published by the Centre for Wind Energy Technology (CWET), 19 wind turbine manufacturers are present in India. Besides this, at least five new manufacturers have firm plans to enter the Indian market. All together, the total number of WTG manufacturers in India is likely to touch 25 in the next 2 to 3 years. With a few new entrants, the existing annual wind turbine manufacturing capacity is expected to grow from 12 GW to more than 13 GW by FY16.

The annual manufacturing capacity of different manufacturers is shown in Table 2.1. At present, about 34 WTG models of ratings in the range of 225 kW–2500 kW, with more than 50 variants are offered in India. The estimated WTG manufacturing capacity in India is about 12 GW per annum and is likely to increase further with increasing new players like NuPower Technologies and Garuda Vayu. The manufacturing capacity and the product portfolio of various Indian WTG manufacturers are given in Table 2.1. A complete overview of the various offerings by wind turbine manufacturers in India is given in **Annexure 2**.

Table 2.1: Annual WTG Manufacture/Assembly Capacity of the Indian Manufacturer

S. No.	Manufacturer Name	Manufacturing Capacity per annum, MW	Product portfolio, WTG rating, kW
Megawatt scale			
1	Gamesa Wind	1,500	850/2000
2	Global Wind Power	600	750/1500/2500
3	GE India	450	1500/1600
4	Inox Wind	800	2000
5	Kenersys	400	2000/2400/2500
6	Leitwind Shiram	250	1500/1800
7	NuPower Technologies	Not available	2050
8	ReGen Powertech	750	1500
9	RRB Energy	300	500/600/1800
10	Suzlon Energy Ltd	3,700	600/1250/1500/2100
11	Vestas India	1,000	1800/2000
12	WinWinD	1,000	1000
Sub-Megawatt scale			
13	Chiranjeevi Wind Energy	Not available	250
14	Garuda Vaayu Shakti	Not available	700
15	Pioneer Wincon	200	250/750
16	Shriram EPC	Not available	250
17	Siva Wind	15	250
18	Southern Windfarm	Not available	225
19	Wind World (Enercon)	960	800
Total		11,925	

^Information compiled through reports, bulletins, company websites, press news, etc.

Although, India has approximately 12 GW per annum WTG manufacturing and assembly capacity, the relative demand is low, with a maximum of 3.2 GW of capacity installed in the year 2011-12. The capacity of several manufacturers was underutilised following the withdrawal of AD and GBI in 2012-13. The fledgling REC market and non-compliance of RPOs have induced negative investor sentiments. International players like Vestas have scaled down their operations in India recently (Business Line,The Hindu, 2012). Even major Indian manufacturers like Suzlon India went for corporate debt restructuring to the tune of USD 1.8 billion due to a dwindling wind market in

2012-13 (Business Line,The Hindu, 2013b). WinWinD, a Finland-based wind turbine manufacturer with the Siva Group, India as major stakeholder, also filed for bankruptcy in 2013 (Business Standard, 2013). The wind installation and manufacturing capacity utilisation for key players for 2013-14 is given in Table 2.2.

Table 2.2: Wind Installations in 2013-14 and Manufacturing Capacity Utilisation

Manufacturer	Installations in 2013-14 (MW)	Utilization[14] of annual manufacturing capacity (%)
Gamesa	395.9	26.4
GE India	198.4	44.0
Inox Wind	150.0	18.7
Regen Powertech	331.5	44.2
Suzlon Energy	403.0	10.8
Wind World (Enercon) India	353.6	36.8
Total	1832.40	Avg: 30.15

The six manufacturers shown in Table 2.2 had around 88% of the market share during 2013-14 and the average capacity utilisation for the manufacturing/wind turbine assembly base was less than a third.

In terms of cumulative wind power installations in India (as of March 2014), Suzlon has a market share of 38% followed by Wind World India (formerly Enercon India) - 22%, Vestas -8%, ReGen Powertech -7%, Gamesa -6%, Inox and GE -2% and Others -12%. These top five manufacturers have been responsible for 81% of the installations in India. Figure 2.11 shows the market share of major Indian wind turbine OEMs.

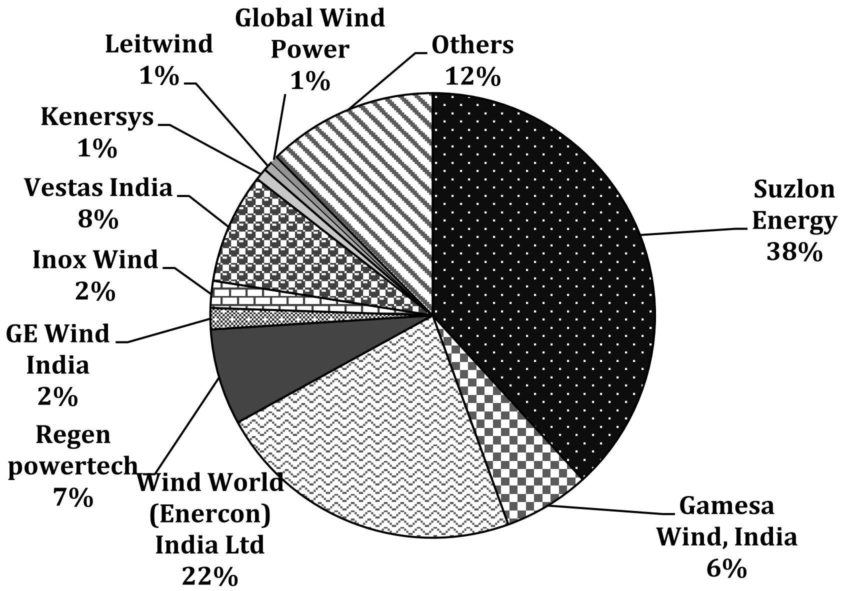

Figure 2.11: Market Share of Wind Turbine Manufacturers, March 2014

In FY13, the market share of major players including Suzlon, Gamesa and Vestas reduced and a positive growth was observed only for GE India (531%) and Inox Wind (408%). In 2012-13, wind witnessed a decrease in installations (1,199 MW), which was much lower than the previous year's figure of 3,196.7 MW (MNRE, 2013a) and (C-WET, 2012). Lower installations were attributed to the removal of AD and GBI.

[14]The capacity utilisation of wind turbine manufacturers has been estimated on the basis of data given in Table 2.1.

It is notable that during 2012-13, six WTG manufacturing units of major corporate groups like Kenersys, WinWinD, Leitwind, Global Wind, Vestas India and the oldest market player RRB Energy, together had a marginal 6% of market share. Their presence in 2011-12 was close to non-existent in the Indian market. In 2013-14, the share of these companies was more than 10% of annual installations.

The year 2013-14 has been a better year for most wind OEMs except Inox Wind, Suzlon and Wind World India, who recorded negative growth in terms of annual capacity additions as compared to the previous financial year.

The wind market has seen a major shift with the emergence of IPPs with a long-term vision, in contrast to earlier investors who sought short-term profits. These IPPs are increasingly involving themselves with the project development process, instead of completely relying on turnkey OEMs. This approach seems to be cost effective in the long run.

The Indian wind market is likely to witness 4-5 new entrants in the coming years. Xyron Technologies, Madhya Pradesh and Patel Steel and Alloys have started providing turnkey solutions. Jyoti Ltd., a Vadodra-based engineering company has also announced plans to venture into this field. Punj Lloyd, an engineering and construction firm wants to widen their product portfolio by entering into the wind business. Siemens India has already launched a wind turbine in the Indian market (Siemens India, 2013) and BHEL has indicated plans to enter the wind segment as well.

One of the strategies followed by wind OEMs is to identify major components and indigenise them (WISE & CSTEP, 2013). For this purpose a few OEMs have their own facilities for manufacturing blades, towers and generators in various parts of India and there are also some foreign players who have set-up their component manufacturing facilities in India. An overview of the major component manufacturers/suppliers in India is given in Table 2.3.

Table 2.3: Tier-I WTG Component Suppliers in the Indian Wind Industry

SI.No.	Component	Tier-I Supplier	Profile
1	Bearing	FAG	▪ Origin- Germany ▪ Clients- Suzlon, ReGen Powertech, Wind World, Kenersys, Leitwind ▪ Product- Rotor shaft and gearbox bearings ▪ Location- Savli, near Vadodra, Gujarat
		SKF	▪ Origin- Sweden ▪ Clients- Suzlon, Kenersys and others ▪ Product- Bearings for rotor shaft, pitch and yaw, gearbox and generators ▪ Location- Pune, Bangalore, Ahmedabad
		NTN	▪ Origin- Japan ▪ Clients- Kenersys, others ▪ Product- Bearings for rotor shaft, gearbox and generator ▪ Location- Chennai and Haryana
		Timken	▪ Origin- USA ▪ Clients- Wind World, others ▪ Product- Bearings for rotor shaft sand gearboxes ▪ Location - Chennai and Jamshedpur
2	Blade	Gamesa	▪ Origin- Spain ▪ Production Capacity- 200 MW/annum ▪ Location- Vadodra, Gujarat ▪ Miscellaneous- Uses pre-preg technology, rather than the commonly used infusion technology

SI.No.	Component	Tier-I Supplier	Profile
		Inox Wind	▪ Origin- Mumbai, India ▪ Production Capacity- 700MW/annum ▪ Location- Ahmedabad, Gujarat
		Kemrock	▪ Origin- Vadodara, Gujarat ▪ Production Capacity-Not Available ▪ Location- Vadodara, Gujarat ▪ Miscellaneous- Largest manufacturer of thermosetting resins in India and first manufacturer of carbon fibre in India
		Leitner Shriram	▪ Origin- Chennai, India ▪ Production Capacity- 375 MW/annum ▪ Location- Gummidipundi, Tamil Nadu
		LM Wind	▪ Origin-Denmark ▪ Clients- Regen Powertech, Gamesa, Kenersys, Others ▪ Production Capacity- 1850-1950 MW/ annum ▪ Location- Dabaspet near Bangalore and Rajasthan ▪ Miscellaneous- Largest blade manufacturer in the world with about 25% global market share
		RRB Energy	▪ Origin- Chennai ▪ Production Capacity-700MW/annum ▪ Location- Poonamallee, Chennai
		Nu Power	▪ Origin- Mumbai, India ▪ Production Capacity- Not Available ▪ Location- Bhuj, Gujarat
		Suzlon	▪ Origin- Pune, Maharashtra ▪ Production Capacity- 4,324 MW/annum ▪ Location- Pondicherry, Daman, Padubidri (Karnataka), Dhule (Maharashtra) and Bhuj (Gujarat)
		Wind World	▪ Origin- Enercon GmbH (Germany) ▪ Production Capacity- 10 blades a day or approximately 1,216 MW/annum ▪ Location- Daman
3	Forging and casting	Bharat Forge	▪ Origin - Pune, India ▪ Clients - Wind World, Kenersys ▪ Product – Open die forging ▪ Production Capacity - 3 lakh tonnes per annum (not limited to wind segment only) ▪ Location - Pune
		L&T (Forging)	▪ Origin- Mumbai, India ▪ Clients – Wind World, Gamesa ▪ Production Capacity - 40,000 tonnes per annum (not limited to wind segment) ▪ Location - Surat, Gujarat
		L&T (Casting)	▪ Origin- Mumbai, India ▪ Clients – Wind World, Gamesa ▪ Production Capacity – 30,000 tonnes per annum ▪ Location - Coimbatore, Tamil Nadu ▪ Miscellaneous- Can cast up to 25 tonnes of single piece for wind generators
		SE Forge (Casting)	▪ Origin- 100% subsidiary of Suzlon Energy Ltd, Pune ▪ Clients – Suzlon Wind Energy, Ltd ▪ Product - Hub, Main Frame, Planet Carrier, Torque Arm, Housing ▪ Production Capacity – 1,20,000 tonnes per annum ▪ Location - Coimbatore, India ▪ Miscellaneous- Can cast up to 25 tonnes of single piece for wind generators

SI.No.	Component	Tier-I Supplier	Profile
		SE Forge (Forging and Machining)	▪ Origin- 100% subsidiary of Suzlon Energy Ltd, Pune ▪ Clients – Suzlon Wind Energy Ltd ▪ Product –Tower Flanges ,Bearing Rings , Gear rings and Blanks , Other Rings ▪ Production Capacity – 42,000 forged rings per annum ▪ Location - Vadodara, Gujarat
		Premier	▪ Origin- Mumbai, India ▪ Clients – Wind World, Regen Powertech, Kenersys ▪ Product – Casting and forging parts for stator ring, stator carrier, disc rotor, generator, supporting structure, brake disc, rotor hub, main carrier, axle pin, blade adaptor, hub and main frames. ▪ Location - Pune
		Patel Alloy	▪ Origin- Ahmedabad,India ▪ Clients – Suzlon,Vestas,Regen Powertech ▪ Product – Casting for manufacturing hub, main frame, shaft, base frame, main bearing housing, nacelle components ▪ Production Capacity – 40,000 tonnes/annum ▪ Location - ▪ Miscellaneous-
4	Gearbox	Winergy	▪ Origin- Germany ▪ Clients – Major players including Suzlon, Gamesa, Kenersys ▪ Location - Chennai
		ZF Wind Power Antwerpen	▪ Origin- Germany ▪ Clients – Major players including Suzlon, Gamesa, Kenersys ▪ Location - Coimbatore, India
5	Generator	ABB India	▪ Origin- Switzerland ▪ Clients – Gamesa, Inox and others ▪ Product - Doubly fed and convertor type, also manufactures Permanent Magnet Synchronous Generator (PMSG) ▪ Production Capacity – 2,400 MW per annum ▪ Location - Vadodara, Gujarat ▪ Miscellaneous- Major generator supplier in India to wind industry and otherwise
		Leitner Shriram	▪ Origin- Chennai, India ▪ Product - Asynchronous generators ▪ Location - Gummudipundi near Chennai
		Regen Powertech	▪ Origin- Chennai , India ▪ Product – PMSG Generators ▪ Location - Mamandur near Chennai
		Suzlon	▪ Product - SFIG and DFIG ▪ Production Capacity – 5,000 MW per annum ▪ Location - Coimbatore (Tamil Nadu) and Chakan (Maharashtra)
		The Switch	▪ Origin- Finland ▪ Product - PMSG ▪ Location - Chennai, India
		WindWorld	▪ Product - Annular generators suitable for direct drives ▪ Production Capacity – 1,075 MW per annum ▪ Location - Daman
6	Tower	Gestamp	▪ Origin- Spain/Bangalore ▪ Location - Sricity(Andhra Pradesh), ▪ Kolhapur (Maharashtra)
		Global Wind Power	▪ Origin- Mumbai/Hong Kong ▪ Product - WTG assembly as well as tower manufacturing

SI.No.	Component	Tier-I Supplier	Profile
			▪ Production Capacity – 600MW per annum ▪ Location - Silvassa, India
		Inox Wind	▪ Product - Towers of 68 meters, 78 meters and 98 meters in height ▪ Production Capacity – 150 towers per annum ▪ Location - Ahmedabad ▪ Miscellaneous-
		Premier	▪ Clients – Wind World, Regen Powertech, Kenersys ▪ Product – Tubular tower ▪ Location - Pune
		Suzlon	▪ Product - Tubular tower, lattice tower, hybrid towers ▪ Production Capacity – 1,000 MW per annum ▪ Location - Gandhidham, Gujarat
		Tool Fab	▪ Origin- Trichy, India ▪ Clients – Suzlon, Regen Powertech, Leitwind Shriram, Gamesa and Wind World ▪ Product - Lattice, hexagonal, tubular towers ▪ Miscellaneous - Tool Fab has over 2 decades of experience in tower manufacturing
		Windar	▪ Origin- Spain ▪ Clients – Suzlon, Gamesa and other major players ▪ Product – Tubular towers ▪ Production Capacity – 900 MW/annum ▪ Location - Vadodara, Gujarat
		WindWorld	▪ Product - Tubular towers ▪ Location - Jamnagar, Gujarat

Note: Data has been compiled from multiple sources such as websites, reports, questionnaires and industry interactions

2.4.2 Cost /Price of WTG Components

The typical cost breakup for WTG components is given in Table 2.4. The total cost of a wind project comes to around INR 7 crore per MW.

Table 2.4: Cost Share of WTG Components per MW (CRISIL, 2013)

Component	Total cost in INR crore per MW	Percentage of total cost
Tower	1.05	15%
Blades	0.85	12%
Hub	0.05	1%
Bearings	0.05	1%
Main shaft	0.08	1%
Main frame	0.12	2%
Gearbox	0.57	8%
Generator	0.15	2%
Yaw system	0.06	1%
Pitch system	0.12	2%
Power convertor	0.22	3%
Transformer	0.16	2%
Brake system	0.06	1%
Nacelle housing	0.06	1%
Cables	0.04	1%

Component	Total cost in INR crore per MW	Percentage of total cost
Screws	0.05	1%
Others	0.47	7%
Grid connection	0.76	11%
Planning & miscellaneous	0.63	9%
Foundation	1.11	16%
IDC (Interest During Construction)	0.37	5%
Total Project Cost	7.03	100%

2.4.3 Import and Export Status of the Indian Wind Industry

A report titled *New renewable energy in India: Harnessing the potential* (EXIM Bank of India , 2011) states that 50-80% indigenisation has already been achieved and a few manufacturers have started manufacturing wind electric generators without any foreign collaboration. In relation to wind-related equipment, wind electric generators (HS code: 850231) are the most commonly exported product from India. The import/export figures for the last five years (2008-09 to 2012-13) have been plotted in Figure 2.12.

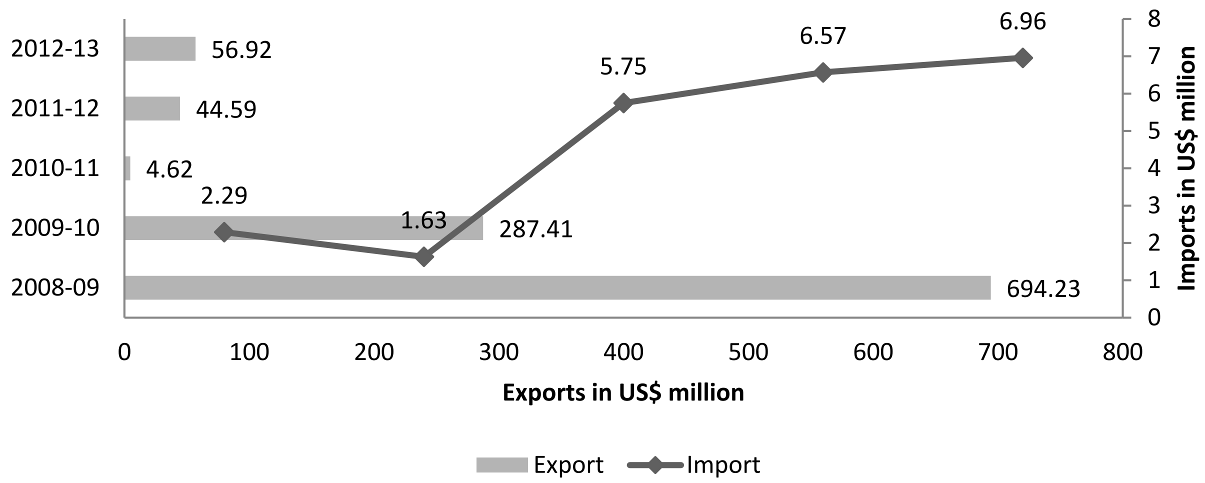

Figure 2.12: Import/Export Figures for Wind-Powered Generation Sets (Department of Commerce, 2013a)

Although the last three years (2010-11 to 2012-13) show a considerable increase in imports and decline in exports, the figures for exports vastly exceed those of imports. Clearly, there stands a good opportunity for India to become an export hub in the field of wind turbine manufacturing.

Country-wise, wind turbine exports from India are shown in Table 2.5. The countries shown are the top seven countries to which India has exported its wind turbines in the last five years. The US is the major importer of WTG sets from India, followed by Australia and Brazil (Department of Commerce, 2013a).

Table 2.5: Country-Wise Export of Wind Turbines from India, 2008-13

Country	WTG Export (in USD, millions)	Share (%)
Australia	159.37	16
Brazil	179.18	18

Spain	59.81	6
Sri Lanka	47.22	5
USA	487.15	49
Italy	16.17	2
Turkey	35.33	4

India is a major petroleum and energy importer; a significant contribution to our balance of payments deficit comes from petroleum and energy imports. India has a large manufacturing base of WTG and standard of production accepted by various countries. Promoting wind energy manufacturing can not only fulfil our energy needs but also reduce our fiscal deficit.

2.4.4 Solar OEM Overview

NSM has a target of enhancing the domestic solar manufacturing capacity to 4-5 GW by 2017 (MNRE, 2012a). As of March 2015, India had approximately 1,386 MW of cell manufacturing capacity and 2,756 MW of module manufacturing capability (Energetica, 2014) (MNRE, 2014d). Figure 2.13 highlights the growth of cell and module manufacturing in India, which has grown at a CAGR of 63% and 66% respectively. Though the growth rates appear healthy, but it still falls far short of the targets set by MNRE.

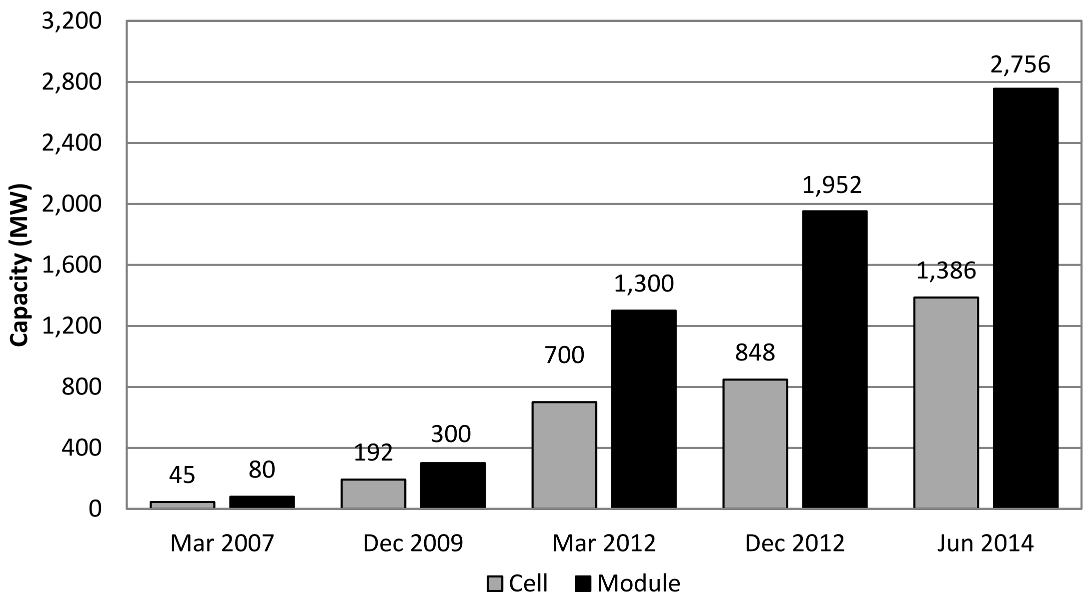

Figure 2.13: Installed Capacity of PV Cell and Module in India (MNRE, 2014d)

Globally, over the last few years there has been a glut of PV cell and module supply as against the demand (EPIA, 2013)[15]. Estimates of 2012 global module production capacity ranged from below 60 GW to above 70 GW, with production from China alone exceeding the global module production of 35.5 GW (REN21, 2013). Global PV production in 2013 reached 39.8 GW, including all major technologies; with the share of c-Si being 90% (Mehta, 2014).This was 3% more than 2012's figure of 38.8 GW. PV installation is expected to reach 38-62 GW by 2017 under the low and high demand scenarios (EPIA, 2014). In 2012, more than 20 solar manufacturers in the US and approximately 10 European and over 50 Chinese manufacturers have left the industry (REN21, 2013). In addition, a

[15] The PV industry showed a turn-around in 2013. The manufacturers focused on profitability as opposed to revenue or growth in shipment. The top producers Yingli Solar and Trina Solar operated at close to 100% utilisation (Mehta, 2014).

few Tier-I manufacturers operated at lower capacity utilisation or consolidated (REN21, 2013)(Ma, Feinstein, Jun Li, & Hartshorn, 2013).

This allowed cheap imports of cells and modules to India from China. In the Indian market, five out of the top 10 suppliers are Chinese. First Solar, a US-based organisation, has the largest market share of 22%. In addition, 82% of the total installations in India used imported cells and modules in 2013 (Khurana, 2013). Figure 2.14 highlights the quantity of cells and modules imported to India between 2010 and March 2013. A comparison of the number of cells and modules imported and the total PV commissioned shows low capacity utilization of indigenous production lines. Figure 2.15 highlights imports against the total PV commissioned in 2010-13(Prabhu, 2013)(PV Magazine, 2013e). Despite DCR[16], the capacity utilisation of domestic PV module production is in the range of 15-20% (PV Magazine, 2013e)(Subramaniam, 2013). It is even lower for cell production. Another estimate claimed that 90% of Indian manufacturing had either closed down or filed for debt restructuring (REN21, 2013).

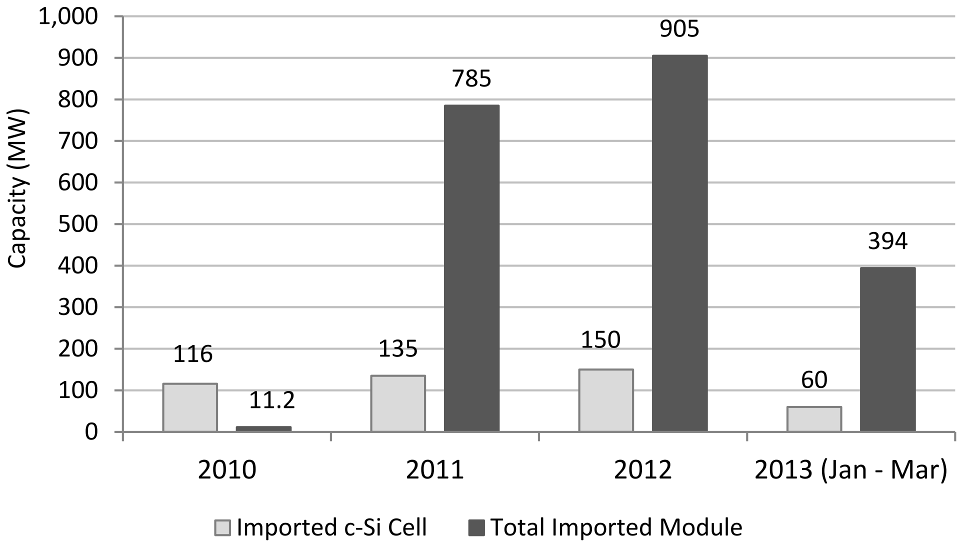

Figure 2.14: Import of Solar Cells and Modules in India, 2010-13 (PV Magazine, 2013e)

[16] NSM Phase I had a DCR stipulation extending two batches. In Batch 1, 100% of the modules for c-Si technology had to be procured from Indian manufacturers. In Batch 2, both, 100% of the cells and modules for c-Si technology had to be sourced domestically (CEEW & NRDC, 2012).

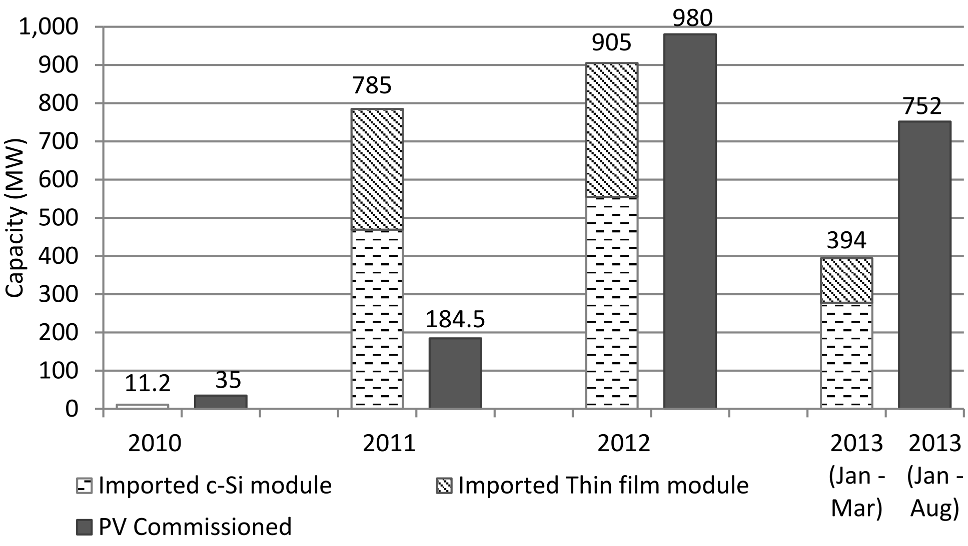

Figure 2.15: Import vs. Total PV Commissioned in India, 2010-2013

2.4.5 Solar PV

PV manufacturing in India mainly involves manufacturing cells, assembling modules and assembling or manufacturing some of the Balance of Modules (BOM) that go into manufacturing the module such as low Iron glass, encapsulant, backsheet, etc. Thus, the activities are mainly downstream. India doesn't have a polysilicon, wafer or ingot manufacturing facility [17](ESMAP/World Bank, 2013).

Across the globe, the manufacture of upstream products is dominated by a few players. Ninety percent of the total polysilicon feedstock is produced by seven companies, whereas only five companies produce 90% of the total ingot consumed by the c-Si PV industry (ESMAP/World Bank, 2013).

OEMs and Tier-1 suppliers play a major role in the manufacture of solar PV technology. Among major players, India has 48 OEMs (module manufacturers) and 31Tier-I suppliers (i.e., 15 major cell manufacturers and 16 BOM component manufacturers). The annual manufacturing capacity of the 48 OEMs of PV module stood at 2,756 MW and that of the 15 Tier-I suppliers at 1,386 MW of cells (Energetica, 2014). Figure 2.16 gives an overview of the share of OEM in module manufacturing in India.

[17] Technically, 15 MW of ingot and wafer manufacturing capacity exists, but, this was primarily for R&D purposes, serving as a testing unit (ESMAP/World Bank, 2013). This is currently not in operation.

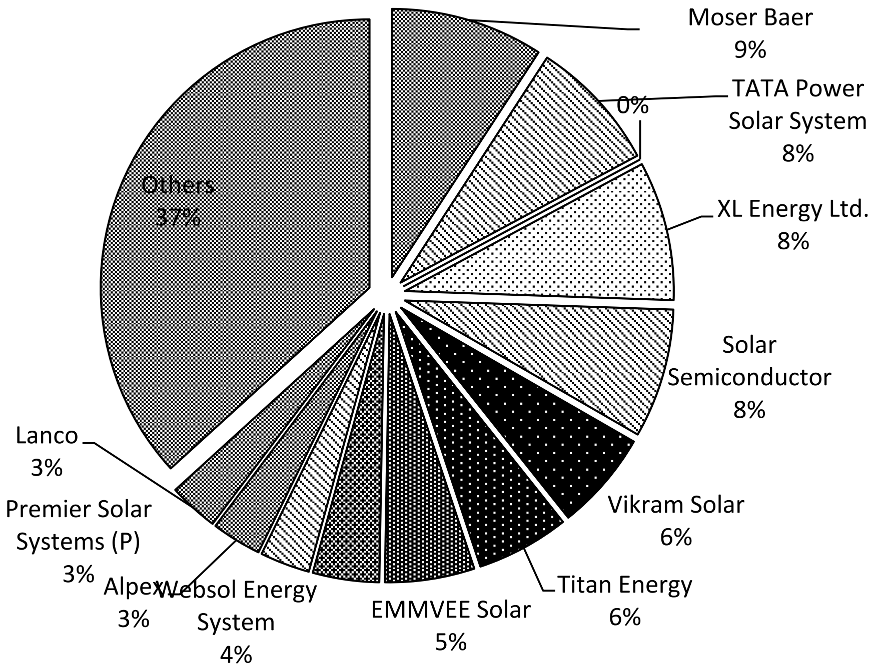

Figure 2.16: Share of OEM in Module Manufacturing in India, Total = 2,756MW (Energetica, 2014)

The increase in manufacturing capacity was triggered by NSM. Despite this, projects with a cumulative capacity of around 800 MW were either kept on hold or abandoned in the absence of demand from the market (CSE, 2012). Moser Baer, a major module manufacturer, with 9% of the total module manufacturing capacity in India is operating at a low capacity utilisation and has gone into corporate debt restructuring (CDR) (Johnson, 2013). Barring Vikram Solar and Tata Solar, major OEMs engaged in manufacturing modules in India are operating at low capacity utilisation (Khurana, 2013).

Amongst the Tier-1 suppliers engaged in cell manufacturing, the situation is no different. The influx of imported cells at lower prices from countries like China, the USA, Taiwan, etc. has adversely affected cell manufacturers in India. The Solar Manufacturer's Association of India lead by IndoSolar, Jupiter Solar and Websol Energy filed an application with the Director General of Anti-dumping and Allied Duties (DGAD), GoI requesting that an anti-dumping investigation be initiated and anti-dumping duties be levied due to the alleged dumping of solar cells from Malaysia, China, Taiwan and the US (DGAD, 2012). On finding prima facie evidence, the authority began investigations in November 2012. In September 2014, the Finance Ministry of India decided against notifying anti-dumping duties on solar modules imported from these four countries (The Hindu, 2014).

In India, Indosolar (33%) leads the Tier-I suppliers in the total installed cell manufacturing capacity. Both, Websol (9%) and Indosolar have approached their lenders to restructure their debts (EFY Times.com, 2013)(Indosolar, 2012). This is the second instance when Indosolar is approaching its bankers for Corporate Debt Restructuring (CDR)(Indosolar, 2013). Figure 2.17 shows the market share of Tier-I suppliers in India (Energetica, 2014).

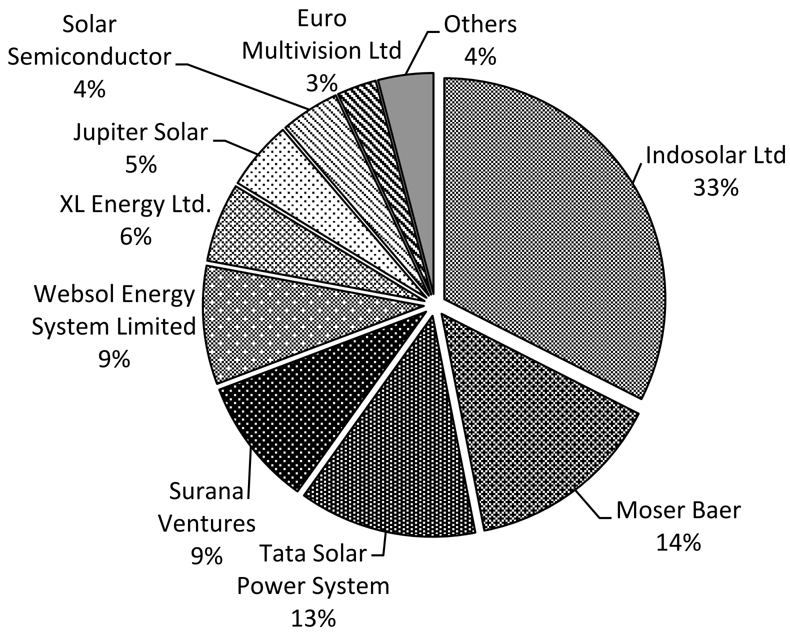

Figure 2.17: Share of Tier-I Cell Suppliers in India, Total = 1,386MW [18](Energetica, 2014)

Glass, encapsulant, ribbon, backsheet, junction box and frame are other major BOM that go into manufacturing PV modules. Table 2.6 provides a list of major Tier-I suppliers of these products along with their production capacity in India. Despite this, a bulk of the components for manufacturing a PV module in India is imported (FICCI, 2012). This comprises of gases, Silver paste, Ethylene Vinyl Acetate (EVA), etc. (ESMAP/World Bank, 2013).

Indian module and cell manufacturers are subjected to the vagaries of currency fluctuation. A study by World Bank points out that the domestic solar PV manufacturing industry in India operates at an average capacity utilisation of less than 50% (ESMAP/World Bank, 2013). Provision of support for the development of a solar ecosystem, akin to the cluster development initiative promoted by Germany, would be useful in reducing many supply chain challenges (Grau, Huo, & Neuhoff, 2011).

Table 2.6: List of Tier-I Suppliers of Major BOM Components in India

Material	Suppliers	Annual Capacity	Unit	Quantity in MW
Junction Box	Volex	7,20,000	Nos.	169
	Yukita	28,80,000	Nos.	678
Encapsulant	Lucent	1,00,00,000	m^2	711
	Renewsys	80,00,000	m^2	500
	Brij Footcare	12,00,000	m^2	80
	Allied	50,00,000	m^2	355
Backsheet	Polycom	7500000	m^2	1,000
	Renewsys	11250000	m^2	1,500
Glass	Borosil	4200000	m^2	600
	Allied	4,80,000	m^2	69
Ribbon	G and G	165	tonnes	200
	Sukriti	120	tonnes	150
Frame	Alom	2400	tonnes	2,000
	Valco	1600	tonnes	1,200
	Hindalco /Century	6250	tonnes	5,000

[18]Information compiled from reports, bulletins, company websites, press news, etc.

Material	Suppliers	Annual Capacity	Unit	Quantity in MW
	Banco	2000	tonnes	1,600

Of the 2.63 GW of total solar PV installations commissioned as of March 2014 only 18% utilised modules from domestic manufacturers (Bridge to India, 2014).Tata Power Solar (6%) is the only Indian manufacturer among the top 10 OEMs whose modules have been used by developers in India (Khurana, 2013). Vikram Solar, Moser Baer and Waaree Energies (2%) are the other major Indian module manufacturers that feature in the list. Majority of the modules are either supplied by the Chinese or First Solar, an American company. Figure 2.18 highlights the share of OEMs in Indian installations.

To meet the NSM objective of having an indigenous annual manufacturing capacity of 4-5 GW, India needs to first identify which component(s) of the supply chain it would want to be the global manufacturing leader. This should be based on existing domestic strength, global demand/supply market, competition and availability or capability to earmark and spend funds (ESMAP/World Bank, 2013). Subsequent chapters on critical component and 'Make or Buy' assist in this process.

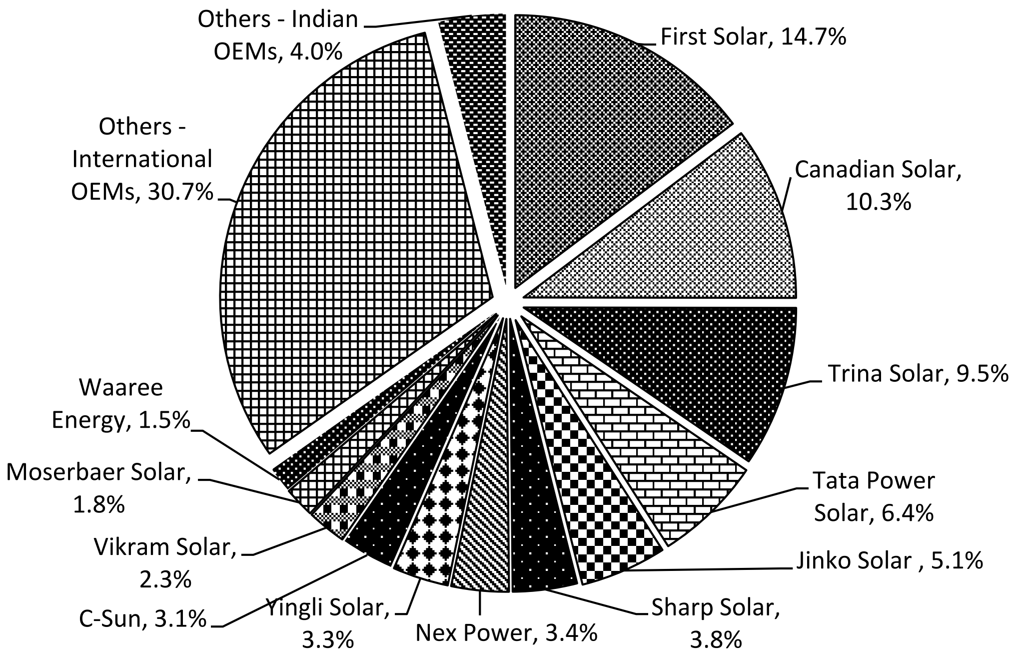

Figure 2.18: Share of OEMs in Indian PV Installations (Bridge to India, 2014)

Cost/Price of Components

Polysilicon makes up approximately one-third of the total cost of a solar PV cell. A sharp decline in polysilicon prices, which came down from USD 80/kg in late March 2011 to less than USD 30/kg in December 2011 can be attributed to the huge investments in the polysilicon industry over the last five years (Prior & Campbell, 2012). This is one of the major reasons for the decrease in the prices of solar PV modules (ESMAP/World Bank, 2013). The Average Selling Price (ASP) of polysilicon in 2014 stood at USD 22/kg (GCL-Poly Energy Holdings Ltd., 2015).

The total cost of a c-Si module with a mix of imported and domestic components produced in India is INR 42/Wp, of which bulk of the cost can be attributed to cells. The costs of manufacturing are comparable with Chinese and US-manufactured modules. The significant difference lies in the cost of cells obtained in India; this corresponds to the cost of importing a cell[19]. Table 2.7 provides a summary of costs associated with manufacturing a c-Si PV module in India, China and the US.

Table 2.7: Cost of Manufacturing PV Module in India, China and the US (USD 1 = INR 56)

	Indian Costs~ (INR/Wp)	**Chinese Costs (INR/Wp)**	**US Costs (INR/Wp)**	**Indian Indigenous Manufactured Price* (INR/Wp)**
c-Si Cell	23.56^	11.50	12.02	--
Glass	2.03	2.81	3.75	
Interconnect Ribbon	1.09^	0.05	1.37	--
EVA Encapsulant	1.26^	2.73	2.73	1.37 – 1.64
Backsheet	1.71^	1.56	1.56	2.05 – 2.74
Al Frame	2.08	2.91	3.50	
Sealant	0.07	0.00	0.11	
Junction Box	1.46	0.98	0.98	
O&M#	5	4.58	8.64	
Others@	3.74	3.66	6.47	
Total	**42**	**30.78**	**41.12**	

~ As obtained from Indian manufacturer
* Price as quoted by Indian manufacturer
^ Imported price (from China, Taiwan or Malaysia)
# Indian – Cost of Direct Labour, Overhead Labour and Maintenance
Chinese and US – Cost of Direct Labour, Energy, Maintenance and Overhead Labour
@ Indian – Packaging, Energy, Depreciation and Margin
Chinese and US – Depreciation (Equipment and Building)

Overview of Components in a PV System

Land, module, inverter, electrical Balance of System (BoS), other BoS, site preparation and permits, system design and management are the major components of a utility-connected PV system. A study by CEEW-NRDC had found that BoS and installation comprise 70% of the PV value chain. The study also points that 60-80% jobs are created in design, installation and sales whereas the rest is created in the manufacturing sector (CEEW & NRDC, 2012).

The cost of a c-Si based utility-scale PV system is INR 7.0-7.5 crore/MW[20]. In both c-Si and thin film technologies, the module, inverter and site preparation and permits comprise 73% of the total cost of the system. The total cost of the system for c-Si and the benchmark capital costs of a PV system, as mentioned by industry and CERC (CERC, 2014) are depicted in Table 2.8.

Table 2.8: Cost of a PV System

Technology	**c-Si PV System (INR crore/MW)**	**CERC (INR crore/MW)**
Land	0.2-0.67	0.25
Modules	3.66-5.03	3.66
Inverter	0.5- 0.85	0.50
Transformer & DC cable	0.55-1.1	0.60
Mounting Structure	0.5 - 1.15	0.50
Civil & General Works	0.2 - 1.15	0.60

[19]We were not able to obtain the cost of c-Si cell manufactured in India.
[20]This applies to a 5 MW c-Si based system.

Preliminary & Pre-operative expenses	0.5 - 0.75	0.69
Degradation	0.33 - 0.71	0.11
Total Cost	7.06 - 12.08	6.91

2.4.6 CSP

In the case of CSP, 946 MW was added globally in 2013 (Helios CSP, 2014) out of which the US added the bulk (410 MW). Abengoa, a Spanish manufacturer and developer is one of the top manufacturing companies, followed by Schott Solar. In 2013, Spanish companies had ownership interests in approximately 60% or more of the capacity under development across the globe (REN21, 2013).

In India, CSP is in a nascent stage with approximately 227.5 MW installed to date. Around 270 MW of the total 470 MW plants that were bid in Phase I Batch I of JNNSM are under various stages of construction – the rest have been commissioned (CSP World Map, 2015)(Godawari Green Energy, 2013) or have entered the pre-commissioned stage (Business Line,The Hindu, 2013a). Only one plant (20 MW) by Aurum Renewable Energy 'hasn't made any progress' (Pearson, 2012). Majority of the projects are based on PT technology; only the plant by Reliance Power (125 MW) engages Compact Linear Fresnel Receiver technology (NREL, 2015).

The following sections provide a detailed overview of the different OEM and Tier-I suppliers in both types of CSP technologies in India.

2.4.6.1 Parabolic Trough

Under JNNSM Phase I Batch I, projects by Lanco, Abhijeet, KVK Energy, Megha engineering works and the Hira Group accounting for 350 MW are/plan on engaging PT technology. Of these, only Godawari Solar Project (50 MW) by Hira Group and Megha Solar Plant (50 MW) by Megha Engineering and Infrastructure have been commissioned (NREL, 2015). In addition, a 0.6 MW PT plant has been installed by IIT Bombay at the National Institute of Solar Energy campus in Gurgaon (NREL, 2013d). Further, Gujarat Solar One project by Cargo Power & Infrastructure Limited (under Gujarat Solar Policy) and projects by Lanco as well as KVK Energy Ventures have been designed to include thermal storage technology.

Solar field, thermal storage and power block are the major components of a PT system. A solar field comprises of a receiver, mirrors, support structure, HTF and solar trackers. Heat exchangers, a steam turbine, generators, pumps, fossil boilers and condensers are the major components of a power block. Molten salt, storage tank, foundation, pump, heat exchanger and heat tracing element are the primary components of thermal storage. Thus, the critical components used in the production of PT are a receiver, mirrors, tracking, HTF, turbine and generator. Tier-1 suppliers of some of the salient components in a PT system are described in the subsequent section.

Receiver

Schott Solar, Huiyin-Group, Archimede Solar Energy and Rio Glass are the major global companies engaged in manufacturing receivers. In India, Schott Solar supplies receivers for operating PT plants (NREL, 2013c).

Mirror

Rio Glass, Saint Gobain, Glasstech, FlabegGmbH, 3M, Asahi Glass Ltd and Thermosol glass are the primary mirror suppliers to the CSP industry. FlabegGmbH and Rio glass have supplied mirror for the ongoing PT installations in India (NREL, 2013c). Flabeg dominates the Indian market with approximately 98.81% market share (NREL, 2013c).

Heat Transfer Fluid

Dow Chemical, Solutia Inc. and Lanxess are the only producers and suppliers of HTF. Dowtherm by Dow Chemical, Therminol by Solutia and Lanxess's Diphyl are the HTFs used in the PT system (Dow, 2014)(Solutia, 2014)(Lanxess, 2013). Dow Chemical has a major market share, followed by Solutia Inc. in the plants that are at various stages of commissioning in India (NREL, 2013c).

Turbine

This is one of the segments where Indian manufacturers have established a competitive base. GE, Siemens, Maxwatt Turbines, Triveni Turbine and Bharat Heavy Electricals Limited (BHEL) are some of the major turbine manufacturers in India. Currently, all the PT plants in India have engaged turbines produced by Siemens (NREL, 2013c)(Singh S. K., 2013).

Generator

This is another segment where Indian manufacturers have established a competitive base. BHEL, Toshiba, JSW Turbine & Generator Private Ltd, ISGEC John Thomson and BK Aalborg are some of the major generator manufacturers in India. Currently, for the operational PT plants in India, Siemens has supplied the generators (NREL, 2013c).

India has a well-developed Tier-1 or OEM for support structure, boilers, condensers, pumps and heat exchangers. Table 2.9 lists the names of Tier-1 suppliers of the PT components. The table only lists a few major suppliers.

Table 2.9: Tier-1 Suppliers of Different Components for PT Technology in India

Mirror	Receiver	Support Structure	HTF
▪ Rioglass Solar ▪ Saint Gobain ▪ Asahi Glass Ltd. ▪ Guardian ▪ Glasstech ▪ Flabeg GmbH ▪ 3M ▪ Thermosol Glass	▪ Schott Solar ▪ Huiyin-Group ▪ Rioglass Solar ▪ Archimede Solar Energy	▪ Shrijee Tower and solar structures ▪ Skyfuel ▪ Jyoti Structures ▪ Aacess Cranes & Equipments ▪ Associated Power Structures ▪ Larsen and Toubro ▪ Sener ▪ Flagsol GmbH ▪ Jindal Steel and Power ▪ IOT Anwesha Engineering & Construction Limited	▪ Dow Chemical ▪ Solutia Inc ▪ Lanxess
Pump	**Tracking**	**Heat Exchangers**	**Turbine**
▪ Flowserve India Controls Pvt Ltd	▪ Bosch Rexroth Ltd ▪ Renen Power	▪ Man Turbo ▪ Thermax India	▪ Triveni Turbines ▪ GE

▪ Sulzer Pumps ▪ KSB India ▪ Grundfos India	Technologies Pvt. Ltd. ▪ Vorks Energy ▪ Parker Hannifin Ltd. ▪ Lorentz	▪ BHEL	▪ Siemens ▪ Maxwatt Turbines ▪ BHEL
Generator	**Condensers**	**Boilers**	**Piping**
▪ BK Aalborg ▪ BHEL ▪ D Solutions ▪ ISGEC John Thomson ▪ Toshiba JSW Turbine & Generator Private Ltd ▪ Holtec International ▪ N S Thermal Energy (P) Ltd.,	▪ P M Industries ▪ Triofab (India) Private Limited	▪ Forbes Marshall ▪ KIP Boilers ▪ Thermax India Ltd. ▪	▪ BHEL ▪ ACS Cobra Group ▪ Ferrostaal GmbH

A typical 50 MW PT system costs INR 9.6-14 crore/MW[21]. The mirrors, receiver, HTF, turbine and generators correspond to approximately 53-60% of the total system cost. Table 2.10 highlights the cost break-up of a 1 MW PT system without storage.

Table 2.10: Component-Wise Cost Segments of a P T System

Components	Cost INR Crore/MW	Percentage share
Mirror	1.06 – 1.24	9 - 11%
Receiver	1.07 – 1.66	11 - 12%
Support structure	1.23 – 2.25	13 - 16%
HTF	0.21 – 0.8	2 - 6%
HTF System	0.82 – 1.3	9%
Trackers	0.07 – 0.16	1%
Swivel Joints	0.11 – 0.25	1 - 2%
Foundations	0.09 – 0.37	1 -3%
Electronics, controls, electrical and solar equipment	0.43 – 0.8	4 -6%
Land	0.21	1 - 2%
Power block	2.4 - 2.68	17 - 28%
Indirect cost	1.62 – 2.7	17 - 19%
Total	9.59 – 14.14	100%

2.4.6.2 Solar Tower

In India, a 2.5 MW ST plant became operational in Bikaner, Rajasthan in 2011. Currently, this plant, commissioned by the ACME Group is not generating any power (Bhushan, Kumarankandath, & Goswami, 2015). Under NSM Phase 1, no developers have proposed to establish an ST plant. But, the technology holds immense potential and about 1,491 MW of global installations are expected in the near future with 471 MW being under-construction, 1,020 MW in the development stage (NREL, 2015).

As in the case of PT technology, the components of ST are mainly categorised under solar field, thermal storage and power block. Solar field comprises of a receiver, heliostat, tower, HTF and pumps. Heat exchangers, steam turbine, generators, pumps, fossil boilers and condensers are the

[21] CERC guideline for solar thermal project is INR 12 crore/MW (CERC, 2014b). The solar thermal developers have estimated the project cost between INR 13-14 crore/MW (ESMAP, 2013).

major components of the power block. Finally, molten salt, storage tank, foundation, pump, heat exchanger and heat tracing are the primary components of the thermal storage. The Heliostat, receiver, HTF and turbine are some of the major components whose Tier-1 manufacturers are mentioned in greater detail in the subsequent sections.

Receiver

Schott Solar, Babcock Power, eSolar, Saint Gobain and Victor Energy are the major receiver manufacturers across the globe. Victor Energy has provided the receiver for the ACME plant in India (NREL, 2013a).

Heliostat

Ausra, Rioglass Solar and eSolar are the major global manufacturers of heliostat. Heliostat basically consists of a reflective surface, a support structure, drive mechanism (tracking), a pedestal, the foundation and a control system. The properties of heliostat mirrors and PT mirrors are same. The main difference between heliostat mirror and PT mirrors are, in heliostats nearly flat mirrors (though some curvature is required to focus the sun's image) are used whereas in PT parabolic curved mirrors are used (ESMAP, 2010). eSolar has supplied the heliostats for the only operational plant in India (NREL, 2013a).

Turbine

The turbines used in PT and ST technology are of similar nature. GE, Siemens, Maxwatt Turbines, Triveni Turbine and BHEL are the major turbine manufacturers in India. Maxwatt turbine has supplied the turbine for the only operational plant in India.

Heat Transfer Fluid

Globally, ST use molten salt or water as the HTF. SQM, Haifa Chemicals and Durferrit are the major suppliers of molten salt (60% Potassium nitrate and 40% Sodium nitrate mixture)(Koning, 2007)) across the globe (hef-Durferrit, 2012)(Haifa, 2013)(SQM, 2013). Molten salt is used as a HTF in ST against synthetic oil because of the higher boiling temperature i.e. approximately 593°C and also higher thermal conductivity and Latent Heat (Padowitz, 2012) (Sandia National Laboratories, 2010). But, in the ACME plant, water is being used as HTF (NREL, 2013a).

Other components used in the ST are similar to the ones engaged in PT viz. piping, heat exchangers, pumps, turbine, generator, condensers and boiler. Table 2.11 provides a list of potential Tier I suppliers of different ST components in India.

Table 2.11: Tier-1 Suppliers of Different Components of ST Technology in India

Heliostat	Receiver	Support Structure
▪ eSolar ▪ Ausra ▪ Rioglass Solar	▪ Victor Energy ▪ Schott Solar ▪ Babcock Power ▪ eSolar ▪ Saint Gobain	▪ Shrijee Tower and Solar Structures ▪ Abengoa ▪ ALTAC ▪ Novatec
Pump	**Heat Exchangers**	**Turbine**

▪ Flowserve India Controls Pvt Ltd ▪ Grundfos ▪ Sulzer Pumps ▪ KSB India	▪ Man Turbo ▪ Thermax India ▪ BHEL	▪ Triveni Turbines ▪ GE ▪ Siemens ▪ Maxwatt Turbines ▪ BHEL
Generator	**Condensers**	**Piping**
▪ BK Aalborg ▪ BHEL ▪ D Solutions ▪ ISGEC John Thomson ▪ Toshiba JSW Turbine & Generator Private Ltd ▪ Holtec International ▪ N S Thermal Energy (P) Ltd.,	▪ P M Industries ▪ Triofab (India) Private Limited	▪ BHEL ▪ ACS Cobra Group ▪ Ferrostaal GmbH
Boilers	**Ball Joints**	**Heat tracing**
▪ Forbes Marshall ▪ KIP Boilers ▪ Thermax India Ltd.	▪ Vardhman Bearings ▪ Ingus Pvt. Ltd. ▪ Carbon Rotofluid Pvt. Ltd.	▪ Lloyd Insulations (India) Pvt. Ltd ▪ Thermon

The cost break up of a 50 MW plant with 15 hours of storage is INR 48.36[22] crore/MW. The Heliostat, receiver, turbine and generator correspond to 59% of the total system cost. Table 2.12 highlights the cost break up of a 50 MW ST system with 15 hours of storage (Fichtner, 2010). A typical ST system is 48% more costly than an equivalent PT system (CSTEP, 2013a)(ESMAP, 2013). But, this could change considering the ease of using a storage system in an ST system, in the foreseeable future.

Table 2.12: Summary of Cost for a ST System (Fichtner, 2010)

Components	Millions of USD[23]/MW	INR Crore/MW	Cost Share (%)
Heliostat Field	3.31	15.13	31
Receiver System	1.72	7.85	16
Tower	0.18	0.8	2
Thermal Energy Storage	0.99	4.51	9
Power Block	1.31	5.98	12
Balance of Plant	0.60	2.74	7
Indirect Cost	2.08	9.52	23
TOTAL	10.57	48.36	100%

2.4.6.3 Thermal Storage

SQM, Haifa Chemicals and Durferrit are the major suppliers of molten salt which is a mixture of 60% Potassium nitrate and 40% Sodium nitrate (Koning, 2007)(hef-Durferrit, 2012)(Haifa, 2013)(SQM, 2013). Globally, 1,343 MW plants have been commissioned which employ thermal storage technology (CSP World, 2013) (NREL, 2013e). As the technology is relatively new[24] a few more years of operation at the field will prove its efficacy.

[22] The study was not able to obtain the costs of ACME plant and hence a 50 MW reference power plant with 15 hrs of thermal storage located in South Africa was used in this study.
[23] 1 USD = INR 45.73
[24] Archimede solar power plant of capacity 5 MW at Priolo Gargallo near Syracuse in Sicily, Italy is the first CSP plant that engaged molten salt storage. It was commissioned in July 2010.

Currently, three plants plan to engage molten salt storage technology - Diwakar Solar Project (100 MW) by Lanco Infratech (under NSM) has 4 hours of storage, Gujarat Solar One (28 MW) by Cargo Power & Infrastructure Limited (under Gujarat Solar Policy) has been designed with 9 hours of storage and KVK Energy Solar Project (100 MW) by KVK Energy Ventures Ltd (Under NSM) has a provision for 4 hours of storage (Hamberg, 2012) (NREL, 2015).

Molten salt, hot and cold storage tank, foundation, heat tracing element, pump and heat exchangers are the major components of a molten salt storage system. Molten salt, storage tank and pump are some of the major components whose Tier -1 manufacturers are mentioned in greater detail in the subsequent sections.

Molten salt

Sociedad Quimica y Minera de Chile SA (SQM), Haifa Chemicals and Durferrit are the three manufacturers of molten salt across the globe (Haifa, 2013)(SQM, 2013)(hef-Durferrit, 2012).

Storage Tank

Bertrams Heatec AG, Halliburton and Caldwell Energy Company are the Tier-1 developers of molten salt storage tank.

Pump

Flowserve India Controls Pvt Ltd, Sulzer Pumps, KSB India and Grundfos India are the Tier-1 molten salt pump manufacturers in India (ESMAP, 2013).
Table 2.13 provides a list of potential Tier-1 suppliers of different molten salt storage system components in India.

Table 2.13: Tier-1 Suppliers of Different Components of Molten Salt Storage System

Molten salt	Storage Tank	Foundation
▪ Sociedad Quimica y Minera de Chile SA (SQM) ▪ Haifa Chemicals ▪ Durferrit	▪ Bertrams Heatec AG ▪ Halliburton ▪ Caldwell Energy Company	▪ Shrijee Tower and Solar Structures ▪ Aacess Cranes & Equipments
Pump	**Heat Exchangers**	**Heat tracing**
▪ Flowserve India Controls Pvt Ltd ▪ Grundfos ▪ Sulzer Pumps ▪ KSB India	▪ Man Turbo ▪ Thermax India ▪ BHEL	▪ Lloyd Insulations (India) Pvt. Ltd ▪ Thermon

The cost of a molten salt storage system for a 25 MW PT plant with 9 hours of storage is INR 3.56 crore/MW[25]. Molten salt, storage tank and pump correspond to 69% of the total system cost. Table 2.14 depicts the component wise break-up of the storage system. A study by IRENA estimates the cost of a 50 MW PT plant with 7.5 hours of storage at INR 3.52 crore/MW (IRENA, 2012c),in which, molten salt (48%), storage tank (17%), pipes and insulation (13%) and civil work (9%) correspond to 87% of the total system costs.

[25] This was obtained from the industry.

Table 2.14: Component-Wise Cost of Molten Salt Storage System

Molten Salt Storage System	INR (crore/MW)	Cost Share (%)
Molten salt	1.72	48%
Storage tanks	0.61	17%
Heat tracing	0.07	2%
Foundation	0.21	6%
Heat exchanger	0.47	13%
Pumps	0.14	4%
Civil work	0.35	10%
TOTAL	3.56	100%

3 RE Manufacturing: Critical Components and Supply Chain Challenges

As has been observed in Chapter 2, each technology has several components. Due to various limitations, this report focuses on a few critical components. This section defines the criteria used to label a component 'critical'. Subsequent sections provide a brief narrative of the process followed to manufacture these components. Finally, challenges (related to material, technology, etc.) experienced in manufacturing components are articulated.

There are several accepted definitions for a 'critical' component. The United States' Food and Drug Administration's code of federal regulations defines a critical component as 'any component of a critical device whose failure to perform can be reasonably expected to cause the failure of a critical device or to affect its safety or effectiveness' (FDA, 2014). The United States Department of Energy (DoE) defines a material critical 'if it serves an essential function in the manufacture of a product – the absence of which would cause economic or social consequences – and if its supply is vulnerable to disruption' (Bauer, 2012). This study is based on DoE's definition.

3.1 Methodology

Component categorisation, cost share, industry expert opinion, and functionality are the four parameters considered for the assessment of components criticality. **The component is considered critical if it meets the established criteria for at least three of the four parameters**. The description of the four parameters is given below:

1. Component categorisation: Components and sub-components have been classified into core, common and custom categories based on their functional significance and use across different industries.
   a) Core: Core components are those that are specifically manufactured for a particular sector
   b) Custom: Custom corresponds to components that were originally designed for a different industry but have been customised for the RE industry
   c) Common: The components categorised under common are manufactured and used by many industries in the same form

Core or custom components are considered to be meeting the criteria.

2. Cost share: For the technologies, i.e., wind and solar CSP, a component's cost share is high if it is more than 10% of the total cost. For solar PV the cost share is high if it's more than 15% of the cost. It is medium if the cost share is in the range of 5-10% and low if the cost share is less than 5%. Table 3.1 depicts the component categorisation based on the cost share of different technologies.

Table 3.1: Cost Share (%) of Different Technologies for Component Categorisation

Technology	High	Medium	Low
Wind	>10	5-10	<5
Solar - PV	>15	5-15	<5
Solar - CSP	>10	5-10	<5
Storage - Molten Salt	>10	5-10	<5

3. Industry inputs: Wind industry experts, OEMs and manufacturers of PV and CSP technologies were asked the following questions[26]:

   Please offer your thoughts on the criticality (Low/Medium/High) of the following components from the perspective of domestic manufacturing.

The components rated by the industry as medium or high were chosen for consideration as being critical.

4. Functionality of components: Through literature survey and stakeholder interactions, the components, which have high functionality within RE technologies, were identified. *The functionality of the component determines its significance in the operation.* Based on the functional significance, the components were rated as high, medium, and low. High denotes that the component is highly critical, while medium indicates it is moderately critical and low signifies very low level of criticality. **The component labelled medium or high are considered for the selection.**

The critical components selection matrix for wind, c-Si PV, a-Si PV, parabolic trough, solar tower, and thermal storage is explained in the subsequent sections

3.1.1 Wind

The different components and sub-components used in wind technology have been analysed and rated as low, medium of high for the different parameters. Table 3.2 provides a comprehensive list of components that have been categorised as low, medium or high for the defined set of parameters.

Table 3.2: Critical Components Selection Matrix for Onshore Wind Technology

Name of Components	Cost Share (% of total cost)	Industry Inputs	Category	Functionality
Rotor Blades	**High**	**High**	**Core**	**High**
Pitch Drive	Low	Low	Customized	Medium
Hub	**Low**	**Medium**	**Core**	**Medium**
Nose cone	Low	Low	Core	Low
Shaft system	**Low**	**Medium**	**Customized**	**Medium**
Gearbox	**High**	**High**	**Customized**	**High**
Bearing	**Low**	**High**	**Customized**	**Medium**
Coupling and dampers	Low	Low	Customized	Low
Generator	**Medium**	**Low**	**Customized**	**High**
Cooling system	Low	Low	Customized	Low
Brake system(Hydraulic)	Low	Low	Customized	Medium
Yaw system	Low	Low	Customized	Medium
Nacelle cover and main frame	Medium	Low	Core	Low
Wind sensor assembly	Low	Low	Customized	Medium
Tower	**High**	**Medium**	**Core**	**High**
Flanges and bolts	Low	Low	Common	Low
Transformer	Medium	Low	Common	Low

[26] A feedback survey was sent to wind and solar (PV and CSP) component and sub-component manufacturers to obtain their perspective on critical components, short and long-term sourcing mix and the priority order of policy incentives. This is described in **Annexure 5.**

The analysis showed that **Rotor Blade, Gearbox, Tower, Generator, Bearings, Rotor Hub,** and **Main Shaft** can be labelled as critical components. These have been analysed further in the subsequent sections.

3.1.2 Solar

c-Si PV

Different components and sub-components of c-Si PV have been analyzed based on the methodology mentioned above. The component, which corresponds to 15% of the total system cost, is defined critical. Accordingly, only cells qualify as a critical component. However, other parameters yield different results. The critical components selection matrix for c-Si is shown in Table 3.3.

Table 3.3: Critical Components Selection Matrix for c-Si PV Module

Components	Cost Share (% of total cost)	Industry Inputs	Category	Functionality
Cell	**High**	**High**	**Core**	**High**
Interconnect Ribbons	Low	Medium	Custom	Medium
Glass	**Low**	**High**	**Custom**	**High**
Encapsulant	**Low**	**Medium**	**Custom**	**High**
Backsheet	**Low**	**Medium**	**Custom**	**High**
Frame	Low	Low	Common	Low
Sealant	Low	Low	Common	Medium
Junction Box	Low	Medium	Common	Medium

Using the methodology mentioned above, **Cell, Glass, Encapsulant,** and **Backsheet** meet the criteria for being critical components of a PV module.

a-Si PV

The various components and sub-components of a-Si thin film PV have been analyzed based on the methodology mentioned in the previous section. According to the 15% cost share criteria, backsheet, and TCO-coated glass are the critical components. From a categorization perspective, TCO-coated glass and silane are core components. The critical components selection matrix comprising the inputs for the different parameters is given in Table 3.4.

Table 3.4: Critical Components Selection Matrix for a-Si Thin film PV

Components	Cost Share (% of total cost)	Industry Inputs	Category	Functionality
TCO-coated Glass	**High**	**Medium**	**Core**	**High**
Silane & Other gases	**Low**	**Medium**	**Core**	**High**
Encapsulant	**Medium**	**Medium**	**Custom**	**High**
Backsheet	**High**	**Medium**	**Custom**	**High**
Junction Box	High	Low	Common	Medium
Back coating	Medium	Medium	Common	Medium
Frame and others	Medium	Low	Common	Low

The analysis shows that **TCO-coated glass**, **Backsheet, Silane** and **Other gases** and **Encapsulant** should be considered as critical components, according to the criteria specifications chosen for this study.

CSP - Parabolic Trough

The various components and sub-components of a PT have been analyzed based on the said methodology. Using the cost share criteria, the receiver, power block and support structure are considered as critical components. Industry inputs show that mirror, receiver, HTF, power block, and trackers as highly critical. Based on the functionality criteria, mirror, receiver, HTF and power block are critical components. The critical components selection matrix for PT for the different parameters is shown in Table 3.5.

Table 3.5: Critical Components Selection Matrix for PT

Components	Cost Share (% of total cost)	Industry Inputs	Category	Functionality
Mirror	**Medium**	**High**	**Core**	**High**
Receiver	**High**	**High**	**Core**	**High**
Heat Transfer Fluid	**Medium**	**High**	**Core**	**High**
Power Block (Turbine + Generator)	**Medium**	**High**	**Customized**	**High**
Heat Transfer Fluid System	Medium	Low	Common	Low
Support Structure	High	Medium	Common	Medium
Foundation	Low	Low	Common	Low
Trackers	Low	Low	Customized	Medium
Electronics, controls, electrical and solar equipment	Low	Low	Common	Low
Swivel Joints	Low	Low	Common	Low
Power Block - Balance of Plant	Medium	Low	Common	Low

From the analysis**, Mirror, Receiver, HTF, and Power Block** (Turbine and Generator) meet the selection criteria and are the critical components.

CSP - Solar Tower

Using the 10% cost share criteria, the heliostat, receiver system and power block are critical elements. From the industry, heliostat, thermal energy storage and power block are the critical components. Heliostat, Receiver, Thermal energy storage and power block have a high functionality. The critical components are tabulated in Table 3.6.

Table 3.6: Critical Components Selection Matrix for ST

Components	Cost Share (% of total cost)	Industry Inputs	Category	Functionality
Heliostat	**High**	**High**	**Core**	**High**
Receiver	**High**	**Medium**	**Core**	**High**
Tower	Low	Medium	Customized	Medium

Thermal Energy Storage[27]	**Medium**	**High**	**Core**	**High**
Power Block (Turbine + Generator)	**High**	**High**	**Customized**	**High**
Balance of Plant	Medium	Low	Common	Low

From the analysis above, **Heliostat, Receiver system, Thermal storage,** and **Power Block (Turbine and Generator)** meet the established criteria and therefore are considered critical. The components of a Power Block (Turbine and Generator) are similar for PT and S T technologies. Currently, molten salt storage is the only thermal storage system, which is commercially in operation.

Thermal Storage

The various components and sub-components of a molten salt storage system have also been analyzed. The cost contribution of molten salt, storage tank, and heat exchanger are beyond the threshold of 10% of the total system cost. When the components were categorized, only molten salt and storage tank were considered core components, whereas pumps had to be customized and this too fits the criteria established. Interactions with the industry yielded in the identification of molten salt and pump as highly critical whereas the tank itself was considered at medium level. The various inputs for the different parameters have been tabulated in Table 3.7.

Table 3.7: Critical Components Selection Matrix for Molten Salt Storage System

Components	Cost Share (% of total cost)	Industry Inputs	Category	Functionality
Molten salt	**High**	**High**	**Core**	**High**
Storage tanks	**High**	**Medium**	**Core**	**Medium**
Heat tracing	Low	Low	Common	Low
Foundation	Medium	Low	Common	Low
Heat exchanger	High	Low	Common	Low
Pumps	**Low**	**High**	**Customized**	**High**
Others	Medium	-	-	-

From the analysis above, **Molten Salt, Storage Tank,** and **Pump** meet the established criteria and are therefore considered critical.

The following sections will provide an overview of critical components. In addition, supply chain related challenges for raw material, manufacturing process, R&D, design and testing and others will be examined. This will be followed by an evaluation of the components from a 'Make or Buy' perspective.

3.2 Overview of Critical Components

An overview of the wind and solar technology critical components is discussed in this section based on five parameters viz. current market position, raw material used in manufacturing, current technology, upcoming technology and manufacturing process. These parameters provide a comprehensive overview of the different critical components. The market position indicates the

[27] The study obtains the information from a plant in South Africa and as this plant has incorporated storage technology, we too have included it in our analysis.

current manufacturing output of the component among various manufacturers. Raw material highlights the source and type of materials used in manufacturing the component. Current and upcoming technology parameters provide a brief understanding of the technology. Finally, manufacturing or assembling process informs the technologies involved in these processes. A component-wise summary of analysis for wind and solar technologies is highlighted in Table 3.8.

3.2.1 Wind

There is a strong local presence of various (if not most) wind component manufacturers in India. Most of the manufacturers are either MNCs or Indian companies having a strong global presence. The tower is one of the only components, which have low barriers to entry, and small and local players can master this technology. Prepreg technology to manufacture blade, gearless technology, and steel cage roller bearing are some of the technological innovations across different components. Table 3.8 summarizes and groups the evaluation of the different critical components of wind technology.

Table 3.8: Overview of Critical Components for Wind Technology

Critical component	Market status	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
Blade	▪ Other than OEM manufacturers, LM wind is the market leader in manufacturing blades in India ▪ Major OEMs produce in-house.	▪ Carbon and glass fiber are the primary types of materials used in manufacturing blades ▪ Adhesives, other fasteners, urethane/foam products are also used. Balsa forms the core of the blade.(Gurit, 2013)	▪ Because of its low cost, glass fiber has a major market share ▪ Infusion technology is the widely used manufacturing process technology in India.	▪ Prepreg (abbreviation for pre impregnation) manufacturing technology could play a vital role in future if it achieves cost competitiveness ▪ Stiff and light blades are required for large turbine sizes (Ashwill, 2003) ▪ Innovations are possible in the area of new raw material or aerodynamic enhancement.	▪ Infusion technology involves drawing a resin into the reinforcing fibres using a vacuum. The vacuum reduces pressure at one end of the fabric stack allowing atmospheric pressure to force the resin through the stack. The fibre is then cured at high temperatures (50°C to 70°C) to solidify (Gurit, 2013) ▪ In prepreg technology, a homogenous mixture of high viscosity resin and fibre are used to manufacture the composite material. Although this makes manufacturing more convenient, it requires extra cold storage facilities to store the raw material. (Gurit, 2013)
Tower	▪ Number of tower manufacturers in India is higher than blade manufacturers ▪ Leading tower manufacturers (OEMs) in India are Suzlon,WindWorld India, Windar, Gestamp, DN Wind	▪ Three types of towers according to the type of raw material are - concrete, steel and hybrid tower ▪ This is the heaviest part of the system.	▪ In the current market, of 34 turbine models with 50+ variants, 6 use lattice, 1 engages both lattice and tubular and the rest employ tubular type tower. Lattice type of	▪ Hybrid design of tower could be a good strategy for cost reduction for tower of larger size.(Iken, 2012) ▪ Self-erecting or partially self-erecting towers could minimize	▪ Steel tower manufacturing process comprises of 9-10 primary steps, beginning with cutting of steel plates to various inspection and testing ▪ According to the type of raw material, tower

Critical component	Market status	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
	systems, Global Wind Power etc. ▪ Approx 80-100% of tower is indigenized currently ▪ Small players are also active in this segment. Local establishments play a significant role.		tower is used only for sub MW turbines (250 KW- 750 KW).	logistics constraints and reduce cost.	manufacturing process differs ▪ Total weight and load of turbine is calculated before determining the thickness and weight of tower.
Gearbox	▪ Not a single wind turbine manufacturer in India has in-house gearbox manufacturing facility ▪ OEMs find it more competitive to outsource it to global players than manufacturing it in-house ▪ Winergy, ZF Wind Power Antwerpen and Kirloskar pneumatics are some of the major gearbox suppliers in India ▪ New entrants are not able to enter this segment because of its capital-intensive nature and the expertise required.	▪ High grade steel and cast iron/ductile iron are the two major raw materials used in gearbox.	▪ Increasing trend in the size of wind turbines has led to very expensive gearboxes ▪ Currently WindWorld, RegenPower and Leitner Shriram have introduced the direct drive or gearless train concept.	▪ The gearless technology in wind turbines improves the pitfalls associated with geared turbines. Gearless technology can be successful if it manages to achieve cost competitiveness ▪ A hybrid technology using mid-sized gearboxes with PMSG generators' resulting in compact drive trains is still at a conceptual stage in India ▪ WinWind was one of the manufacturers who had initiated this hybrid concept ▪ The hybrid technology may have a large impact in the future domestic wind industry.	▪ The forged round bars and round blanks for pinions undergo various steps like hobbing (gear cutting), heat treatment process, etc. to form gears which are mounted on stands and assembled in the housing ▪ The gearboxes are then tested and monitored for several hours before receiving a final coat of paint, after which it is ready to be shipped.
Generator	▪ ABB India, TD Power systems	▪ Copper is required for	▪ Variable speed	▪ High pole generators	▪ Various steps followed are

Critical component	Market status	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
	and Emerson electric are some of the major generator suppliers in India ▪ Number of suppliers could increase as the demand is expected to grow. Innovation and simplification will be the key game changers.	stator and rotor windings ▪ Steel casting is required for generator housing ▪ Bronze and Copper alloys are used for slip rings (in case of WRIG) ▪ The grade of steel required for generator rotor is Heat traceable Cr Ni Mo (V) steel ▪ Alloy of rare earth metals Neodymium (Nd) and Dysprosium (Dy) is required to make magnets for (PMSG).	generators currently govern the market ▪ Double Fed Induction Generator (DFIG) and PMSG are used by Indian turbine manufacturers ▪ The direct drive or gearless drive trains make use of synchronous generators (Electrically Excited Synchronous Generator or PMSG).	along with segmented rotor designs could be employed in future ▪ The decrease in cost and increase in availability of rare earth permanent magnets could significantly affect the cost of future generators.	punching of rotor cores, winding of Copper field coils, building of laminated stator cores, inserting stator coils in skewed stator slots etc. ▪ The major difference between manufacturing induction generator and Permanent Magnet (PM) generator is that in PM generators, magnets form the poles for the rotor while in induction generators the rotor is punched from steel.
Bearings	▪ World market leader SKF, FAG and NTN are the major suppliers of large bearings in India ▪ Apart from these international players various small and local players also supply different types of small bearings to wind manufacturers.	▪ High quality stainless steel and brass are used in manufacturing bearings. The size or working of bearing depends on the application, chemical composition of the lubrication used etc. and such type of steel could vary.(JTEKT, 2008)	▪ As per the increasing size of the wind turbine and industry moving towards gearless technology, the type and dimension of bearing has been changing periodically ▪ For large size turbines tapered roller bearing trends will go upward, often in combination with a cylindrical roller bearing. In gearless and in compact drives	▪ FAG engineers are working on a steel cage roller bearing which would have a 6% higher load rating compared to the conventional cylindrical roller bearing, this means 20% longer life in practice. (Sun & Wind, 2011)	▪ Common steps followed in bearing manufacturing are raw steel forging, machining, semi fine grinding, heat treatment, grinding surface, centre less grinding, race away grinding, washing and rust preventive measures and finally, fine washing and packaging.

Critical component	Market status	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
			the tapered roller bearing has international standard. (Sun & Wind, 2011)		
Hub	▪ Suzlon, Leitner Shriram and Inox wind have their own hub manufacturing facilities. SEFORGE, L&T castings, Premier, Patel alloy etc. are the major suppliers in India. ▪ India lacks large forging and casting facilities.	▪ The primary raw material required to make rotor hubs is cast iron. Cast iron of the grade GJS or ADI (MO alloyed) is preferably used by the manufacturers to produce good quality rotor hubs ▪ Steel is required on a minor scale.	▪ Large castings are available with some players including OEMs that can manufacture up to 25 tonne casts required in wind turbines.	▪ In the future, for larger size rotors hub sizes will increase. There is a need to develop casting facilities to cater to larger hub sizes.	▪ Rotor hub of wind turbine is made of cast Iron ▪ The castings are received primed or are painted before machining ▪ CNC machines are required to automatically carry out various processes ▪ Finally, the product undergoes quality checks and final inspection before it is painted and prepared for shipment.
Main shaft	▪ Currently, all the major manufacturers either procure shafts from Indian suppliers or import from overseas. The major shaft suppliers in India are Bharat Forge and L&T special steels and heavy forgings. There is a wide scope for new entrants in this segment since large forging facilities are limited in India.	▪ The main raw material to make main shaft is high grade steel. The steel used is preferably Heat traceable Cr Mo, GJS or ADI.	▪ Rotor shaft size increases as turbine size increases.	▪ Large scale forging facilities	▪ The main shaft is made of steel forgings. Steel forging undergoes various processes to form a well-furnished shaft of required dimensions.

3.2.2 Solar PV

Solar cell, encapsulant, backsheet, solar glass, and silane gas are the critical components in Solar PV technology. Raw material is a major issue for all critical components except glass and cell. Indium for TCO coating on glass, EVA for encapsulant, Tedlar/Mylar for backsheet and silane for a-Si thin film

PV are completely imported. Though the industry has technological capability to manufacture domestically, lack of large-scale demand makes it economical to import. Currently, India does not have any wafer manufacturing facility. However, there are a couple of fabrication units promoted by the Government of India, which have been put on the backburner due to the global supply glut (livemint, 2013). While companies like Lanco had elaborate plans to establish an integrated PV manufacturing facility (from ingot stage to module) in Chhattisgarh, it is currently in a dormant stage given the prevailing market conditions (Intersolar, 2013). Table 3.9 provides an overview of the different critical components of both c-Si and a-Si technologies.

Table 3.9: Overview of Critical Components of Solar PV Technology

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
Cell	▪ India has cell manufacturing capacity of around 1,386 MW ▪ Moser Baer is the largest manufacturer followed by Tata Power Solar ▪ Imported wafers are used for manufacturing cells ▪ The average capacity utilization for 2011-12 was around 20-30% ▪ Lanco is setting up a fully-integrated manufacturing facility for high-purity polysilicon, Silicon ingots/ wafers and modules in a SEZ facility at Chhattisgarh. The project is the first of its kind in India with 1800 TPA (Tonnes Per Annum) of Polysilicon	▪ Metallurgical grade Silicon (MG-Si) is the raw material required to produce solar cells ▪ The raw materials chiefly silica (obtained from sand) and Silver are not a major source of concern (Moss, Tzimas, Kara, Willis, & Kooroshy, 2011).	▪ Poly-crystalline Silicon wafers are made by wire-sawing block-cast silicon ingots into very thin (180-200 μm) slices or wafers. The wafers are usually lightly p-type doped and a surface diffusion of n-type dopants is performed on the front side of the wafer to make it a solar cell. This forms a p–n junction a few hundred nanometres below the surface.	▪ Crystal Solar's ***Direct Gas to Wafer***™ technology using epitaxial deposition allows for monocrystalline Silicon to be deposited directly from feedstock gas. This eliminates three cost-intensive steps in manufacturing c-Si wafer viz. manufacturing polysilicon, ingot and wafer (Crystal Solar, 2013) ▪ Direct Wafer by 1366 Technologies is a one-step, kerfless wafer-making process that has the potential to revolutionize wafer manufacturing. The semi-continuous, high-throughput process eliminates Silicon waste, resulting in a more powerful, low-cost wafer(1366 Technologies, 2013)	▪ Mono crystalline Silicon cells are made from Silicon wafers i.e. ingot is cut from boules grown by Czochralski Process and Float Zone Technique ▪ The ingot is cut into wafers and doped to form a PV cell.

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
	and 100 MWp of wafer production (Lanco Solar, 2013)				
Glass (used as a front glass in Crystalline PV and as a substrate in Thin film PV)	▪ Gujrat Borosil is the sole 'Low Iron content glass' manufacturer in India with capacity of 600 MW ▪ TCO coated glasses used in Thin film PV are not manufactured in India ▪ Sourcing of the raw materials like low Iron sand, low Iron limestone and low Iron glass cullet is one of the major challenges (Thompson & West, 2013)	▪ Sand, soda ash, limestone, dolomite and alumina are the major raw material required to manufacture low Iron content glass	▪ Patterned glass, a kind of flat glass is used for crystalline PV. ▪ Float glass is used for thin film PV and CSP technologies.	▪ To improve the performance and reduce the cost, a new generation of smart coatings that combine anti-reflective (AR) with self-cleaning properties is being developed ▪ Several independent R&D efforts are using nanotechnology to develop glass coating technologies with multi-functional properties. These can both enhance module output by reducing the amount of light reflected from the glass surface and prevent the glass from getting dirty and dusty ▪ Research groups around the world have been using the 'principal of moths'- compound eyes that do not reflect incoming light, as the basis for developing highly efficient anti-reflective solar glass coatings. (PV Magazine, 2013a) ▪ Similarly for thin film PV, TCO coating at the source is being encouraged ▪ Low cost inexpensive foreign substrate (e.g., glass, ceramic, steel) which can operate at low temperatures are being promoted ▪ Hydro substrate material	▪ Patterned glass, a kind of flat glass is manufactured by calendaring moulds using single and double roller ▪ In a single roller method, liquid glass is poured on to a calendar table made of cast steel or cast iron. To form a pattern, the roller is made to roll on the glass surface after which the embossed glass is sent to the annealing furnace ▪ Twin-roll production of embossed glass manufacturing is divided into two semi-continuous and continuous rolling processes, the liquid glass goes through the water-cooled twin roller, and moves forward with the roll into the annealing furnace ▪ (Dexing Glass, 2013)

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
				consisting of highly conductive rolled Aluminium strip, which is characterized by low surface roughness (Hydro Aluminium Deutschland GmbH, 2013).	
Encapsulant	▪ Renewsys, Lucent, Brij Footcare and Allied Glasses are the primary manufacturers of encapsulant ▪ Total manufacturing capacity is around 1.6 GW ▪ However, Solar grade EVA (ingredient) used for encapsulant is imported.	▪ The raw materials used are the following: EVA, Poly Vinyl Butyral (PVB), Polydimethylsiloxane (PDMS), Ionomer, Thermoplastic Polyurethane (TPU), and Polyolefin (Markets and Markets, 2013).	▪ Earlier PV modules used Polydimethylsiloxane (PDMS). Currently, the most commonly used encapsulation technologies are EVA and Poly Vinyl Butyral (PVB).	▪ Polyolefin encapsulant film: This is an innovative product by Dow Chemicals, which is made up of Polyolefin and is better than EVA based encapsulant (Targray, 2012). This product has various features that differentiate it from other encapsulants i.e. no cross-linking, no acetic acid generation, and longer resistivity to PID etc.	▪ An extrusion process is used to manufacture encapsulants in a sheet form ▪ This is a two-step process. In the first step, EVA resin is mixed with antioxidants, UV absorber and light stabilizer in a Polymer master batch and secondly, it runs through a single-screw extruder with a flat die(Johnson, 2013).
Silane Gas	▪ India does not produce any silane due to high safety requirements and strict regulatory norms from explosives department ▪ Silane used in industries is imported in cylinders.	▪ Magnesium silicide, Hydrogen chloride, and metal halides are used as catalysts.	▪ Earlier hydrolysis of Magnesium silicide was used for production of silane, disilane and trisilane. This method is however abandoned now ▪ Current technology for silane manufacturing is a two-step process using MG- Silicon.	▪ An alternative industrial process for the preparation of very high purity silane, suitable for use in the production of semiconductor grade Silicon, uses MG-Silicon, Hydrogen, and Silicon tetrachloride and involves a complex series of redistribution reactions and distillations.	▪ In the first step, MG-Silicon is reacted with Hydrogen chloride at about 300 °C to produce trichlorosilane, along with Hydrogen gas ▪ The trichlorosilane is then boiled on a resinous bed containing a metal halide catalyst like Aluminium chloride, which promotes the formation of silane.
Backsheet	▪ India has two backsheet manufacturers viz.	▪ Fluoropolymers like traditional Tedlar[28] made	▪ Conventionally, backsheet is a three layer laminate having	▪ Cool Back Backsheet: The backsheet is designed under the	▪ Different layers of backsheets are laminated

[28] Tedlar® is a registered trademark of E. I. DuPont Co.

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
	Renewsys and Polycom with total manufacturing capacity of 2.5GW.	of Poly vinyl fluoride (PVF) and the relatively recent Kynar[29] made of Polyvinylidene Flouride (PVDF) are used ▪ Other materials used are Polyester – Polyethylene terephthalate (PET) and EVA.	either a single layer or a double layer of fluoropolymer or non-fluoropolymer ▪ Tedlar is becoming increasingly difficult to obtain, other options including a single layer of fluoropolymer and non-fluoropolymer designs are being tested (Flexon, 2012) ▪ A non-fluoropolymer backsheet alternative using polyester and EVA is fast gaining acceptance for its adequate performance and greater affordability.	trademark Powershield by Honeywell to help in reducing a module's operating temperature by reflecting un-used solar radiations. Therefore, the panel operates at lower temperature which allows the electrical components to work more effectively and generate more power (Honeywell, 2013) ▪ Biobased Backsheet: These backsheets are made-up of bio based materials i.e. castor beans which contain a resin that could be processed further to form a polyamide resin and cotton which contributes cellulosic fiber (Casey, 2013) ▪ Backsheet with Copper layer: This backsheet is designed for the modules with cells for rear side contacting. It comes with a layer of Copper so that it can act as a back contact material(Osborne, 2013)	by adhesives for around 15 minutes.

3.2.3 Concentrated Solar Power

Parabolic Mirror, receiver (used in PT technology), HTF, turbine, heliostat, and receiver (used in ST technology) have been identified as critical components of PT and ST systems. Raw material is a significant issue for all critical components except for turbines and receivers used in ST. Currently, all the components are being imported. Though the industry has technological capability, critical market demand is an issue for producing domestically. Table 3.10 provides an overview of the critical components of CSP technology.

[29] Kynar® is a registered trade name of Arkema.

Table 3.10: Critical Components Overview for PT and ST Technologies

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
			Parabolic Trough		
Parabolic Mirror	▪ Asahi, NSG Group (Pilkington), Saint Gobain, and Guardian are the Tire 1 manufacturers of float glass in India. These companies have the production capacity of around 0.68 Mt per year with 75% market share of total glass production (ESMAP, 2013) ▪ Skyfuel manufactures a metalized polymer film which is laminated to an Aluminium substrate which is a competing technology with similar features of a mirror ▪ Skyfuel has signed a Memorandum of Understanding (MoU) with Megha Engineering and Infrastructures Limited (MEIL) to supply	▪ Sand, soda ash, limestone, dolomite, alumina are used for manufacturing glass. ▪ Silver and Copper substrates are the major raw materials used to convert glass to mirror (Pilkington, 2013)(World Bank, 2011).	▪ Float glass method, Quench bending or sag bending process and wet chemical process are used to manufacture parabolic mirrors (World Bank, 2011)(ESMAP, 2010).	▪ Black Sun solar collector is the upcoming technology which uses two parabolic reflectors to capture the solar radiation and then reflect it onto a circular cavity. The new innovative cavity is designed to absorb all the incoming solar radiation. Water-filled tubes are placed inside the cavity which in turn is heated to drive the turbine and generate electricity (Alcauza, 2013) ▪ Polymeric Mirror Films-NREL and 3M have developed a novel silvered polymeric mirror film which is more viable and abrasion resistant compared to glass mirror. Polymethylmethacrylate durable hard coat is applied on the front surface of the film which in-turn increases the reflectance from 90% to 95% and increases the durability from 10 years to 15-30 years (Padiyath, Peterson, & Chen,	▪ Float Process: High quality sand, soda ash, limestone, salt-cake and dolomite are poured into the furnace where they are heated at 1500°C for 50 hours to convert into molten glass. The molten glass is then poured continuously from the furnace onto a shallow bath of molten Tin. Molten glass flows over the molten Tin due to surface tension; these glasses spread out and form a level surface. The thickness of the glass sheet can be controlled by varying the speed of the solidifying glass ribbon. Chemical vapour deposition is done on the glass to enhance the optical properties of glass. Annealing is performed on these glasses to remove the stresses. Automated on-line inspection takes place to remove the faults and

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
	collectors for the 50 MW PT plant under JNNSM phase 1 (ESMAP, 2013) ▪ Currently, for the JNNSM phase 1 CSP projects (excluding MEIL) India is importing mirrors (FICCI, 2013b).			2013).	subsequently glass is cut as per the customer's requirement using CNC machine (Pilkington, 2013). ▪ Glass Bending: Quench bending or sag bending process is employed to achieve parabolic shape. In quench bending process, the glass is tempered and then heated up to 700 °C. Once this temperature is achieved the glass is shock cooled. Due to shock cooling the inner tensions in the glass are induced, which in turn increases mechanical stiffness, thus forming parabolic shape glass (World Bank, 2011). ▪ Wet Chemical Process: Wet chemical process is engaged to convert the bent glass sheet into mirrors. In this process, the bent glass sheets are cleaned using de-mineralized water. After which, the sheets are coated with a Silver coating on the surface, by spraying process. After the silver coating, a protective Copper layer is deposited in a separate

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
					chamber. The coatings are dried by radiant heaters and finally special lacquers (to resist the harsh weather conditions) are applied (Glaeser, 2001).
Receiver	▪ Schott Solar, Huiyin-Group, Archimede Solar Energy and Rio Glass are the global manufacturers of receiver (ESMAP, 2013) ▪ For the JNNSM phase 1 project receivers are being imported ▪ In India NAL, and KG Design Services have developed a high temperature solar selective coating for the receivers (ESMAP, 2013)(K G Design Services Pvt Ltd, 2012) ▪ Milman Thin-film Pvt Ltd is the only organization that has developed receivers for PT from the	▪ Stainless steel 304, Borosilicate glass, Molybdenum (Mo) aluminia (Mo-Al_2O_3) or Nickel aluminia (Ni-Al_2O_3) and Copper substrate are the raw materials used in the production of receiver (World Bank, 2011) (Selvakumar & Barshilia, 2011)	▪ Sputtering and solgel process are the technologies used for manufacturing receivers (World Bank, 2011).	▪ Advanced Low-Cost Receivers are the novel receivers developed by Norwich Technologies. An innovative design and novel coating materials are used for manufacturing receivers which in-turn achieves higher optical-field efficiency at lower cost. These receivers operate at higher temperature (≥650°C) with high thermal efficiency (≥90%) (Stettenheim, Brambles, & McBride, 2013)(SunShot, 2012).	▪ The assembly of the absorber tube and the concentric glass cover together is known as receiver ▪ Sputtering Process: Absorber tube is the integral part of the receiver made up of stainless steel. Selective coating on the absorber tube is done by sputtering process. Sputtering is carried out in an evacuated chamber by the self-maintained noble gas discharge, known as plasma. The absorber coating on the stainless steel tube is a complex process with three different layers of sub-systems. The first layer of Stainless steel metal tube with low thermal emissivity is applied with a coating of

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
	manufacturing plant in Pune, India [30](Milman, 2013).				$Mo–Al_2O_3$ or $Ni–Al_2O_3$, which reduces heat loss, by infrared radiation. The second layer sub-system is made of cermet (mixture of ceramics and metal) which increases the absorption of sunlight. The third layer comprises of anti-reflective coating on the tube surface to further reduce reflection losses (World Bank, 2011) ▪ Sol-Gel Process: The coatings consist of a varying porous structure that serves as a gradient of the reflective index from its level in air to its level in a glass tube. The reflection is reduced to a theoretical minimum due to continuous gradient. The sol-gel process is performed on the borosilicate glass tube. To coat the borosilicate tube, it is dipped in an acid-modified solution containing silicon dioxide and is pulled out of it at a speed of one centimetre per second. 110 nanometres is the width of the resulting layer. The porous structure of

[30]These receivers are in the testing stage and yet to be commercialized

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
					the film is achieved by adding a porogen material to the sol-gel solution. This compound is removed during a heat treatment after dipping which generates pores inside the polymeric silica films (World Bank, 2011).
Heat Transfer Fluid	▪ Dow Chemical, Solutia Inc and Lanxess are the few manufacturers of synthetic oil (HTF) across the globe (FICCI, 2013b)(World Bank, 2011) ▪ For the JNNSM phase I CSP projects HTF is being imported ▪ Lanxess, Indian Oil, and Reliance Petrochemicals are few potential players in India who are having the capability to manufacture HTF for Phase 2 projects (ESMAP, 2013).	▪ Diphenyl oxide ($C_{12}H_{10}O$) and biphenyl oxide ($C_{12}H_{10}$) are the materials used to manufacture HTF (Wagner & Ing, 2013)	▪ Biphenyl is an aromatic hydrocarbon that exists naturally in coal tar, crude oil, and natural gas. Biphenyl is extracted from mineral oil and coal by a direct single drop micro extraction process (World Health Organization, 1999)(Sarkhosh, Mehdinia, Jabbari, & Yamini, 2011) . Diphenyl is manufactured using direct phenol method(The Dow Chemical, 2007)	▪ Nitrate salt is the next generation HTF for PT developed by Texas A&M. Carbon nano-tubes is embedded into the nitrate salt to modify the freezing temperature and increase the heat absorbing capacity by 75% (Skumanich, 2011) ▪ 36% NaCl 14% KCl and 50% $AlCl_3$ is the eutectic salt mixture can be used as the HTF for PT system. The melting point of this salt is below 150°C and boiling point is >600°C(Li, et al., 2013).	▪ Biphenyl oxide and Diphenyl oxide are the eutectic mixture which are mixed in an insulated evacuated chamber in the proportion 73.5% diphenyl oxide ($C_{12}H_{10}O$) and 26.5% biphenyl ($C_{12}H_{10}$) (The Dow Chemical, 2007)(Wagner & Ing, 2013).
Turbine	▪ Siemens, GE, Triveni Turbines, Maxwatt turbines, and BHEL are the Tier 1 manufacturers of	▪ Low-alloyed steel, High-alloyed steel, Iron, Copper, Brass, Aluminium and concrete are the major raw materials required for	▪ Multi-stage simple condensing type impulse turbines or reheat turbine are used in the CSP plant (Ulrich Rueth, 2010) ▪ In solar steam turbine, the	▪ US DOE's SunShot initiative is supporting research areas to develop next generation turbines that operate at higher pressure and higher	▪ Shaft, rotor, blades, upper and lower casing , sturdy base, cooling water tank, valves, inlet steam control valve setup, Inlet piston

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
	power block in India.	manufacturing turbines(Clixoo, 2012) (Siemens, 2013a) .	steam coming from the steam generator is routed to the High Pressure (HP) module of the steam turbine. After initial expansion in the HP module, the steam is superheated again in a re-heater before entering the intermediate pressure/ low pressure (LP) turbine. At the outlet of the LP turbine, the steam is condensed and pumped to the steam generator via pre-heater (Ulrich Rueth, 2010) (Siemens, 2013b).	temperature with increased efficiency. (Muirhead & Kraemer, 2013).	setup etc. are the major components of a turbine(Rajput, 2012) ▪ Rotor Assembly: Rotor assembly is one of the most critical parts of the turbine that consists of shafts, rotors, and blades. Shafts and rotors are manufactured using high-grade steel, which are initially casted, and then heat-treated to higher temperature. Blades are manufactured using special alloy steel which are forged as per the design criteria using CNC machines. Shafts and blades are fixed to the rotor to form a rotor assembly ▪ Casing: Casing for a steam turbine is divided into two parts uppercasing and lower casing. Globular cast iron is the major raw material used in the casing, where the raw material is casted and forged as per design requirement ▪ Assembly: The rotor assembly is first housed in a lower casing and then it is covered with upper casing. Valves and sturdy base are

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
					fixed on to the upper casing. Subsequently inlet steam control valve setup and Inlet piston setup are assembled on to the rotor (Arnold & Stewart, 1999).
Solar Tower					
Heliostat	▪ Ausra, Rioglass Solar and eSolar are the Tier 1 manufacturers of heliostat across the globe ▪ Guardian, FLABEG, and Saint Gobain are the Tier 1 Heliostat mirror assembly manufacturers across the globe (ESMAP, 2013) ▪ eSolar has supplied the heliostats for the only operational plant in India(NREL, 2013a).	▪ Stainless steel, sand, soda ash, limestone, dolomite, alumina, Silver and Copper are the primary raw materials (Pilkington, 2013)(ESMAP, 2010)	▪ Heliostat basically consists of a reflective surface (mirror), support structure made up of stainless steel, drive mechanism (tracking), a pedestal, and foundation and control systems ▪ Float glass method, wet chemical process and vacuum process are used to manufacture Heliostats (ESMAP, 2010)(Kuntz & Falcone, 1986)	▪ Sunfolding, an upcoming organisation in US has developed an innovative heliostat for future. Sunfolding uses a high precision dual axis tracking system made with miniature, pneumatic plastic drives instead of heavy-duty steel and motor-driven system. The main advantage of these systems is 10x reduction in cost and also 90% weight reduction compared to current heliostats and 2-axis tracking systems (Madrone, 2013) ▪ CSIRO is developing a new heliostat system, which reduces the cosine loss by 20%. This system uses a closed loop control system made up of inclinometers and encoders, which ensures better optical performance (CSIRO, 2013).	▪ Large foundations are required for supporting conventional heliostats. These foundations contain tonnes of concrete and reinforced steel. Once the foundation is placed, the pedestal is rooted on to the foundation. In a heliostat assembly, the mirror is fixed to a steel frame with steel nails on the facets of jig table. The structure is made of hot dipped galvanized steel. Glass-Reinforced Concrete (GRC) casting is made on the structure where the mirrors are attached using a simple flat tool. Finally, concrete azimuth tracking for the heliostat is casted and moulded on to the epoxy holder, which has been incorporated in the azimuth drive mechanism (ESMAP, 2010).
Receiver	▪ Schott Solar, Babcock Power, eSolar, Pratt &	▪ AISI 304 stainless steel, Carbon steel, Silicon	▪ Tubular and volumetric are two types of receivers used in solar	▪ Beam down solar tower: This is an innovative technology	▪ The principal components of the receiver subsystem

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
	Whitney, Bright source Energy, Saint Gobain and Victor Energy are the Tier 1 manufacturers of receiver across the globe ▪ Victor Energy has provided the receiver for the operational solar tower (ACME Group) plant in India (NREL, 2013a).	carbide, ceramics and pyromax (ESMAP, 2010)(Kuntz & Falcone, 1986).	tower ▪ Tubular receivers use liquid HTF such as water, molten salt, thermic oil, liquid Sodium, and Hitec salt, whereas volumetric receivers use air as HTF (Aichmayer, 2011) .	developed by Masdar Institute, Tokyo Institute of Technology, and Cosmo Oil. In this system a ceramic receiver is used which is placed at the base of the tower where it absorbs twice the solar radiation and increases the efficiency by 15-19% (Raj, 2013)(Kanellos, 2010) ▪ Particle receiver: An innovative technology developed by Sandia National Laboratories (SNL) with Georgia Tech, Bucknell University, and King Saud University. The concept uses low-cost stable materials, a ceramic solar receiver, and storage containers with refractory liners. The receivers are designed to accommodate high temperature oil or salt (CSP World, 2012).	include the absorber surface, multiple module tubes, panel interconnecting piping, inlet and outlet manifold piping, surge tanks or steam drum ▪ Absorber panels are fabricated in individual modules. Each module consists of the panel tubes, inlet and outlet headers, buckstays, support struts, strong backs, and insulation and sheathing ▪ Absorber panels are assembled to the receiver structures which are made up of steel columns, beams, and trusses ▪ The piping and tanks are assembled inside the receiver structure (Kuntz & Falcone, 1986).

3.2.4 Thermal Storage System

Molten salt, pump, and storage tanks are the critical components of the molten salt storage system. Table 3.11 provides a detailed summary of the effort. Currently, in India there is no CSP plant with molten salt storage technology. If the storage technology does enter the Indian market, then the majority of the components will have to be imported.

Table 3.11: Overview of Critical Components of Molten Salt Storage System

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
Molten salt	▪ Sociedad Quimica y Minera	▪ Potassium nitrate (KNO_3)	▪ Sodium nitrate is	▪ NaK a hypoeutectic alloy	▪ Potassium nitrate (KNO_3)

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
	de Chile SA (SQM), Haifa Chemicals and Durferrit are the only manufacturers of molten salt across globe ▪ India does not have a single plant, which has a commissioned CSP plant with molten salt thermal storage system.	and Sodium nitrate ($NaNO_3$) are the raw materials used in the manufacture of molten salt (Koning, 2007).	abundantly available in nature in the form of nitratine, nitratite or soda niter Sodium nitrates are produced by neutralizing nitric acid with soda ash (Zumdahl, 2007) ▪ Potassium nitrate is an ionic salt, which occurs in nature in the form of solid source of Nitrogen. Potassium nitrate is manufactured by double displacement reaction between Sodium nitrate and Potassium chloride (LeConte & Joseph, 1999)(Rigby, Cochran, & Holt, 2002).	of Sodium (54% by weight) and Potassium (46% by weight) which has a melting point at 20°C and boiling point at 785°C is the next generation primary HTF (Kotzé, Backström, & Erens, 2012) ▪ Super critical CO_2 developed by NREL for *Sunshot Initiative* can be used as a primary HTF in CSP plants. Super critical CO_2 has higher operating temperature, which works in a closed-loop recompression Brayton cycle and achieves a high thermal cycle efficiency and more efficient thermal energy storage (Gallego, 2011).	and Sodium nitrate ($NaNO_3$) are available in tertiary or binary mixtures. Molten salt is formed by mixing a proportion of 60% Potassium nitrate (by weight) and 40% Sodium nitrate (by weight) (Koning, 2007).
Storage Tank	▪ Bertrams Heatec AG, Halliburton, and Caldwell Energy Company are the Tier 1 developers of molten salt storage tank across the globe.	▪ SA-516 Gr-70 carbon steel, AISI 321 H stainless steel, ceramic fiber, Fine sand, firebricks, foam glass and reinforced concrete are raw materials used in the construction of storage tank(Gabbriell, 2009).	▪ Direct single tank and direct two tanks thermal energy storage (TES) is the current technology ▪ In direct single tank TES, the hot and cold molten salt are separated with thermal gradient (filler material - Quartzite) (Grogan, 2013)(Pacheco,	▪ Thermocline tank is the upcoming technology. These tanks are cost effective compared to two-tank system. Thermocline tank have better tank discharge performance and high thermal quality discharge efficiency (Flueckiger,	▪ The cylindrical storage tank vessel is constructed using SA-516 Gr-70 Carbon steel which will not be in direct contact with the heat transfer fluid ▪ A layer of insulating firebricks protects the internal surface of the cylindrical tank. A flexible

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
			Showalter, & Kolb, 2001) ▪ In two-tank TES system, hot and cold molten salt are stored in two different semi cylindrical tanks (Pacheco, Showalter, & Kolb, 2001).	Yang, & Garimella, 2013).	AISI 321 H stainless steel liners corrugated in both horizontal and longitudinal direction is applied on top of the firebricks. A thin layer of ceramic fibre insulating material is positioned behind the firebrick. To resist the thermal strains and also to ensure the stability of the firebrick column, they are mounted on the brackets which are welded to the steel vessel ▪ A coat of ceramic fibre insulation, which is covered by a thin Aluminium sheet, protects the external surface of the shell. Fine sand, insulating firebricks, foam-glass, cooled reinforced concrete and foundation piles are some of the protective layers which are used in the making of tank foundation and the external layers to ensure proper insulation (Gabbriell, 2009) ▪ The tank roof is made up of a fixed ellipsoid shaped

Critical component	Market position	Raw material	Current technology	Upcoming technology	Manufacturing process/ Assembling process
					sheet. The flexible stainless steel liner is placed above the molten salt to form a closed cylindrical storage chamber. The upper surface of the liner is coated with ceramic fibre insulating material to complete the storage tank (Herrmann & Nava, 2002).
Pumps	▪ Flowserve India Controls Pvt Ltd, Sulzer Pumps, KSB India, ITT India, Process Pumps Pvt Ltd, and Grundfos India are the OEM molten salt pump manufacturers in India (ESMAP, 2013).	▪ 316 Carbon steel is used in impeller and volute ▪ 304 stainless steel is used in pump support rods ▪ Shafts are made up of 400 series stainless steel (Daniel, 2007)(Jonemann, 2013) ▪ Titanium, polypropylene, Ethylene tetrafluoroethylene, polyethylene and ceramics are the other raw materials used for manufacturing pumps (Daniel, 2007)(Jonemann, 2013)(Rheinhutte Pumpen).	▪ Vertical cantilever shaft pump is used for the molten salt application (Mount, 2013)(Daniel, 2007).	▪ Sandia laboratories with NREL have developed a new generation molten salt pump which will reduce the heat loss by 10-20% by eliminating the pump sumps, valves and interconnecting pipes ▪ These pumps have a length of 15m, which helps in operating at very high temperature without much energy loss (Barth, 2013).	▪ Pump tank, rotary assembly, and the drive motor are the three major components of vertical cantilever pumps ▪ Pump volute or casing, salt level indicators and nozzles are sub components of the pump tank ▪ A rotary assembly consists of shafts, ball bearings, seals, a shield plug and impeller ▪ Pump tank, rotary assembly, and the drive motor are assembled with ring-joint gasketed flanges (Daniel, 2007)(Rheinhutte Pumps, 2013) (Smith, 1970) .

3.3 Supply Chain Challenges

The utility scale solar PV and CSP technologies are in a very nascent stage. A bulk of the supply chain is still evolving; a majority of the components are being imported. This is not true in the case of wind, which has fairly established suppliers. The critical components identified in the previous section have been examined thoroughly and industry inputs were sought to identify the challenges in raw material availability/procurement, manufacturing process, research and development, design and testing and other challenges affecting the manufacture of components. This section describes these challenges in detail. The rationale for selecting these challenges is as follows:

Raw Material

Cost competitiveness depends on the availability of raw materials required for component manufacturing in adequate quantity and of required quality at a reasonable price. In the case of wind technology, although India has a large wind turbine assembling capacity, the availability of certain raw materials (quality and quantity) is doubtful. Hence, there is a dependence on overseas suppliers.

Manufacturing Process

The quality of components is of utmost importance. Like a good design, good quality improves the cost competitiveness of the product. To achieve this it is necessary to have the ability to manufacture good quality products, which in turn is largely dependent on the manufacturing process of the components. An efficient manufacturing process is important to obtain high product quality and reduce O&M of components, which in turn will increase the cost effectiveness of the product.

Research & Development, Design and Testing

For the past 25 years, both wind and solar technologies have made several advances. In the case of wind, use of larger capacity turbines is the current norm whereas in solar, efficiency of PV technologies has improved by several folds. Both these approaches have resulted in cost reduction. In the wind sector, major manufacturers obtained their licenses from their international counterparts. In some of the cases, the designs were not optimum for wind speeds in India. Even after having a base of more than 10 GW of annual manufacturing facility, India lacks its own designing and R&D facility as compared to other wind-rich countries. Innovative designs for a low wind regime need to be explored.

Transportation and Logistics

This is a specific challenge faced by the wind industry; transportation and logistics for large and heavy wind turbine components are the major issues. Some components like tower, blade and nacelle require special permissions from state transport departments for transportation and a special type of logistic arrangement is involved. In addition, good approach roads to transport these components to remote sites are another challenge faced by the industry.

Other Challenges

Other challenges pertain to infrastructure availability, skill development, etc. In 'The global competitiveness report 2013-14", a report published by the World Economic Forum, lack of adequate infrastructure was identified as a major issue for doing business in India (World Economic Forum, 2013). RE projects are located in remote locations where there is inadequate evacuation infrastructure and grid interconnection. It is one of the biggest barriers to RE deployment.

The following section provides the different challenges faced by the wind and solar industry individually.

3.3.1 Wind

Availability of critical raw material resources is crucial for large-scale manufacturing of wind turbines. The requirement of raw material for manufacturing wind equipment depends on the design of WTG and varies with different technologies. The most important raw materials are steel, fibre glass, resins, core materials for blade, permanent magnets and Copper. The capacity addition target for wind power in India could be in the range of 110-183 GW in 2032 (Refer **Annexure 3**)

The supply chain challenge pertinent to the critical components of wind technology is mentioned in Table 3.12.

Table 3.12: Supply Chain Challenges of Critical Components

Name of the component	Raw material	Manufacturing process	R&D, Design and Testing	Transportation, Logistics and Other Challenges
Blade	▪ To develop and manufacture raw material for blades, i.e. glass/Carbon fibres, capital expenditure, and expertise required is high. (Enercon GmbH, 2012).Therefore, raw material for blade is mostly (>50%) imported ▪ Few raw material providers are available; some of them have quality issues ▪ Saertex, a German-based company has a unit in Pune, which supplies raw materials for wind turbine blade manufacturing.	▪ Most manufacturers in India adopt the infusion process for blade manufacturing, instead of prepreg process which is more efficient, automated and give a better mechanical performance ▪ The raw material(mixture of fibre glass and resin) used in the prepreg type blade manufacturing process needs to be stored and transported at low temperatures under isolated and well-secured conditions, which is a challenge ▪ Infusion process is manual and labour intensive, which leads to a lack of repeatability and accuracy.	▪ Blade testing facilities is available with LM Wind, Suzlon, WindWorld, Regen Powertech, etc. ▪ In India, aerodynamics technology is underdeveloped, and is only limited to HAL. Major pioneers of aeronautics are US, Germany and France ▪ Modern and sophisticated R&D and design facilities are lacking in the country.	▪ Modern wind turbine blades are long (35 to 50 meters on an average) and weigh several tonnes. They exceed common trailer lengths available for road transport. 40-50m blades require 6-8 axle trailers for transportation which are big and costly ▪ Limited availability of large size cranes and trailers has a great impact on project completion cycle.
Tower	▪ As the turbine sizes are increasing, longer and heavier towers will be required which will need thicker steel plates. The availability of raw material (S 355 grade steel) for longer and thicker towers may be a challenge in the future. The delivery time of S 355 grade steel is also long ▪ *Arcelor*Mittal supplies high quality steel for wind turbine towers in the Indian market.	▪ Tower manufacturing is a highly energy intensive process with an energy consumption of about 16.11% of turbine manufacturing (Martinez E, 2009) ▪ Lack of sophisticated welding technologies.	▪ Lack of sophisticated design and R&D facilities and dynamic testing centres in India.	▪ Although towers are transported in 2-3 sections to reduce transportation issues, large towers are considered to be over-dimensional cargo ▪ Limited availability of large trailers, preferably Double Schnabel trailer, 6-8-axle-65 tonne and 8-axle-75 tonne trailer which are required to transport large and heavy tower sections ▪ Lack of proper roads and existing old bridges make it even more

Name of the component	Raw material	Manufacturing process	R&D, Design and Testing	Transportation, Logistics and Other Challenges
				challenging to transport these large wind turbine towers ▪ Crawler cranes, which are required to handle towers 100 m or above are expensive and rarely available.
Gearbox	▪ There is a moderate availability of the high grade carburized steel required to make gearboxes and with increasing sizes of gearbox, there can be a shortage of raw material in the future ▪ Large forged bars and blanks are required to manufacture gears, which require huge casting and forging facilities. Casting and forging facilities are less in India.	▪ Gearbox manufacturing process is the most energy intensive process with an energy consumption of about 46.9% of wind turbine manufacturing(Martinez E, 2009) ▪ Manufacturing process is sophisticated and requires a high degree of accuracy and expertise.	▪ Lack of dynamic loading test runs makes it difficult to check the viability and quality of the manufactured gearboxes in India ▪ Lack of sophisticated design and R&D facilities in India ▪ Technological capability and knowhow for large wind turbine gearboxes is less in India.	▪ Shortage of skilled personnel.
Bearing	▪ Less availability of steel used in large bearings. The steel grades required for wind turbine bearings are hardened Cr-Steel (100 Cr6), or CrMo steel (100 CrMo7-3)(International Molybdenum Association, 2011).	▪ Sophisticated manufacturing technologies to manufacture large-sized bearings are limited in India.	▪ It is a challenge to design large-sized bearings required for gearbox, main shaft and yaw system with high reliability and lifetime and also develop high performance bio-degradable lubricants ▪ Sophisticated bearing testing facilities to test the robustness and fatigue of bearings is not available in India.	▪ Since there is a shortage of large casting facilities in India, manufacturing main bearing housing, which is casted from steel, is a challenge. Lack of large forging capacities pose a challenge for manufacturing large yaw bearing (Gamesa, 2011) ▪ Wind industry is a very small business segment for the major manufacturers ▪ For wind industry, manufacturers have to customize their manufacturing facility. Further, demand of large bearing is

Name of the component	Raw material	Manufacturing process	R&D, Design and Testing	Transportation, Logistics and Other Challenges
				market driven and hence not stable. So manufacturers are not willing to invest money in this segment ▪ High demand volume is required to set up manufacturing facility ▪ There is a shortage of skilled personnel in manufacturing large bearings.
Generator	▪ Rare earth metals (Nd) and (Dy) whose alloy is used to manufacture permanent magnets are not available in India ▪ Annealed Copper strips, which are used to make conductors for generator, have a very limited vendor base in India, which poses a big challenge.	▪ Generator manufacturing process is the most energy intensive process after gearbox. The energy consumption for manufacturing a generator is approximately 25.12% of the total consumed in manufacturing all the major components of wind technology (Martinez E, 2009) ▪ Generator manufacturing process is also a highly labour intensive process and requires skilled personnel to provide acute precision and supervision.	▪ Designing a high pole-low speed generator for a gearless turbine is very expensive and complicated ▪ Demagnetization of the magnets due to stator magnetic overload in PMSG is seen due to flaws in designing.	
Main shaft and rotor hub (Casting and forging challenges)	▪ Large size casting and forging facilities are not developed relative to the increase in the size of turbine ▪ Requirement of high technology, extensive skill, modern and sophisticated manufacturing process ▪ Significant investment required to add heavy casting and forging capacity as needed by the wind industry. Despite high levels of investment, the margins are very low due to the cost pressures in the WTG industry. Manufacturers are therefore unwilling to invest unless very high (>80%) capacity utilization can be guaranteed (E4tech and Avalon consulting, 2012b) ▪ Restrictive procurement policies, time consuming and costly bidding processes, and high quality requirements shows that WTG manufacturers are reluctant to contact new suppliers for critical components. Thus new entrants are limited ▪ Capacity-wise availability of forging and casting facilities in India has been discussed in **Annexure 4**.			

3.3.2 Solar

Despite a decreasing trend (before recovering in late 2013) in the cost of c-Si technology, coupled with concerns on energy security which makes solar a better and cleaner option, the critical components have a unique set of challenges. Some of these are pertinent to technology, i.e., high-energy intensity for manufacturing solar wafer, technology to manufacture receiver; others relate to the process – wastage, coating of TCO glass, storage of silane, bending of mirrors, etc. This section examines the different challenges affecting the manufacture of the critical components in PV, CSP, and storage industry.

Solar PV

Cell, Glass, EVA encapsulant, TCO-glass substrate, silane gas, and backsheet are the critical components of solar PV (c-Si and a-Si thin film) technology. The manufacture of glass involves raw material constraints, a wafer's manufacturing process is associated with wastage, EVA films can absorb moisture over time resulting in the release of acetic acid (which causes corrosion), and silane needs to be handled carefully as it has a potential for delayed ignition and explosion. The different challenges affecting the critical components are highlighted in Table 3.13.

Table 3.13: Challenges Associated With Critical Components of PV

Components	Raw Material	Manufacturing Process	R&D, Design and Testing	Other
Cell	▪ Silica sand is the raw material required for ingot production. Silica is abundant in the earth's crust, but, the purification process of silica is energy intensive i.e. approximately 80-150 kWh/kg (Greenpeace International, 2012) and costly.	▪ Before slicing, the ingot should be mounted on a sawing machine with a correct orientation otherwise it can damage the final wafer (Indian Semiconductor Association, 2008) ▪ Wafers are cut from ingots with a diameter of 200 micrometres, which causes wastage of Silicon and further grinding-honing leads to Silicon loss (Tech-On, 2013) ▪ Wire saws are used for wafer slicing, which involves the intense use of wires where a significant amount of Silicon gets wasted.	▪ The Czochralski process is the most commonly used process for silicon ingot growth but it is relatively slow, requires high precision and proficiency. Automation is possible only for few sub-processes, but a relatively high degree of involvement from skilled operators and process engineers is required. So a Silicon wafer manufacturing plant should have 20 or more Czochralski furnaces to meet the continuous demand (Laube, 2013) ▪ Technology that can reduce the wastage of Silicon during cutting should be introduced ▪ Metallization of Silver and Aluminium are highly expensive, so the consumption of these metals	▪ The establishment of wafer and cell manufacturing is capital intensive. This coupled with global supply glut doesn't motivate an Indian investor or existing module assembler to establish such plants ▪ The manufacturing process requires highly trained, experienced and skilled individuals, solar being a nascent technology in India, this requirement is difficult to fulfil (Lanco, 2013).

Components	Raw Material	Manufacturing Process	R&D, Design and Testing	Other
			can be reduced and alternative technologies must be promoted(ITRPV, 2013)	
Glass	▪ Sourcing of low Iron content and raw material to manufacture low Iron solar glass are major challenges. Even though the raw material is widely available, their extraction is limited and expensive[31]. These raw materials are low Iron sand, dolomite, and limestone and glass cullet (Guardian, 2012).	▪ A single batch production of low Iron content glass requires a high volume of 10-15,000 tonnes to make it economical. Thus, the demand has to be adequately high for its production. Further, the low Iron content glass needs to be coated with anti-reflection coating within a time of 2 months from manufacturing[32] after which the coating fails to hold the surface.	▪ For Thin film substrate, optimum texturization of glass is crucial before coating the TCO for better long-term performance for enhanced absorption of sunrays ▪ The development and availability of high-performance[33] solar glass coating is a major challenge.	▪ Low Iron content glass has low shelf life. ▪ Manufacturing facilities are highly specialized; manufacturing facility for one type of glass cannot be easily utilized for other type of glass production.
Encapsulant	▪ India does not have a single manufacturer engaged in the preparation of the primary raw material i.e. EVA copolymer resin. The resin costs more than 90% of the total cost of the encapsulant. So cost of production of raw material is a major challenge for the manufacturers.	▪ EVA shrinkage occurs due to change in the density of the polymer from processing temperature to the ambient temperature.	▪ EVA films can absorb moisture over time, releasing acetic acid that attacks the transparency coating of the photovoltaic cell and circuitry. The hydrolysis of EVA films has also been shown to result in de-lamination at the module edge and along the wires, as well as yellowing –which decreases cell reliability and efficiency ▪ EVAs need to be cured during module manufacturing, which results in relatively long cycle times in the vacuum lamination process. (Sinha & Hofius, 2011)	▪ Potential Industrial Degradation (PID) - solar panel could be affected by PID with EVA encapsulate due to release of acetic acid and its' subsequent reaction with moisture. This results in glass corrosion (Advanced Energy, 2013) ▪ Snail Tracks Refers to the trace of slime released on the path traversed by the snails on the modules. These usually appear after 3-5 months of out-door climatic exposure, which results in discoloration of EVA, and lead to the development of micro

[31] The raw material cost and transportation costs of low iron containing ore increases the cost of production (Guardian, 2012).
[32] This information was obtained during stakeholder interaction.
[33] Accurate tests for lifetime performance, self-cleaning or hydrophobic coating, minimizing front surface reflection, standards for solar mirror requirements and choosing material for Transparent Conductive Oxide (TCO) are some of the key technical challenges for coating.

Components	Raw Material	Manufacturing Process	R&D, Design and Testing	Other
				cracks on the module.
Silane Gas	▪ MG-Si is the primary raw material.	▪ Being pyrophoric, silane has potentially hazardous properties. The main challenge involved is in handling and storage. As PV manufacturing is scaled-up to meet a growing demand, preserving a safe, environmentally friendly nature of the industry becomes even more important.	▪ In all aspects of the bulk silane supply chain, the storage and delivery systems require careful design, installation, and operation.	▪ Silane is one of the inherently dangerous materials used in the deposition of Silicon nitride (SiN_3) and amorphous Silicon (a-Si). Due to its potential for delayed ignition and explosion, silane needs to be handled carefully ▪ Silane related risks are illustrated by the number of incidents recorded in the semiconductor industry. These accidents involved different parts of the silane system, from changing cylinders to emission control (Biello, 2010).
Backsheet	▪ Continuous and reliable supply of traditionally used Tedlar is a major challenge for backsheet manufacturers (Flexon, 2012) ▪ The delay in testing and certification process does not ensure the continuous supply of raw materials to meet the ever-growing demand of the PV Industry.	▪ The greatest challenge for backsheet manufacturers is to develop product that meets strict performance requirements and industry standards, at a time when there is increasing pressure to reduce costs ▪ The long time required for completing the aging tests of damp heat, UV exposure, etc. results in the delayed introduction of materials to the PV market. However, HAST (highly accelerated stress test) is becoming popular; the procedure needs to be standardized and correlated with damp heat and outdoor performance.	▪ The ambiguity in requirements of certification process between various agencies like UL and IEC standards, for example, UL 746C states that only materials directly exposed to sunlight have to be tested with respect to UV stability.	▪ Backsheets are multilayer structures and assigning one Relative Thermal Index (RTI[34]) value for the entire construction as per standards creates confusion. It is unclear which value should be assigned and certifying agencies have different opinions on this matter ▪ Flammability is another key property that needs to be defined clearly ▪ All the testing measures ranging from comparative tracking[35] to partial

[34] RTI is a measure of the thermal stability of the polymeric material and determines whether the material is suitable for continuous use at a certain temperature.
[35] Tracking index measures the rates of resistance of an insulating material to electrical breakdown, which could cause a potentially hazardous conductive path on the surface

Components	Raw Material	Manufacturing Process	R&D, Design and Testing	Other
				discharge test[36] to high current arc ignition[37] should be carried out (Ostiguy, 2012).

CSP

Parabolic mirror, receiver, HTF, turbine and generator are the critical components of PT whereas Heliostat and Receiver are the critical components in ST technology. Except for turbine and heat transfer fluid, there is no indigenous manufacturer of any of the other critical components. In addition, availability of low Iron content ore for manufacturing glass mirror, achieving temperature stability and application of anti-reflection coating on the borosilicate glass (in manufacturing receiver) and HTF operating at high temperature (> 600 °C) are some of the challenges affecting the CSP industry. Finally, in the case of receiver of a solar tower, a major challenge in manufacturing a tubular receiver is to manufacture tubes that can tolerate thermo-mechanical stress, which varies based on the type of HTF used. The different challenges are summarized in Table 3.14.

Table 3.14: Challenges Associated With Critical Components of PT and ST System

Components	Material Challenges	Technology Challenges	R&D, Design and Testing	Other Challenges
		Parabolic Trough System		
Parabolic Mirror	▪ Parabolic mirrors require low Iron content glass. Feasibility of low Iron content glass is a major constraint in the Indian context (ESMAP, 2010) ▪ Gujarat Borosil Limited is the only Indian company, which manufactures low Iron glass for PV module (Borosil, 2013) .	▪ Float glass method is one of the critical manufacturing processes used in the production of parabolic mirrors. It is a state-of-the-art technology which requires large quantities of material and is highly energy intensive (World Bank, 2011) ▪ Maintaining 4mm uniform thickness throughout the glass sheet without shrinkage poses a major technical challenge ▪ Maintaining high geometric precision for bending 4mm thick glass poses a	▪ Significant R&D is sought in developing point focus mirror to increase the collector efficiency (Glasstech World, 2013) ▪ The standards for testing the quality of parabolic mirror are missing (FICCI, 2013b).	▪ In establishing a glass manufacturing plant the engineering procurement and construction requires highly skilled professionals. Secondly, in India there is a lack of experienced people in the solar mirror manufacturing field (ESMAP, 2013) ▪ The float glass process and the quench bending process are capital intensive (World Bank, 2011)

[36]A partial discharge test can also verify that the backsheet is engineered with insulation properties to suit the voltage requirements of the module and UV resistance, thereby ensuring the appropriate resistance to UV degradation if the end use requires the backsheet to be directly exposed to sunlight

[37]Determines the likelihood of a power surge by simulating a loose connection or broken lead

Components	Material Challenges	Technology Challenges	R&D, Design and Testing	Other Challenges
		challenge (ESMAP, 2013). ▪ High precision is required because a marginal reflection loss of direct radiation leads to a low degree of electrical efficiency and therefore jeopardizes the economic efficiency of the project (World Bank, 2011) ▪ Complex manufacturing lines are required for the production of parabolic mirrors (World Bank, 2011).		▪ The extraction of low Iron content ore from mines is a high cost capital intensive process (Guardian, 2012).

Components	Material Challenges	Technology Challenges	R&D, Design and Testing	Other Challenges
Receiver	▪ Lack of availability of good quality borosilicate glass in Indian context (Vermani, 2013).	▪ Manufacturing a PT receiver is a challenge as it comprises several complex processes ▪ The outer surface of the receiver glass tube is provided with an optically transmissive antireflective coating. The process of applying anti-reflective coating on the borosilicate tube is known as sol gel process. A major technical challenge involved in the sol-gel process is to achieve temperature stability (World Bank, 2011) ▪ Maintaining anti-reflective coating over a 4m length of borosilicate glass tube imposes a challenge (FICCI, 2013b) ▪ Techno-economic feasibility of borosilicate glass is one of the critical challenges (World Bank, 2011) ▪ Coating thin layers of absorber material on large surface using sputtering technology is another challenge ▪ There is also an additional difficulty in connecting the absorber tube to the receiver glass tube due to different thermal conductivity of the two materials (Barshilia & Selvakumar, 2011) ▪ Only few companies across the globe have commercial experience in making high quality receiver. To replicate these technologies in an Indian context poses a challenge (FICCI, 2013b).	▪ National Aerospace Laboratory (NAL) is developing a high temperature solar selective coating for the receivers. This technology is currently being tested (NAL, 2012) ▪ To achieve pressure less than 0.0013 Pa in the receiver tube in order to achieve maximum evacuation is a major design challenge (Alberti, Crema, & Bozzoli, 2011) ▪ The critical challenge in manufacturing absorber tube is to provide selective coating on Stainless Steel (SS) tube (having high absorption and low emissivity) and glass to metal seal between SS tube and glass(ESMAP, 2013).	▪ The cost of equipment required in the manufacture of receiver tube is high (ESMAP, 2013) ▪ Oligopolistic market structure: There are only a few tube manufacturers across the globe.

Components	Material Challenges	Technology Challenges	R&D, Design and Testing	Other Challenges
HTF	▪ Dowtherm, Therminol VP-1 are some of the commercially available HTFs which are imported ▪ Currently, no indigenous manufacturer of low Hydrogen emitting synthetic oil is present in India (CSTEP, 2013a).	▪ The limitation of the HTF (Therminol) is that it operates in the range of 400 °C. Whereas, a conventional steam turbine operates in the range of 540°C. In addition, whenever therminol is heated above 400 °C the Hydrogen from the synthetic oil is emitted. Once the Hydrogen gases are emitted they get collected in the annulus of the receiver which reduces the absorber tube efficiency (Northern Innovation, 2010)(Moens & Blake, 2008).	▪ Significant R&D should take place in developing HTF which can operate at higher temperature (>650°C) without emitting the Hydrogen gas (Sarkhosh, Mehdinia, Jabbari, & Yamini, 2011).	▪ There are very few suppliers of HTF in the world. US-based Dow Chemicals and Solutia monopolise the market. The cost of HTF has increased almost by 50% in the past two years. The current price of HTF is around INR 385,000 per tonne. Typically, a 50MW project requires approx. 1,100 tonne (Paliwal, 2013).
Turbine	▪ The primary components required to manufacture the turbine are shafts, disks, high pressure and low-pressure casing, blades, gland, valves and seals. A well-established market of Tier-1 suppliers exists in India. The study does not anticipate challenges in procuring components to manufacture turbine.	▪ Part load and fatigue factor are major technical and design challenge involved in manufacturing steam turbine (Turbine Info, 2012) ▪ Frequent start stops in turbines due to intermittency in solar radiation is experienced. This yields in drop in performance and efficiency of turbines over the years coupled by reduction in life of the turbines (Siemens, 2013b) ▪ In addition, the moisture content in the steam should be reduced to increase the turbine efficiency (Chaplin, 2010).	▪ Significant R&D should take place in improving the efficiency of turbine under part load condition (Rueth, Quinkertz, & Fichtner, 2010).	▪ High maintenance costs.
Generator	▪ Nd and Dy are the two rare earth materials used manufacture generators. These components are chiefly imported from China (Resnick Institute, 2011) .	▪ There are no significant technology challenges involved in manufacturing generators as India has a well-established market.	▪ There is a significant design challenge in inserting high voltage coils on to the wound stator (Biermana, O'Donnella, Burkea, McCormick, & Lindsay, 2013).	▪ The capital cost is high since the solar steam generator used for CSP plants is different from the conventional steam turbine (ESMAP, 2013).
Solar Tower System				

Components	Material Challenges	Technology Challenges	R&D, Design and Testing	Other Challenges
Heliostat	▪ Mirrors used in heliostat require low Iron content glass, similar to that in PT. Obtaining low Iron content silica is a major constraint in the Indian context (FICCI, 2013b) ▪ Availability of IP65 motor for the tracking system is another challenge.	▪ The coating of heliostat is a challenge. It is a state of the art process. Mirror surface of the heliostat should be coated with Silver nitrate to enhance reflectivity (Pilkington, 2010). Coating to withstand harsh weather conditions and maintaining optical properties are critical, so better techniques are required to apply these coatings on the heliostat (Glaeser, 2001) ▪ Thermal expansion of the coating material and weight of the supporting structure need to be considered (Google, 2012).	▪ The cosine effect[38] plays a vital role in the heliostat field design. R & D is taking place across the globe to reduce this effect (Koretz, 2013) ▪ R&D is currently ongoing to optimize the heliostat field layout with respect to increase in the solar field efficiency.	▪ Heliostats contribute 30-35% of the total cost of the system. Hence, further research or substitution with alternate material for the structures and mirrors without compromising the quality would lead to an overall reduction of the total system cost (ESMAP, 2013).
Receiver	▪ Pyromax is one of the critical raw materials used in manufacturing the receiver. Currently, no indigenous manufacturer of Pyromax is available in India (Joshi A. , 2008).	▪ Receiver structure should be able to sustain natural calamities like wind, soil erosion and rain (Kennedy, 2005) ▪ Tubular panels consist of thermal fluid flowing inside the tube that removes the heat by convection. A challenge is to manufacture tubes that can tolerate thermo-mechanical stress which varies based on the type of fluid ▪ For volumetric receiver, the challenge is to manufacture highly porous structure that can allow radiation to penetrate deeply thereby attaining efficient convective heat transfer with air as the medium (Romero-Alvarez, 2007).	▪ Spillage effect plays a significant role in the receiver design. 20% of solar radiation losses are due to spillage. Significant R&D is taking place across the globe to reduce the spillage effect and increase the solar field efficiency (Joshi A. , 2008) ▪ In volumetric air receivers, cavity areas must be effectively closed and insulated to minimize heat loss and to protect structure, headers, and interconnecting piping from incident flux (Kennedy, 2005)	▪ Techno-economic feasibility in the manufacture of volumetric or tubular receiver ▪ India has a low DNI and high dust and aerosol in the atmosphere which reduces the incident radiation (Joshi A. , 2008) ▪ The capital cost of installing a 50MW system is in the range of 45-50 crore/MW making it expensive compared to other alternatives (Fichtner, 2010) .

3.3.3 Storage

[38] Reduction of radiation by the cosine of the angle between the solar radiation and a normal surface is called the cosine effect.

Molten salt, storage tank, and pumps are the critical components of a molten salt storage system. The non-availability of molten salt (a mixture of Sodium and Potassium nitrate) and high quality seals required in the pumps (used to pump HTF) are some of the major challenges affecting the thermal storage technology. The different challenges are summarized in Table 3.15.

Table 3.15: Challenges in Molten Salt Storage System

Components	Material Challenges	Technology Challenges	R&D, Design and Testing	Other Challenges
Molten salt	▪ The salt mixture i.e., 60 percent Sodium nitrate and 40% Potassium nitrate are not available in India. There is also limited experience in handling this mixture.	▪ Nitrate salt is relatively benign and has a low corrosion potential. Nonetheless, the industrial grade of the salt contain impurities, of which the most chemically active are chlorides and perchlorates. The mixture has a high freezing point (Herrmann & Nava, 2002)(Gallego, 2011).	▪ Freezing temperature of molten salt is very high i.e. 220°C thus, designing heat tracing for each outlet is a major challenge (Gallego, 2011) ▪ India lacks sophisticated facilities for extraction of molten salt from ores, as molten salt contain a lot of impurities such as Chlorine (0.03-0.48%) which are insoluble and corrodes the storage tank(Koning, 2007)(Fabrizi, 2007)	▪ Molten salt costs 50% of the total thermal storage system cost. Hence, research needs to be pursued in finding an alternate material which would be economical without compromising the inherent characteristics.
Storage Tank	▪ There are no major material challenges in constructing a storage tank.	▪ Designing the storage tank and the corresponding control system is a technical challenge, which can be overcome with more field installations (Gabbriell, 2009).	▪ Designing a storage tank is a challenge as molten salt degrades significantly after 550°C (Gabbriell, 2009) ▪ There are design challenges with respect to the construction of storage tanks as low temperature tanks must be allowed to operate at a maximum permissible temperature for resistance against the heat loss (Gabbriell, 2009).	▪ Storage technology is under development and currently India does not have any CSP plant with storage. Information dissemination and technology demonstration are the need of the hour, which would lead to understanding this technology and the resulting challenges. Economic and safety concerns also need to be considered while designing the tank (Herrmann & Nava, 2002)(Farid, Khudhair, Razack, & Al-Hallaj, 2003).
Pump	▪ There are no significant material challenges in manufacturing a pump.	▪ Thermal growth and forestall distortion are high in the vertical cantilever shaft pump. Thus, there is a critical challenge involved in material selection and engineering (Daniel, 2007).	▪ Customized designs of pumps are required to pump the molten salt above 300 °C (Jonemann, 2013). Seals required to pump HTF from hot to cold storage tank and vice versa are major design challenges(Herrmann & Nava,	▪ There are only few Tier-1 pump manufacturers across the globe who have developed the know-how of manufacturing (ESMAP, 2013).

Components	Material Challenges	Technology Challenges	R&D, Design and Testing	Other Challenges
			2002)(Daniel, 2007).	

Exhibit 3.1

Critical Rare Earth Metals in Wind Technology

According to the International Union of Pure and Applied Chemistry (IUPAC), rare earth metals are a set of 17 elements in the periodic table –15 Lanthanides (atomic numbers 57-71) and Scandium (Sc) and Yttrium (Y). The total reserves of these metals in the world are estimated to be 110 million tonnes. China alone accounts for 55 million tonnes. Country-wise share in reserves and production is shown in Table 3.16.

Table 3.16: World Reserves and Production of Rare Earth Metals (Indian Bureau of Mines, 2012a)

World Reserves (as of 2013)		World Production (as of 2009)	
Country	Reserves(in million tonnes of rare earth oxides)	Country	Production (in tonnes)
Australia	1.6	Brazil	200
Brazil	0.036	China	129400
China	55	India	16
India	3.1	Malaysia	20
Malaysia	0.03	US*	2000
US	13	Russia	2500
Others	41		

Out of the seventeen metals, major rare earth metals used in wind turbines are: Dy, Nd, Mo, Nickel (Ni), Chromium (Cr) and Manganese (Mn). Chromium, Nickel, Molybdenum and Manganese are used in the high-grade steel used in WTG (JRC-IET, 2011). Dy and Nd are used primarily in PMSGs, which is the new upcoming trend in generator technology. These rare earth metals pose a critical challenge due to less availability and monopoly of China on most elements. The availability challenges to these metals are given below(JRC-IET, 2011):

Dysprosium: Demand for Dy is likely to increase with increasing penetration of PMSGs. China holds monopoly over the production of Dy and has imposed export quotas on rare earth minerals. Even in European countries with small resources of Dy (Greenland, Sweden), expanding production in the short-term is difficult. Availability of dysprosium can be a major raw material challenge in the near future given China's monopoly.

Neodymium: Nd is also used in permanent magnets and its demand is poised to increase; China enjoys monopoly on Nd and may increase restrictions following the rise in demand for permanent magnets.

Molybdenum: Mo is used in high strength steel, where demand growth will be substantial in the coming year China holds the highest reserves followed by the US, Chile and Peru. Geo-political risk is lower for this material as compared to Dy and Nd due to distribution of supply around the world. Mo has several applications as an alloy with steel in wind turbines, jet engines, etc. Considerable amount of upcoming capacity is expected and lead times are lesser, hence this element poses low risk to wind supply chain efficiency in the near future.

Nickel: Ni is primarily used in stainless steel applications indicating high demand in the future. It is geographically dispersed and global production is expected to ramp-up in the near future. The largest producers are Russia, Indonesia, and the Philippines, which have low-moderate political risk. Production is also dispersed through Canada, Australia, and Europe. Overall, this element is unlikely to pose supply chain constraints in the future.

Chromium and Manganese: The demand for Cr and Mn is relatively low and are available in sufficient quantities in India (Indian Bureau of Mines, 2012a).Cr is extracted from Chromite ore and Mn from Manganese ore. These metals pose no supply chain issues in the near future.

The major challenge to the wind supply chain in India may be posed by Dy and Nd due to the relative unavailability of Dy and lack of commercial production of Nd anywhere else. The Indian government has recently expressed concerns over China's monopoly and has plans to ramp-up the production of rare earths in India (Mineweb, 2011)#. India extracts rare earths from Monazite ores which have higher quantities of lighter rare earths such as Nd (around 20%)(IREL, 2013). Currently, Indian Rare Earths Limited (IREL) a Public Sector Unit (PSU) is responsible for the mining and extraction of rare earths. Since India has the largest monazite deposits in the world (11.93 Mt)(The Economic Times, 2013)), sufficient quantities of Nd can be extracted commercially in India itself. While the Mining Engineers Association of India (MEAI) asserts that private players other than IREL be allowed in mining of rare earths (The Economic Times, 2013), IREL is actively looking out for manufacturing technologies of rare earth metals such as Nd (IREL, 2013).

* As per best estimates available (British Geological Survey, 2013)

Indian Rare Earths Limited (IREL) currently has 5000 metric tonne per annum manufacturing capacity

Exhibit 3.2

Grid-scale Energy Storage^

Variability of power generated from renewable sources and the lack of fulfilment of peak demand by wind farms and solar parks result in a demand-supply mismatch. Any large variation in either of the technologies may create balancing challenges in grid operation. Grid-connected energy storage is one of the favourable solutions to tackle both; the uncertainty and variability of renewable sources (refer to **Annexure4**). Energy storage can be considered as an independent component of RE technology along with other technologies like solar power, wind power, etc. Currently with a negligible presence in the Indian market (except for pumped storage hydro, which exists in India and requires substantial ramping up), grid-connected energy storage can become a critical aspect in the RE scenario. As in the future, the share of renewable energy is expected to increase, it is essential to have energy storage facilities to support RE generation. It is also observed that seasonal other than peak demand and off-peak scenarios from renewables result in surplus power generation whereas peak demand scenarios mostly yield power deficit. This gives an opportunity to deploy grid storage solutions like pumped storage hydro, battery technologies and CSP with storage facility, which can store energy during off peak hour and use the latter during peak hours (PGCIL, 2013). Considering a high renewable penetration scenario, fulfilling the energy storage requirement may prove to be tedious, which makes grid-connected energy storage a critical component in the future.

Table 3.17: Balancing Reserve Requirement (PGCIL, 2013)

Type of storage	Capacity by 2022 (GW)	Capacity by 2032 (GW)	Capacity by 2050 (GW)
Battery based storage and flywheel	2 (2 hrs)	4 (2 hrs)	10 (2 hrs)

Table 3.17 shows the battery-based energy storage requirement in India in the coming decades, up to 2050. This excludes pumped storage. To achieve this, the investment required for battery-based storage in the 13th, 14th and 15th FYP (2 GW in each FYP) will be INR 40,000 crore for each plan period and further, an investment of INR 1,20,000 crore would be required for the next 18 years from 2032 to 2050 (6 GW) (PGCIL, 2013). The implementation of grid-connected energy storage technology in India will provide a boost to RE penetration and help India achieve its RE targets. Lack of a constructive grid-connected storage policy in India is another reason, which makes grid storage technology very critical. The India Energy Storage Alliance (IESA), which was launched in 2012 to promote Electric Energy Storage (EES) technologies, is a major step taken to help make Indian industries and power sector more competitive and efficient. Apart from this, considering the criticality of grid-connected storage and their proven importance in renewable grid integration, there is a major need for R&D in grid storage technologies to come up with cost effective and large density energy storage solutions with excellent cycle life.

^The exhibit only considers electrochemical-based storage.

4 Indigenize or Import

The ‘Make or Buy’ decision for any country has a strategic significance. Economists have considered the ‘Make or Buy’ decision from the perspective of costs (A. Aykut, M. Atilla, & Nuri, 2003). In strategic sectors like energy security, the decision to ‘manufacture locally or import’ is not solely driven by cost considerations. Besides cost, the Make or Buy decision should also be considered from twin perspectives of risks associated with the import dependence and opportunities linked with a particular sector achieving long-term manufacturing leadership.

Import dependence risks are the uncertainties linked with long-term reliability on imports from a single country or countries in a region. The ever changing geo-political scenario and diplomatic relationships can stifle the reliable supply of material in long-term. For instance, China holds a commanding monopoly over the supply of Rare Earth Elements (REE), controlling about 95% of mined production and refining. In 2010, it put an embargo on the export of REE to Japan and the US in the wake of strained diplomatic relationships (Forbes, 2010). In strategic sectors like defence, food grains, etc. import dependence risks can compel the government to manufacture/produce even at a higher cost, defying the principle of cost economics. Keeping this in mind, GoI in its ‘NMP, 2011’ has declared solar and wind energy as strategic industries and categorized them under special focus sectors (DIPP, 2011)

On other hand, the Make or Buy decision should also be considered from the long-term growth potential of an industrial sector. The objective is to harness the comparative advantage in producing at a relatively lower cost with high employability prospects and become an export hub.

A ‘Make or Buy’ analysis has been carried out from the perspective of domestic manufacturing versus imports. This section determines the methodology for such an analysis and uses it to evaluate the critical components and sub-components of wind and solar technologies. The analysis is conducted to arrive at a decision on whether the concerned critical component should be domestically manufactured (Make) or sourced from outside the country (Buy). The decision to ‘Make or Buy’ has been examined for both short (2013-17) and long-term (beyond 2017) scenarios.

4.1 Methodology

For renewable systems, there are several points that must be considered before arriving at a decision to facilitate domestic manufacturing or import. These include unique features of renewable power like specificity, energy security, technology, the need for greater performance capability, to name a few. In this study, the ‘Make or Buy’ analysis has been conducted from short-term (until 2017) and long-term (beyond 2017) perspectives. The matrix has been developed after obtaining inputs from different renewable component manufacturers, policy makers, and developers. A qualitative analysis was also conducted for each critical component in the form of a SWOT analysis. The parameters considered for SWOT analysis are availability of raw material, skilled labour, job creation, infrastructure availability, etc. A ‘Make or Buy’ decision has been arrived at after reviewing both the matrix and SWOT analyses.

4.1.1 Short-Term ‘Make or Buy’

The matrix for short-term Make or Buy (until 2017) is given in Table 4.1. The various parameters considered for evaluation are domestic manufacturing capacity, price of domestically manufactured components vis-a-vis imported price, technology depth, and percentage of domestic content, raw material availability, raw material requirement, and job generation potential.

Table 4.1: Short-term Make or Buy Matrix for Critical Components

Component	Domestic manufacturing capacity	Cost (INR crore/MW)		Technology depth	Domestic content (%)	Raw Material Availability	Raw Material Requirement (2012-17)
		Import	Domestic				

1. Domestic Manufacturing Capacity

The indigenous manufacturing capacity of a particular component would indicate whether current production is sufficient to cater to the demands of the wind/solar industry. This determines whether imports are required or supply from domestic manufacturers should be sufficient.

2. Cost of Import vs. Indigenization

Price plays a very important role in the Make or Buy decision. The difference between the import and the domestic price of components plays an important role in making a case for domestic manufacturing or imports. However, this parameter is considered in consent with the strategic significance of the sector.

3. Technology Depth

Technological depth can be best described in terms of three levels: "*first, the basic level that involves the ability to operate and maintain a production plant based on imported technology and components; second, the intermediate level that consists of the ability to develop local components and supply chain and involves absorption of process technologies; and third, an advanced level that involves absorption of product technologies and fundamental research on materials and components*" (Planning Commission , 2012b). Based on various inputs, the technology depth has been identified as high, medium, or low.

4. Domestic Content (in the component)

The current sourcing mix of renewable energy components show whether a particular component is procured domestically or imported from an overseas supplier. The current sourcing mix has been derived from industry inputs (**Annexure 5)**. A component's domestic content is considered 100% if all the raw materials and/or subcomponents are procured or manufactured indigenously.

5. Raw Material Availability (in India) and Requirement

Inputs on raw material were obtained from the wind and solar industry. They have been classified as high, medium or low based on the industry's inputs on a material's availability in India.

Raw material availability is a useful parameter for the 'Make or Buy' decision. Sufficient good quality raw material availability encourages indigenization while low quality raw material can be a major reason for dependence on the import of components. The study engages a range of renewable energy demand projections[39] as shown in Figure 4.1(for 2017) and Figure 4.2 (for

39

2032) to estimate the component-wise raw material requirement. FYP, NAPCC, and NAPCC Plus are the three scenarios considered in this study. Wind and Solar capacity targets based on the different scenarios are highlighted in **Annexure 3**. **Annexure 6 and Annexure 7** provide a brief description on the methodology and assumptions used to calculate the raw material requirement in Wind and Solar technologies respectively

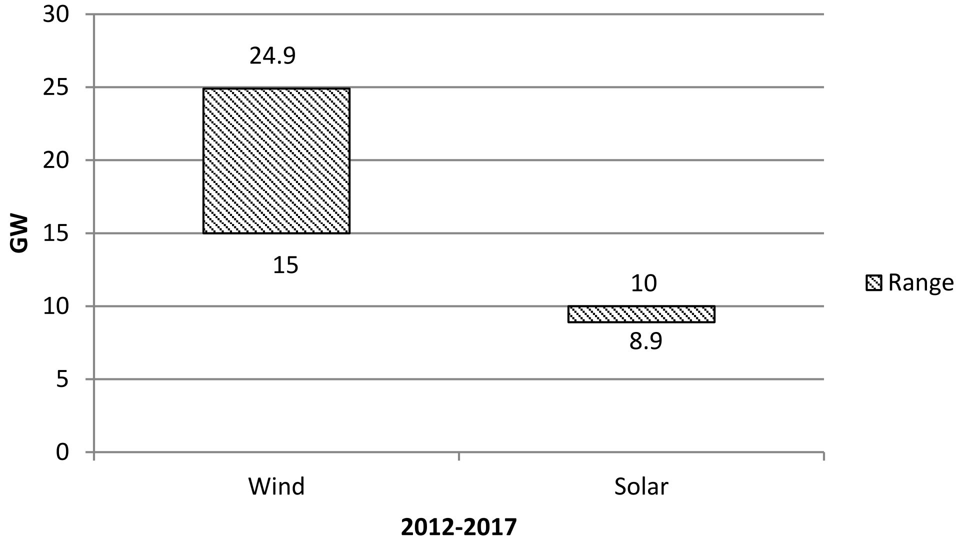

Figure 4.1: Estimate of the Range of Installed Wind and Solar Capacity (in GW) During 2012-17

6. **Jobs**

Availability or creation of jobs is an important criterion for a policymaker. The study seeks information on the creation of direct jobs, which comprises manufacturing (full-time equivalent), and construction (one time) jobs. The study does not examine indirect[40] or induced jobs[41]. In the case of the wind industry, information on jobs was obtained from secondary literature, whereas, for solar, information was sourced from the industry.

4.1.2 SWOT Analysis

SWOT analysis is a qualitative analysis framework, which stands for Strength, Weakness, Opportunities, and Threats. This complements the quantitative analysis conducted for this section of the study. The SWOT analysis is conducted for the critical components identified in the previous chapter.

4.1.3 Long-Term Make or Buy Matrix

The long-term Make or Buy matrix is shown in Table 4.2. In the long-term (horizon 2032), two parameters viz. raw material requirement and job creation become crucial for a 'Make or Buy' assessment of critical components. The raw material requirement is estimated on the basis of a range of projections made for renewable energy penetration in 2017 and 2032 under different scenarios as highlighted in Figure 4.2. No SWOT analysis has been performed for the long-term.

Table 4.2: Long-Term Make or Buy Matrix for Critical Components

Critical Component	Material Requirement (2017-32)	Jobs (per MW)

[40] Indirect jobs are jobs that provide goods and services to companies that provide direct jobs.
[41] Induced jobs support activity related to energy projects.

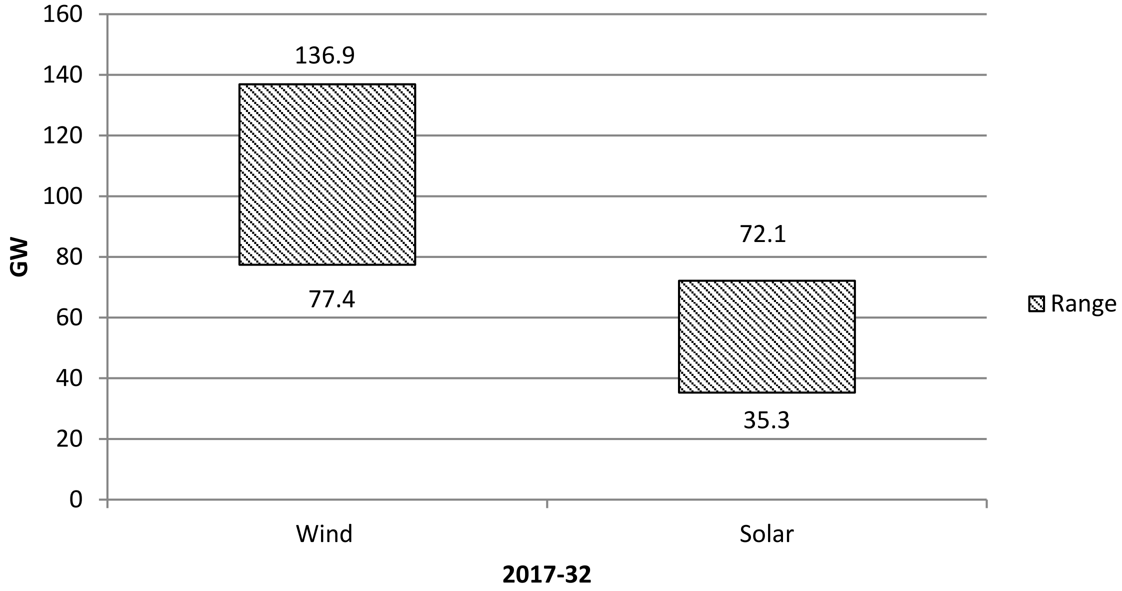

Figure 4.2: Technology Wise Estimate of the Installed Wind and Solar Capacity (in GW) During 2017-32

This exercise attempts to provide a direction for decision makers to adopt a Make or Buy strategy at the national level. The analysis emphasizes on the methodology used to calculate or obtain the different parameters. Both, c-Si and a-Si have several common components (glass, encapsulant, and backsheet), hence the analysis and results of the different components of PV are shown together. This is also the case for CSP. However, this is not the case for wind technology. Technology-specific matrix in the subsequent sections on each industry summarizes the material/component requirement estimates for all the technologies.

4.2 Wind

4.2.1 Short-Term Make or Buy

A matrix has been developed in Table 4.3 to evaluate the short-term Make or Buy decision for wind turbine components. Quantitative (figures and percentages) and qualitative indicators (high, medium, and low) have been obtained from information available on the internet and that sourced from industry and literature review.

Domestic manufacturing capabilities are good for most major components, except large bearings and gearboxes. Large casting and forging capabilities to cater to the needs of the wind industry are also less in number. Cost differences indicate a preference for manufacturing all components indigenously.

Table 4.3: Short-Term Make or Buy Matrix

Component	Domestic manufacturing capacity	Price (INR. crore/MW)		Technology depth	Domestic content (%)[42]	Raw Material Availability[43]	Jobs[44]
		Import	Domestic				

[42] Sourced from the working committee report on "Comprehensive Report on Wind Energy in India" by INAE
[43] Raw material availability is based on information from industry sources or literature review

Component	Domestic manufacturing capacity	Price (INR. crore/MW)		Technology depth	Domestic content (%)[42]	Raw Material Availability[43]	Jobs[44]
		Import	Domestic				
Blades	High	1.06-1.47	0.79-0.85	Medium	38.9	Low	25,600-42,500
Gearbox	Low-Medium[45]	0.85-0.86	0.48-0.57	Medium	37.5	Medium-High	24,100-39,900
Generator	High	0.23-0.54	0.13-0.15	High	44.2	Low	21,700-36,000
Tower	High	1.74-1.77	0.94-1.05	High	100	Medium-High	5,400-9,000
Hub (casting)	Low	0.09-0.31	0.05-0.5	Medium	N/A	Medium	10,800-17,900
Main shaft (forging)	Low	0.13-0.21	0.07-0.08	Medium	N/A	Medium	7,100-11,800
Large bearing	Low	0.08-0.12	0.04-0.05	Medium	N/A	Low	3,500-5,800

Steel/Iron is the main raw material in a wind turbine and constitutes around 90% by weight.

Table 4.4 depicts the steel requirement in the critical components of a wind turbine. In India, the overall consumption of steel exceeds its production and grew to 70.9 Mt in FY12 as against 66.4 Mt in FY11.The overall consumption has expanded at a CAGR of 8.7% during FY07-FY12, while production recorded a CAGR of 4.2% during 2008-11 (IBEF, 2013a).

Table 4.4: Steel Requirement for 2 MW Wind Turbine Components (Martinez E, 2009)

Component	Weight (Tonne)	Steel/ Iron contribution
Tower	150-385	100% Steel
Gearbox	18-19	50% Iron, 50% Steel
Bearings	1	100% Steel
Generator	9-10	66% Steel
Hub	15-18	100% Iron
Main shaft	7-8	100% Steel

Raw material requirements have been estimated assuming a 1.5 MW turbine with a total weight of 164 tonnes. The contribution of various raw materials in a wind turbine is shown in Table 4.5.

Table 4.5: Raw Material Contribution in a Wind Turbine (Congressional Research Service, 2012)

Raw material	Contribution (%)	Tonne Per MW
Steel	89.10	97.416
Fiberglass	5.80	6.341
Copper	1.60	1.749
Concrete	1.30	1.421
Adhesive	1.10	1.203
Aluminium	0.80	0.875
Core material (balsa/foam)	0.40	0.437

[44] These components comprise only for 62% of manufacturing jobs, the rest is covered by other components.
[45] Only international players have setup gearbox manufacturing in India

The material requirements for a wind turbine up to 2017, considering the FYP and NAPCC scenarios have been shown in Figure 4.3.

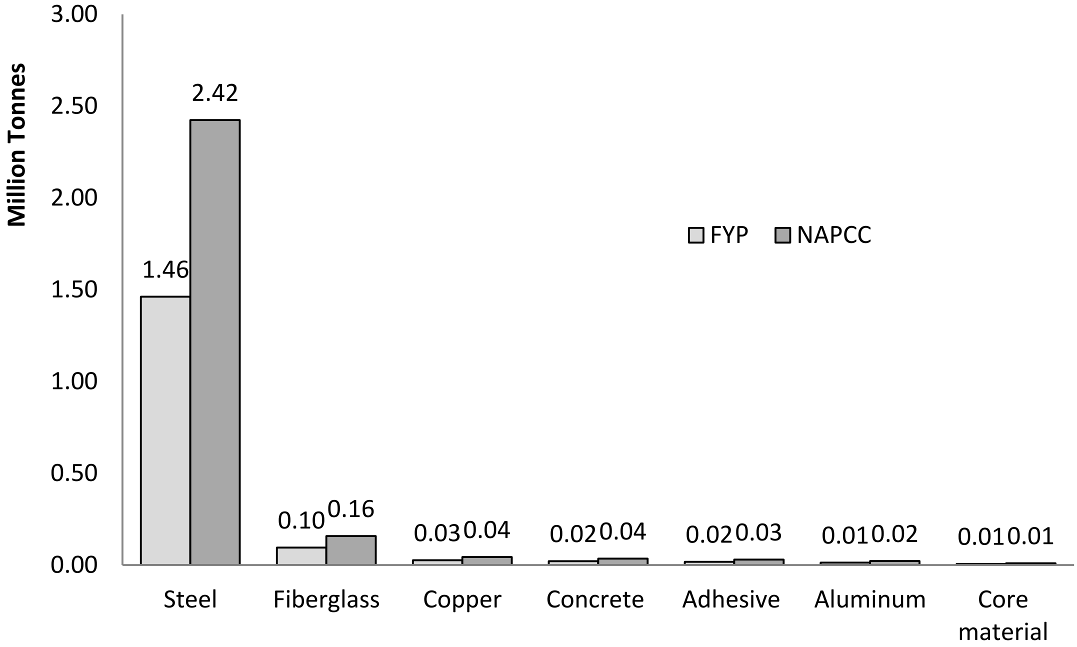

Figure 4.3: Wind Turbine Material Requirements up to 2017

Approximately 15% penetration of PMSG generator is in wind turbine installations. A bottleneck in the supply of rare earth metals could pose a major problem for PMSG generators. India is dependent on the import of Mo and Ni and this is expected to continue until commercially extractable mines are found (FICCI, 2013) (Indian Bureau of Mines, 2012). Cr is extracted from chromite ore; supply of chromite matches the demand (Indian Bureau of Mines, 2012). The critical metal requirements per MW are shown in Table 4.6.The demand of Dy and Nd will depend on PMSG penetration in the wind turbine market.

Table 4.6: Critical Metal Requirements per MW (JRC-IET, 2011)

Critical elements	Dysprosium	Neodymium	Molybdenum	Nickel	Chromium	Manganese
kg/MW	14.06	254.01	136.6	663.4	902.4	80.5

The requirements up to 2017 have been estimated in Figure 4.4.

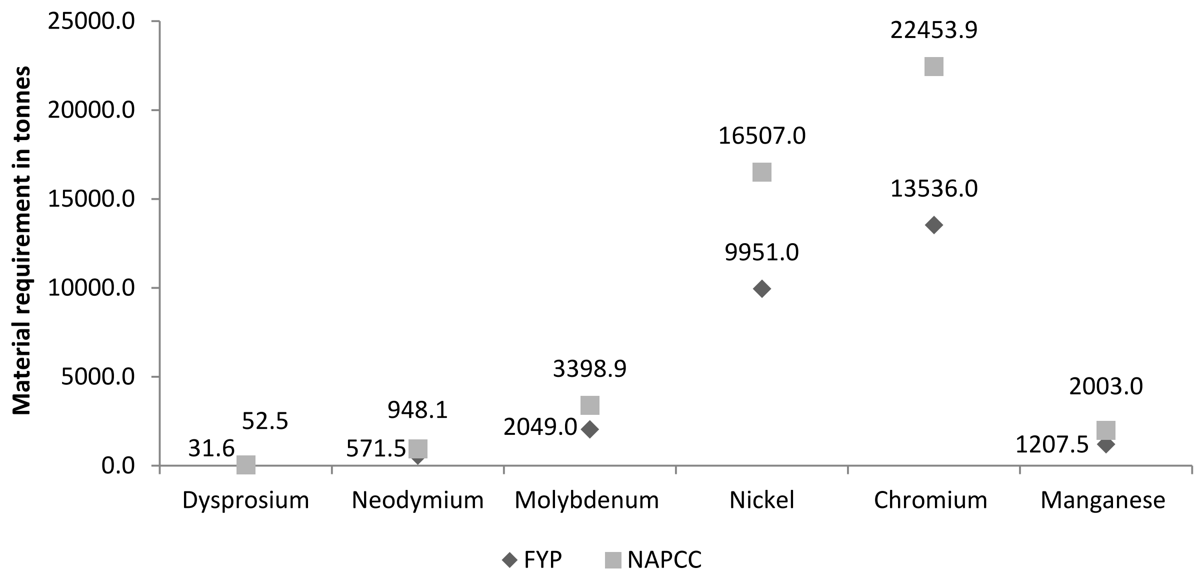

Figure 4.4: Critical Metal Requirement Estimates for Wind Technology up to 2017

Based on an analysis of the information provided so far in this section, barring blade and generator, most of the components can be manufactured indigenously. Further, a SWOT for the critical components of the wind turbine is highlighted in Table 4.7 to bolster the results obtained so far.

Table 4.7: SWOT Analysis for Wind Turbine Components

Component	Strength	Weakness	Opportunity	Threat
Blade	▪ Major blade manufacturer LM wind has facilities in India. Many major players such as Suzlon, Wind World(earlier Enercon) and Inox Wind have blade manufacturing facilities in India ▪ Cheap labour ▪ Manufacturing process is not very sophisticated.	▪ Raw material needs to be imported ▪ Cold storage requirements for the prepreg process needs additional infrastructure ▪ Logistics is a constraint due to unavailability of larger trucks, cranes and warehousing facilities ▪ Maximum carrying capacity of trucks is specified as 44 GVW by Ministry of Road Transport and Highways and capacity needed for carrying blades, towers, etc. exceeds this ▪ Aerodynamics technology in India is underdeveloped ▪ Research and development for wind	▪ One of the largest components of the wind turbine ▪ Research and development on blades will be useful not only for the wind industry but also in the aeronautics field ▪ Tremendous wind potential in India, especially with repowering and offshore ▪ R&D can be done in collaboration with private players and government bodies such as Hindustan Aeronautics Limited (HAL) ▪ Research on speciality fibres and composite materials will be	▪ Uneven demand for wind turbines due to policy uncertainty ▪ Withdrawal of existing benefits by government ▪ Raw material shortages in the future.

Component	Strength	Weakness	Opportunity	Threat
		turbine blades, speciality fibres and composite materials is lacking ▪ High capital expenditure and expertise required for blade manufacturing.	beneficial to several sectors ▪ Development of offshore wind sector will provide more opportunities for designing blade with larger rotors.	
Gearbox	▪ Major international gearbox manufacturers such as Winergy, ZF Friedrichshafen, etc. are present in India ▪ Raw material is not a concern ▪ High job creation ▪ Exposure to other sectors such as power generation, mining, and metal manufacturing.	▪ Technology depth is comparatively low ▪ Lead time is high ▪ High sector concentration.	▪ R&D and testing facilities for gearboxes, if developed, will give a tremendous boost for gearbox manufacturing not only for wind industry, but also other industries where large gearboxes are required ▪ Sectors such as power generation, mining, and metal manufacturing require special grade of steel, which could be catered by supplier to the gearbox manufacturer.	▪ Technology trend towards gearless and hybrid drives ▪ Low demand for wind turbines due to policy uncertainty ▪ Withdrawal of existing benefits by the government.
Tower	▪ High indigenous manufacturing capacity (> 4000 MW) ▪ Technology adoption and development is relatively easy ▪ Sector concentration is low and lead times are low.	▪ Since tower is a large component, logistics cost is high if it is imported ▪ Major equipment used for rolling steel sheets is imported.	▪ Job creation in tower manufacturing is high ▪ Since indigenous content in tower is high, manufacturing tower will also create a lot of employment in other related sectors viz. transportation, logistics, etc. ▪ Tower is customized for wind industry but	▪ CRGO/CRNGO steel used in towers is imported.

Component	Strength	Weakness	Opportunity	Threat
			also finds applications in civil construction, transmission and distribution, etc. ▪ Manufacturing towers and perhaps foundations for marine conditions for offshore wind turbines.	
Generator	▪ Major generator suppliers such as ABB India, TD Power Systems and Emerson Electric are present in India ▪ Both asynchronous and synchronous generators are used in India ▪ Lesser lead times and logistical constraints	▪ Annealed Copper strips which are used to make conductors for generators have a very limited vendor base in India ▪ Highly energy intensive process ▪ Lack of skilled labour ▪ Designing high pole-low speed generators for upcoming gearless turbine is quite complicated	▪ Significant job creation in wind turbine generator manufacturing ▪ Lower sector concentration, use in several other industries like railways and power	▪ Rare earth metals Nd and Dy whose alloys are used in manufacturing PMSG generators are not available in India ▪ Electrical steel used for manufacturing wind generator is usually imported.
Large bearing	▪ Major global players like Timken, SKF, FAG, etc. are present in India.	▪ Low technology depth ▪ Large bearings are meant only for wind turbines resulting in low demand ▪ Lesser job creation opportunity ▪ A specific grade of steel is required for bearing manufacturing, which is not sufficiently available.	▪ Larger demand for wind installations would yield greater demand.	▪ Withdrawal of existing benefits by government.
Hub & Main Shaft	▪ Casting and forging facilities are already present for smaller size components ▪ Technology know-how is present	▪ Forging and casting facilities for larger turbines are not available and up-scaling the existing ones is of utmost importance	▪ Development of casting and forging industry would be crucial to the growth of the wind industry.	▪ Demand uncertainty in wind industry may not be a viable opportunity for setting up large casting and forging facility.

Blade: Blade is one of the largest components of a wind turbine. With increasing rotor sizes and the requirement to suit Indian weather conditions, it is imperative that blades are manufactured indigenously. Currently, a capacity to manufacture around 9,000 MW per annum exists among the major players. Although raw material is largely imported, players such as Kemrock have also set-up a carbon fibre manufacturing facility. Blade manufacturing also has good job creation potential and scope for research and development. The analysis therefore concludes that manufacturing this component can be fully indigenized.

Gearbox: The technical expertise required for designing gearboxes for wind turbines is not available in India. Major gearbox manufacturers in India are international players. Moreover, gearless machines are becoming popular in the market and their share is expected to rise given increasing rotor sizes and corresponding drivetrains. However, there are no raw material issues and the analysis estimates high job creation. The domestic value addition for this component is around 40% as most of the design aspects of a gearbox are not done in India; forging, hobbing heat treatment, etc. are the value additions in India. Hence, for a gearbox, either Make or Buy is preferable in the short-term.

Generator: Major international suppliers such as ABB, TD Power Systems, and Emerson Electric have manufacturing bases in India. Further, a few OEMs have also established their own generator manufacturing facilities. Both synchronous and asynchronous generators are manufactured in India. Indian manufacturers are dependent on the import of CRNGO/CRGO steel, which is the main raw material used in generator manufacturing. Generator manufacturing is well established and India has more than 9,000 MW per annum capacity. Hence, in the case of generator making it indigenously is preferable over import.

Tower: The technical expertise required in manufacturing a tower is less as compared to other major components. The current manufacturing capacity with domestic players is high (more than 5, 000 MW per annum).The availability of S-355 steel used in towers is of a concern as it is largely imported. However, hybrid towers, which use concrete, are on the rise, which can address this issue. Moreover, the tower is a large component and creates greater number of jobs. The domestic contribution to tower manufacturing in India is 100% (in terms of raw material, process, design, and value addition). Hence, the study concludes that tower manufacturing should be indigenized.

Hub and Main Shaft: Large forging and casting facilities are less prevalent in India. Casting and forging operations in India need more technological expertise and higher energy intensity. Moreover, these processes have higher emissions. Processes with lower efficiency, poor welding techniques, and quality delivery are some issues that suppliers face. However, it is important to develop casting and forging facilities in India to address future demand. In the short run, manufacturing indigenously is preferred over Buy.

Large Bearing: The demand for large bearings (specific to wind) is low. Lack of skilled expertise as well as casting and forging facilities to manufacture bearings pose another challenge. Moreover, wind is a small segment for bearing manufacturers; therefore, manufacturers are unwilling to invest in this segment. Job creation in bearing manufacturing specific to wind has also been estimated as low. Most OEMs buy from already established foreign players such as SKF and FAG. Therefore, the analysis and expert inputs suggest that it is preferable to 'Buy' rather than 'Make' this component.

For wind turbine components, the results of the Make or Buy analysis in the short-term (up to 2017) has been summarised in Table 4.8. While a 'Make; strategy is inherently preferable to 'Buy', for some components such as gearbox, main shaft and hub, it is recognized that forging and casting of large components need to be developed and either Make or Buy may be preferable in the short-term. For large bearings, it is more viable to import them rather than indigenously manufacture them.

Table 4.8: Decision to Make vs. Buy of the Different Critical Components for Wind Technology

Component	Make	Buy
Blades	✔	
Gearbox	✔	✔
Generator	✔	
Tower	✔	
Hub (casting)	✔	✔
Main shaft (forging)	✔	✔
Large bearing		✔

4.2.2 Long-Term Make or Buy

In the long-term, emphasis on R&D of different components would be the key to indigenize all the critical components. This entails technology leapfrogging, conducive environment (government incentives) along with the prevalent demand (as projected in this study). Other factors such as T&D infrastructure for power evacuation would also need to be addressed. The material requirements with the current global consumption estimates along with long-term requirement of various components of the wind turbine are given in Table 4.9.

Table 4.9: Material Requirement Estimate for Wind Turbine for Various Scenarios (in kilo tonnes)

Raw Material	(2012- 2032) FYP		(2012- 2032) NAPCC		Production in India (for all sectors in kilo tonnes in 2012-13)
	Solar driven scenario	Wind driven scenario	Solar driven scenario	Wind driven scenario	
Steel	9,001	9,527	15,178	16,093	56,720[46]
Fibreglass	586	620	988	1,048	29
Copper	162	171	273	289	693[47]
Concrete	131	139	221	235	272,000[48]
Adhesive	111	118	187	199	60[49]
Aluminium	81	86	136	144	3,800
Core material	40	43	68	72	N/A

Major material requirement for additional wind power capacity in India, up to 2032, could reach a maximum of 9% of current steel production, 3% of Copper and cement production and 1% of current Aluminium production. The current consumption of epoxy resin is almost equivalent to the future requirements by the wind sector alone. Besides this, fibreglass production will need to be ramped-up in the future to cater to the growing requirements of the industry.

The critical metals requirement estimates assume that penetration of PMSG generators will be 20% in India by 2032. Table 4.10 depicts the critical metal requirement.

Table 4.10: Critical Metal Requirement Estimate for Various Scenarios (in tonnes)

Critical metals	2032 FYP		2032 NAPCC	
	Solar driven scenario	Wind driven scenario	Solar driven scenario	Wind driven scenario
Dysprosium	260	275	438	465
Neodymium	4,694	4,968	7,915	8,392
Molybdenum	12,622	13,360	21,283	22,566
Nickel	61,298	64,881	103,362	109,594
Chromium	83,382	88,255	140,600	149,076
Manganese	7,438	7,873	12,542	13,299

Wind turbines with PMSG have a significant penetration only in China (as of 2010), with conservative estimates of 45%. The global penetration is likely to be 15% of the total installations as of 2020 and possibly 20% by 2030 (Constantinides, 2012).

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[46] Production figures of crude steel (2012-13) (Ministry of Steel, GoI, 2013)
[47] Production figures for refined copper (2012-13) (Economic Times, 2013)
[48] Figures for cement production in India (2012-13) (IBEF,2013)
[49] India's consumption figures(in kilotonnes) of epoxy resin for 2012-13 (Plastindia Foundation, 2013)

China has approximately 80% of the world's rare earth deposits followed by Japan with 17% and Europe the rest (3%). In the past, China has withheld the supply of these materials because of disputes and hence a repeat of such situation could lead to a supply crunch (Bourzac, 2011) (Constantinides, 2012).

Job creation through the manufacture of the various components of the wind industry by 2032 under the FYP and NAPCC scenarios is shown in Figure 4.5.

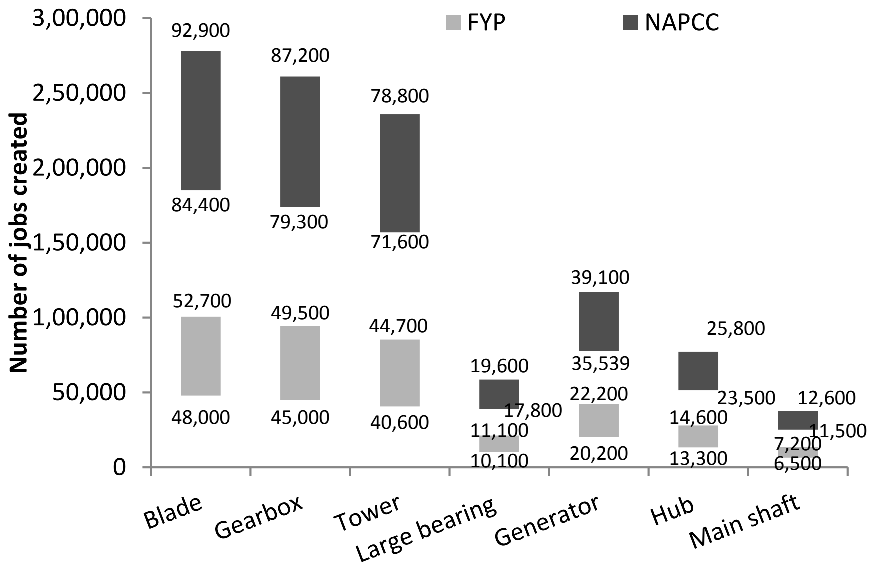

Figure 4.5: Job Creation under Various Scenarios by 2032 for Wind Turbine Components

The long-term scenario suggests that in the raw material availability is not a constraint. Therefore, it is recommended that all components are indigenously produced in the long-term (with the exception of large bearings which could be indigenized or imported), with a potential to create jobs.

4.3 Solar PV

4.3.1 Short-Term Make or Buy

In 2017, the cumulative installed capacity of c-Si and a-Si is expected to be in the range of 5 GW and 0.8 GW, respectively. Figure 4.6 depicts the share and estimate of the two technologies during 2012-17. The subsequent section examines the domestic vs. imported price, existing sourcing mix, materials required (based on the projection) and jobs created for each of the critical components. This is followed by the SWOT analysis of each component.

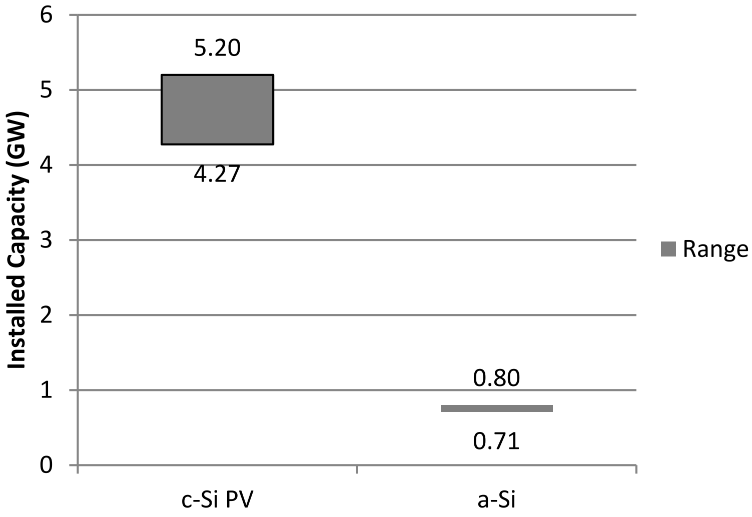

Figure 4.6: Technology Wise Estimate of the Range of Installed c-Si and a-Si (in GW) During 2012-17

Table 4.10 shows the Make or Buy matrix for crystalline and thin film PV. The total module price of a-Si is around INR 42-44/Wp and a-Si PV is not being produced in India. The study collated information from different stakeholders and secondary literature. A difference of INR 6-7[50] between the domestic and imported price of c-Si module was observed. The information on sourcing mix is an estimate of the industry's perspective on the situation in 2017. The material requirement corresponds to a typical 240W and 128W module for c-Si and a-Si technology, respectively. Technology specific projections for PV are highlighted in **Annexure 3.**The assumptions used to determine the material requirement for c-Si and a-Si technologies are described in **Annexure 7.**

From the Table 4.11 it can be observed that India is highly competent when it comes to manufacturing glass, encapsulant, and backsheet.

[50] Imported price is around 36-38 INR/Wp in December'13, while domestic is 42-45 INR/Wp (source: Stakeholders 'Interaction (Refer **Annexure 14**)

Table 4.11: Short-Term Make or Buy Matrix for c-Si and a-Si PV

Component	Domestic manufacturing capacity	Price (INR crore /MW)		Technology depth	Domestic content (%)	Raw material availability	Raw material requirement (2012-17)	Jobs (per MW)
		Import[51]	Domestic[52]					
Crystalline Silicon PV								
Cell	Low	2.37	2.5-2.7	Medium	0	High	29.9 – 36.4 kilo tonnes (kt) of polysilicon	FTE[53] = 21,400 to 26,000
Front glass	Low	0.34	0.2	High	50	Low	239 - 291 kt	7,300 to 8,900
Encapsulant	Medium	0.33	0.14-0.16	High	10	Low	62 - 76 million m^2	25 to 520[54]
Backsheet	Medium	0.19	0.21-0.27	High	10	High	31 – 38 million m^2	20 to 160[55]
Amorphous Silicon Thin Film PV								
Glass Substrate	Low	0.51	--[56]	High	50	Low	65 - 73 kt	1,200 to 1,400
Silane Gas	Low	-	0.1	Low	0	Low	0.045 – 0.05 kt	--
Encapsulant	Medium	0.5	0.3	High	70	Low	8.4 - 9.4 million m^2	4 to 80
Backsheet	Medium	0.29	--[57]	High	100	High	8.5 – 9.5 million m^2	4 to 25

51 Average Selling Price of c-Si PV module imported from China.
52 Stakeholders' interaction information updated on 24th December 2013.
53 FTE = Full Time Equivalent
54 The range corresponds to semi-automated to fully automated lines.
55 The range corresponds to semi-automated to fully automated lines.
56 Approx. INR 19 was quoted which didn't seem correct.
57 Approx. INR 10 was quoted which didn't seem correct.

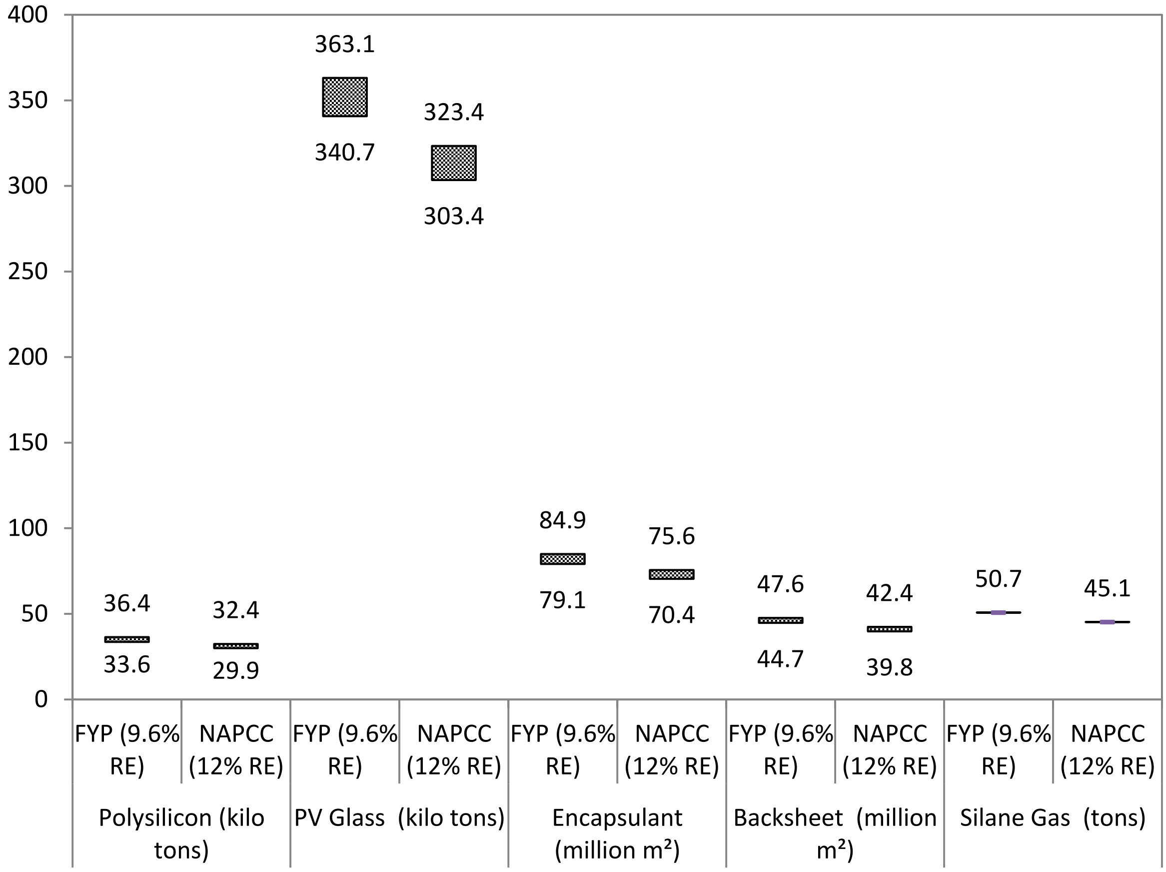

Figure 4.7: Short-Term Material Requirement for Critical Components

The following section provides an overview of the raw material requirement for all critical components, i.e., c-Si cell, PV glass, encapsulant, backsheet and silane gas. Figure 4.7 shows the range of raw materials required by 2017 for FYP and NAPCC scenarios. Table 4.12 gives an overview of the SWOT analysis for the short-term (2012-17).

Table 4.12: Short-Term Swot Analysis for Critical Components

Component	Strength	Weakness	Opportunity	Threat
Si-wafer	• Two fab cities have been proposed and are at various stages of development • India has 1,386 MW of cell manufacturing capacity and 2,756 MW of module manufacturing capacity • BHEL, Lanco Solar are at various stages of developing a fully vertical integrated unit having an assembly line which manufactures solar grade Silicon ingot, wafer, cell and module • Availability of low cost skilled labour.	• Production of polysilicon is highly energy intensive process i.e. approx 80-150 kWh/kg of energy is consumed in the purification of silica to Silicon • Absence of economies of scale increases the cost	• Cost of imported wafer has increased recently due to high demand and depreciating Indian currency • JNNSM target provides an assured market for locally manufactured silicon wafers • Polysilicon and wafers are also used in electronics and IT industry.	• Wafer industry is dominated by few players, so supply of wafers or price increase in future could be a major threat to Indian cell manufacturing industry • Low cost finance and other incentives by different countries (free or cheap electricity, low cost land etc.) could again lead to supply glut situation • Disruptive technologies i.e. direct 'gas to wafer' technology could affect the conventional industry.
c-Si cell	• Solar industry has a high growth potential, so the demand for solar cell will also increase with solar capacity addition • Availability of low cost labour • The price difference between imported and domestic manufactured is not very significant and further reduced if freight charges and opportunity cost due to high lead time are included • Eligible for Domestic Content Requirement.	• The highest manufacturing capacity of any single player is not more than 200 MW. • India has no manufacturing base for the basic raw material i.e. Silicon wafer • Establishment of cell manufacturing facility is capital intensive (USD20 million) • There is no investment in technology development via Solar Research Centres/R&D Labs, Test facilities, Resource assessment facilities, Training centre • Lack of concrete policy support by the government to revive the domestic	• Manufacturing capacity is very less if compared to the demand to meet the JNNSM targets • As per our projections, the total demand of cell (Under various scenarios) varies from 29.9 – 36.4 kilo tonnes by 2017. However, the current production capacity is 5.26 kilo tonnes • High potential to make India a manufacturing hub.	• The wafer industry is dominated by few players, so supply of wafers or increase in price in future could be a major threat to Indian cell manufacturing industry • Low demand for indigenously produced cells • Thin film technology is a competent technology, which is gradually eroding crystalline PV's share.

Component	Strength	Weakness	Opportunity	Threat
		manufacturing industry • Lack of standardization.		
Glass	• India already has a manufacturing capacity of 4.2 million m^2 of low Iron content glass • Availability of low cost labour • Bulk of Indian PV module manufacturers are sourcing the solar glass indigenously • The difference between imported and indigenous cost is not very significant	• Non-availability of low Iron content silica (raw material) • A production line for low Iron content glass requires significant investment • Energy intensive production • Manufacturing facilities are highly specialized • Lack of R&D to develop substitutes and improve the productivity • Absence of specific policy framework to promote solar glass manufacturing.	• There is an adequate demand for low Iron content glass • As per our projections, the total demand for glass (under various scenarios) varies from 1,400 million m^2 to 2,600 million m^2 by 2032. However, the current production capacity is 4.2 million m^2 • The primary application for glass is automobiles, buildings etc. which has a high growth opportunity and low risk of substitution.	• New emerging technologies can lead to a risk of substitution, for instance smart coatings • Industry dominated by 4 to 5 players (Pilkington, Asahi, Saint Gobain etc.), hence, a possibility of price manipulation remains.
Encapsulant	• Demand for encapsulant will also increase with capacity addition • India has an existing manufacturing capacity of 24.2 million m^2 • The difference between imported and indigenous cost in not very significant • Existing encapsulant manufacturers are well established and are export oriented. Secondly, the chemicals industry is also well established • Availability of low cost labour.	• The polymer used for encapsulant is solar grade EVA (32% vinyl acetate), which is currently not produced in India • No specific policy incentives to promote encapsulant R&D • Absence of sufficient demand discourages existing Indian chemical industries to produce solar grade EVA. • Low recycling potential.	• An adequate demand of solar encapsulant to meet the JNNSM targets • EVA resin is used in several industries • Indian chemical industry can focus on manufacturing solar grade polymers • Large scale employment generation • Collaboration between academia-industry and government to promote solar grade polymer development.	• Impact of waste and residue on the environment • Expensive raw materials • Demand from other industries offering better price.
Backsheet	• High growth potential • India has a manufacturing capacity of 2.5 GW • Availability of low cost labor	• India doesn't have any manufacturer of Tedlar and kynar (Raw material for Back sheet)	• To meet the JNNSM targets, there is an adequate demand for back sheets • As per our projections, the total demand for back sheet (under	• Supply of raw material is dependent on Dupont and Arkema as these are their trademarks • Finding skilled workforce

Component	Strength	Weakness	Opportunity	Threat
	• The price difference between imported and domestic is not very significant.	• The polymer (Tedlar & kynar) market is dominated by Dupont and Arkema and there are supply constraints • No specific policy incentives are available to promote back sheet R&D and production • Indian chemical industries are not very keen about manufacturing polymers for solar industry.	various scenarios) varies from 39.8 million m^2 to 47.6 million m^2 by 2017. However, the current production capacity is 18.75 million m^2. Hence, there is a large potential. • To make Indian manufacturers competitive within this industry.	• Raw material used for non-solar applications if these fetch better prices.
Silane Gas	• A well-established chemical and gas production industry • Skilled technical workforce is already available • Manufacturers of a-Si type modules are present in the country.	• Silane is a hazardous gas highly susceptible to explosion when exposed to air • The explosives act and stringent regulatory and safety guidelines do not allow production of silane in India • High investment sought in technological development and safety infrastructure • Silane gas is pyrophoric in nature, hence there are several requirements to be considered for establishing manufacturing facility and storage of silane • Health hazard issues need to be considered.	• Silane has many other applications besides solar – coupling agents, water repellents etc. • Indian academia already pursues a high level of R&D in chemical and polymers • The manufacturing facility can bring in self-sufficiency in other strategic sectors that use silane including defence • Facilitate collaborations between academia-industry and government to promote solar grade polymer development.	• Use of silane may release toxic and hazardous substances which can lead to serious environmental hazards • Chemical exposure and after effects on environment • a-Si technology which is primary source for silane is losing ground steadily to CdTe and CIGS technologies (primarily due to efficiency). Hence, unless a major breakthrough for a-Si technology is attained demand for silane would be subdued.

c-Si PV Cell

The cell is the most critical component of the PV module. Although India has around 1,386 MW of cell manufacturing capacity, with around 12 major manufacturers led by Indosolar, but 80% is lying unused owing to various reasons[58]. There is a worldwide glut of solar cells and modules. As per the views of the industry, the country should not go ahead with the 'Make' decision until issues responsible for lower capacity utilization are addressed. However, there is another view that India could focus on new emerging technologies like 'direct gas to wafer[59]' instead of using the conventional approach to manufacturing wafers and cells.

Glass

Glass is used in solar PV technologies as a critical component. It is used in the form of front glass in crystalline PV and as a substrate in thin film. The current sourcing mix for glass is 50-50 in case of both crystalline and thin film PV. Thin film manufacturing companies are increasingly sourcing glass substrate with TCO (Transparent conductive oxide - Tin oxide or Zinc oxide) coating, as it is convenient and cost effective for them. Presently, India does not have a glass manufacturer who can manufacture glass coated with TCO.

Gujarat Borosil Ltd. is the only company manufacturing low iron glass used in the PV module. The primary raw material used in the preparation of glass is Silica sand and soda ash, which are abundantly available in India (Indian Bureau of Mines, 2012a). The technological capability is also high as they are presently designed as well as manufactured in India. The glass substrate (used in a-Si module) is a heavy and bulky component and hence its import involves high freight charges, which increase the cost. This component could be indigenized.

Another aspect that needs to be recognized is that glass manufacturing is energy intensive, hence, locations where grid supply is continuous and of high quality are well suited. The study finds that approximately 303-363 kt of glass is required to meet the c-Si and a-Si PV projections.

Encapsulant

The raw material used for encapsulant production is EVA resin consisting of High-density polyethylene (HDPE) and vinyl acetate. The EVA resin is used in many non-solar applications depending on the percentage content of vinyl acetate. For solar applications, 28% and 33% vinyl acetate composition is used. Approximately 90% of the encapsulant cost is attributed to EVA. Currently, no Indian company manufactures EVA resin and hence encapsulant manufacturers in India import this critical ingredient.

Backsheet

Although, India has a 2.5 GW backsheet manufacturing capacity, Tedlar (Poly Vinyl Fluoride) used for manufacturing Backsheet is 100% imported from Dupont, which has a monopoly. Renewsys of Bangalore is a leading manufacturer of backsheet in India. Besides Renewsys, Polycom Associates of Mumbai also supplies backsheet to the manufacturers of PV modules. Recently, companies have also started using Kynar – a product of France-based Company, called Arkema. The study finds that approximately 39.8-47.6 million m^2 of backsheet would be used to manufacture 5-6 GW of c-Si and a-Si PV module.

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[58] Stakeholder interaction updated on 24th December 2013

[59] This novel approach involves deposition of Monocrystalline silicon directly from feedstock gas. Thus eliminating polysilicon formation, ingot and wafering: three critical steps of the conventional c-Si value chain (Crystal Solar, 2012).

Silane Gas

The purity level of gases used in a-Si thin film manufacturing has to be 6N, i.e., 99.9999%. The raw material used for manufacturing silane is magnesium silicide and chlorosilane. Currently, India does not produce silane gas. According to the industry, the explosives department does not allow domestic production due to a lack of prescribed safety norms. The amount of silane required is also not very high. However, there are proposals by industries awaiting department approval. Other gases required in a-Si thin film cell manufacturing such as Hydrogen, diborane and phosphine are being produced in India. The analysis finds that approximately 45.1-50.7 tonnes of silane would be required to manufacture 712-800 MW of a-Si modules. In 2012, an estimated 50 tonnes of silane was consumed by the a-Si thin film industry.

Based on the quantitative and qualitative analyses, India should focus on manufacturing front glass, encapsulant and backsheet in the short-term, whereas, it should focus on buying cells and silane gas. Table 4.13 summarizes the Make or Buy strategy in the short-term for the critical components of c-Si and a-Si technologies.

Table 4.13: Decision to Make vs. Buy of the Different Critical Components of c-Si and a-Si Technology

Component	Make	Buy
c-Si		
Cell	✔	✔
Front glass	✔	
Encapsulant	✔	
Backsheet	✔	
a-Si		
Glass substrate	✔	
Silane		✔
Encapsulant	✔	
Backsheet	✔	

4.3.2 Long-Term Make or Buy

In long-term (2017-32), the study assumes that technological capability will not act as a barrier in arriving at ‘Make or Buy’ decision. FYP and NAPCC scenarios, together with the assumptions of the two sub scenarios yield 12.3-32.8 GW and 2.5-7.6 GW of c-Si and a-Si installed capacities. Figure 4.8 highlights the range of c-Si and a-Si technologies. Thus, a long-term Make or Buy decision for critical components has also been assessed from a material requirement perspective.

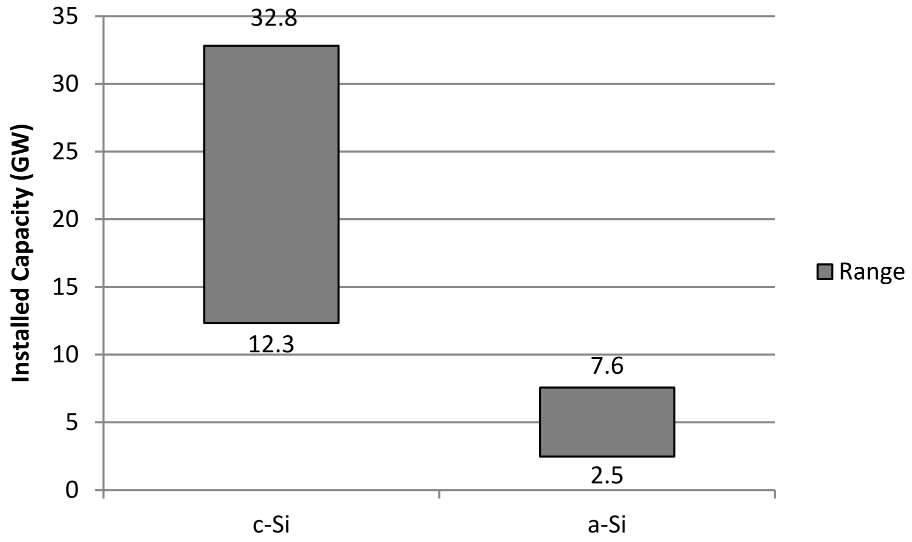


Figure 4.8: Technology Wise Estimate of the Range of Installed c-Si and a-Si (in GW) During 2017-32

Table 4.14 shows the material requirement of the different critical components. As glass, encapsulant and backsheet are common for both c-Si and a-Si technologies, the Table represent the material requirements of these components together. The table also comprises of an estimate of the global consumption of these components in 2012. The comparison shows that for all the components, the material requirement by 2032 will be approximately equal to global consumption in 2012. Finally, in the long-term; all the components should be manufactured in India.

Table 4.14: Long-Term Material Requirement for the Different Critical Components

Critical Components	Material Requirement for c-Si and a-Si PV (2017-32)	Estimated Global Consumption in 2012
Polysilicon (kt)	65 - 174	179
Silane (tonnes)	125 - 303	76
Glass (kt)	914 – 2,520	1,538
Encapsulant(million m^2)	288 - 566	192
Backsheet (million m^2)	120 - 330	98

4.4 Solar CSP

4.4.1 Short-Term Make or Buy

In 2017, the cumulative installed capacity of PT and ST is expected to be in the range of 1.4 GW and 0.10 GW, respectively as depicted in Figure 4.9. The subsequent section examines the domestic manufacturing capacity, domestic vs. imported price, technology depth, existing sourcing mix, raw material availability and the requirements (based on the projection) of critical components for this sector. This is followed by the SWOT analysis for each component.

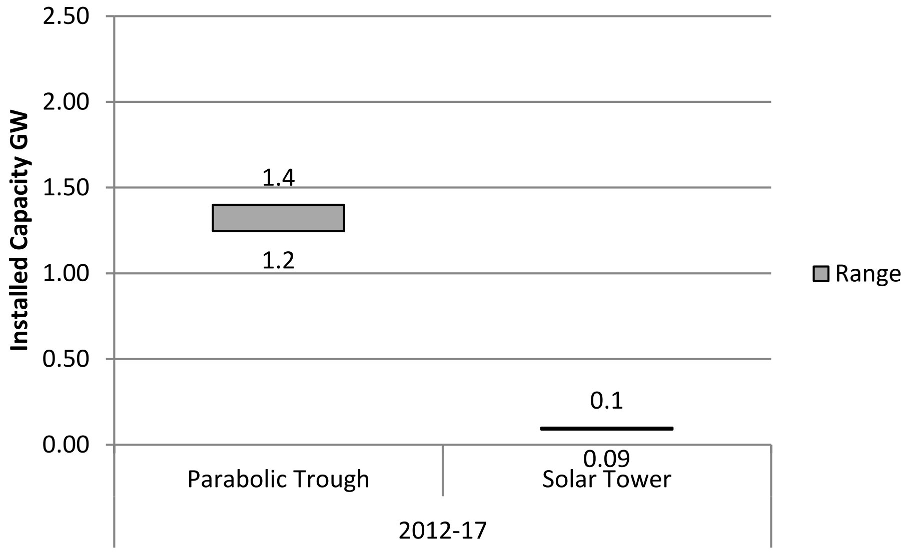


Figure 4.9: Technology Wise Estimate of the Range of Installed Capacity for CSP (in GW) During 2012-17

Table 4.15 shows the Make or Buy matrix for PT technology and ST technologies. The information collated from stakeholders' interactions and literature survey is tabulated. The components are reviewed individually with respect to relevant parameter.

Table 4.15: Short-Term (2012-17) Make or Buy Matrix for PT and ST

Component		**Dom.Mfrg.Cap.**	**Price (INR. crore /MW)**		**Tech.Depth**	**Dom.Cont. (%)**	**Raw Material Avail.**	**Raw Material Req. (kt)**	**Jobs (per MW)**
			Imp.	**Dom.**					
Parabolic Trough									
Parabolic Mirror		Medium	1.2	N.A.	Medium	0	Low	80-90	N.A.
Receiver	SS-304	Low	1.7	N.A.	Low	0	Medium	10-11.2	N.A.
	Boro. Glass	Medium			Medium		High	3 – 3.1	
Heat Transfer Fluid		Medium	0.8	N.A.	Medium	0	Medium	27 – 31	N.A.
Power Block		High	1.5[60]	1.4	High	60	High		N.A.
Solar Tower									
Heliostat	Carbon Steel	High	15.1	N.A.	Medium	0	High	14.9 – 16.7	N.A.
	Glass	Low			Low		Low	6.9 – 7.7	
Receiver - Stainless Steel (SS-316)		Low	7.9	N.A.	Low	0	Medium/ High	0.26 – 0.29	N.A.

Avail. = Availability; Boro. = Borosilicate; Cap. = Capacity; Cont. = Content; Dom. = Domestic; Imp. = Imported; Mfrg. = Manufacturing; Req. = Requirement; Tech. = Technology

[60] Import cost is given by ACIRA Solar

The range of raw material requirement by 2017 is shown in Figure 4.10. As glass is required in both PT and ST technologies, the Figure depicts combined material requirement. The same approach has been considered for stainless steel. The estimates have been made by considering different RE penetration scenarios. In the following section, each component is discussed in brief, followed by a SWOT analysis.

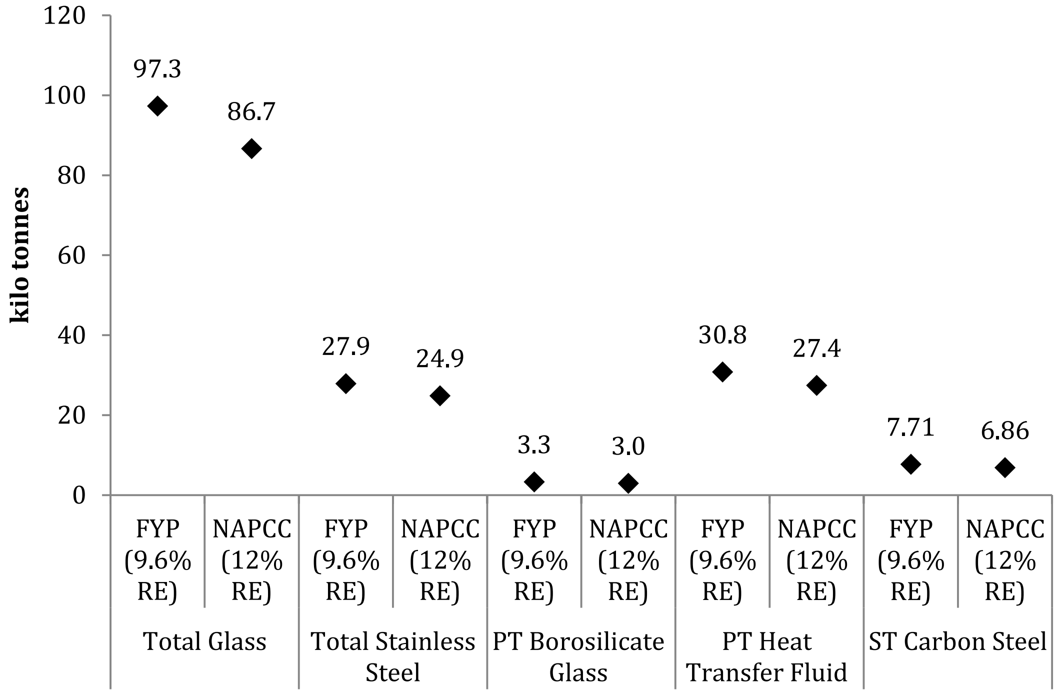


Figure 4.10: Short-Term Material Requirement Estimates for PT and ST Technologies

Parabolic Mirror

High quality low Iron content sand is required in the manufacture of mirrors for CSP. The properties of mirrors used in PT are different from traditional mirrors, as these mirrors need to be highly reflective and more durable. Currently, India is importing mirrors for PT plants due to a lack of sufficient demand (FICCI, 2013b). India produces 0.68 Mt of low iron glass per year from major glass manufacturers, namely – Asahi, NSG Group (Pilkington), Saint Gobain, and Guardian (ESMAP, 2013).As per the views of industry, the country should go ahead with the 'Make' decision by providing suitable incentives and support mechanisms to existing mirror manufacturers to set-up solar mirror manufacturing lines (FICCI, 2013b). However, India can also focus on the development of new polymer film coating rather than the traditional wet chemical coating process (ESMAP, 2013).

Receiver for PT Technology

The receiver is used to collect solar radiations from the mirrors and transfer the heat to HTF. It consists of stainless steel (SS-304) and borosilicate glass. It is the most critical component in a PT plant as most of the optical and thermal losses occur here. Few companies across the globe have commercial experience in making high quality receivers. Currently, there are no players in India who are capable of manufacturing receivers. The National Aerospace Laboratory (NAL) is the only R&D organization in India developing high temperature solar selective coating for receivers. This technology is currently being tested (NAL, 2012).

Heat Transfer Fluid

HTF is used to transfer heat from receivers to the power block without much energy losses. Dow Chemicals, Solutia Inc and Lanxess are the manufacturers of HTF across the globe. Currently, India is importing HTF for the JNNSM, Phase 1 projects. Lanxess, Indian Oil and Reliance Petrochemicals aresome of the potential players in India who have the capability for manufacturing HTF for Phase 2 projects(FICCI, 2013b)(ESMAP, 2013).

Power Block

Turbines and generators are the critical components of a power block. Solar CSP turbines are slightly different from traditional steam turbines. The two turbines vary in three aspects viz. low temperature and pressure, interaction of the solar circuit with the water/steam cycle and daily start up and shut down. In India, for the Godawari Solar Project (50 MW) by the Hira Group, the turbines have been imported and supplied by Siemens (Siemens, 2013b). Triveni Turbine, GE, Siemens India, Maxwatt Turbines, and BHEL are the players in India who have the potential to manufacture CSP turbines (ESMAP, 2013). India has a well-established generator market.

Table 4.16: Short-Term Swot Analysis for PT

Component	Strength	Weakness	Opportunity	Threat
Mirror	• A well-established float glass manufacturing industry • Technology for curving, hardening and tempering glass is available with the float glass manufacturers • A well-established market for support structure, pedestal and foundation • Availability of skilled manpower with low labour cost • Lower production and logistical costs.	• Inadequate demand and uncertainty • Lack of R&D in the development of new mirror manufacturing techniques • No standards and testing facilities available for mirror manufacturing units • Non-Availability of low Iron content silica • Substrate coating technology is not available • There are lots of gaps in the supply chain for delivering high quality mirrors • Economies of scale for production of mirrors for PT are 500 MW/year • The supply chain is not strong enough to deliver high quality flat mirror and tracking devices for heliostats.**(ST)**	• Indigenous manufacturing could generate employment • New potential market for existing mirror manufacturers • Better brand positioning for existing glass manufacturers (entry into green technology area) • Good demand for CSP foreseen in the future, therefore good strategic investment opportunity • Large cost reduction would fuel demand • Indigenous manufacturing of mirror can generate extra revenue for the international mirror manufacturers who have already established their businesses in India • Development of two axis tracking system and their export potential. ST	• Currently, cannot compete with PV on cost basis • Polymer films developed by 3M and marketed by Skyfuel with lightweight Aluminium structures is a competing technology • Chinese manufacturers are slowly and steadily dominating the market.
Receiver - PT	• Few R&D organizations are developing receiver tube coating with government support • Metal-glass seal, a critical step, is available with the incandescent bulb industry • Technology and expertise for vacuum sealing exists • Significant cost saving is anticipated • Lower logistic and breakage	• Cost of equipment required to manufacture receiver tube is high • Uncertainty in demand which prevents private sector to invest in R&D • Global manufacturers not interested in establishing plant due to insufficient demand • Local players who are manufacturing these tubes need some more time to prove their technology	• New business opportunity for existing glass and incandescent lamp companies • Cost reduction can be achieved if the receiver tubes are manufactured indigenously • Synergy with other glass products used in the solar industry (PV glass, glass for reflective mirrors, etc.)	• Technology innovation is high so risk of substitute/obsolescence exists.

Component	Strength	Weakness	Opportunity	Threat
	costs if indigenously manufactured.	• Lack of skilled and experienced people in establishing metal glass seal • Coating technology is also not available.		
Receiver - ST	• ST receiver can perform better than PT receiver as they can achieve a higher temperature i.e. 800-1000°C • Government is supporting a few R&D organizations for the development of volumetric receiver • Large-scale availability of raw materials.	• Supply chain is not well established • Lack of standards and testing facilities • High cost of financing • No clarity in the road map of ST plants as the manufacturing cost of receiver is high.	• Cost can be reduced further as India has the technological capability to manufacture volumetric receiver • To meet the JNNSM targets, there is an adequate demand for receiver • There are very few players across the globe, which have the expertise in manufacturing receivers. Immense scope of indigenization and delivery exists.	• Technology innovation is high so risk of substitute/obsolescence exists.
HTF	• Technology expertise in HTF is available • Petrochemical companies have a large potential to produce HTF as the raw material is a by-product of oil • Low cost of manufacture • Low logistic and storage costs.	• High purity Biphenyl Oxide (raw material for HTF) is not available in India • No standards and testing facilities are available for HTF as the fluid needs to be tested for extended period of time for high quality • Lack of sufficient demand for indigenous production.	• Potential for localization exists by collaborating with global manufacturers • Logistic cost could be reduced if the solar plants are located close to refineries (Gujarat/Rajasthan) • New manufacturers could break the oligopolistic market leading to competitive pricing • Fluids with lower operating temperatures can be used in solar process heat industry.	• HTF (Synthetic Oil) has limited application other than solar industry • At lower temperatures high pressure water could replace all major HTFs.
Turbine	• India has indigenous technology and expertise in turbine manufacturing • The turbine industry is well matured and requires	• Demand for CSP turbine is very less compared to other conventional sources of energy generation • No incentives available for the turbine manufacturers in solar	• Local turbine manufacturers can collaborate with CSP developers (technology providers) and export them • Scope for cost reduction and	• Lack of demand or demand uncertainty may discourage the manufacturers from developing indigenous expertise • Unavailability of incentives may

Component	Strength	Weakness	Opportunity	Threat
	incremental investment to expand its capacity • Technology to 'solarize' turbine relatively simple • Low cost turbine production is possible • Low capacity turbines are available at competitive prices (for remote rural applications).	sector.	technology improvement.	slow indigenous production of turbines.
Generator	• Strong and well established generator manufacturing base in India • The boiler/ heat exchanger industry is fully matured in India and requires an incremental investment to expand capacity.	• Scope of cost reduction is low • Periodic on and off during the operation subjects generator to wear and tear and hence the life • Lack of demand may discourage manufacturers from developing customized generator.	• Immense scope to export • If the share of local component in the total project cost is further increased, it will enhance local manufacturing.	• Large global manufacturers dominate the market, hence, entry of domestic players is difficult • Demand from alternative industries (backup power supply, conventional power technologies) forms a higher priority, as orders are more regular.

Solar Tower

Heliostat

A Heliostat consists of a reflective surface (mirror), support structure made up of stainless steel, drive mechanism (tracking), pedestal, and foundation and control systems. Flat mirrors of thickness 4 mm are used in heliostats. Currently, India has a well-established market of support structure, drive mechanism (tracking), and control systems. Asahi, NSG Group (Pilkington), Saint Gobain, and Guardian are some of the potential players in India who have the ability to manufacture flat glass (ESMAP, 2010).

Receiver

Tubular and volumetric are two types of receivers used in solar tower. A tubular receiver uses liquid HTF such as water, molten salt, thermic oil, liquid sodium and Hitec salt, whereas volumetric receivers use air as HTF. In India, currently 2.5 MW of ST plant has been installed by ACME group in Bikaner, Rajasthan. Victor Energy has provided a dual-cavity tubular receiver for the ST plant (NREL, 2013a). Schott Solar, Babcock Power, eSolar, Saint Gobain and Victor Energy are the companies across the globe with commercial experience in making high quality receivers. Currently, there are no players in India who are capable of manufacturing receivers (ESMAP, 2013).

Table 4.17: Short-Term SWOT Analysis for ST

Component	Strength	Weakness	Opportunity	Threat
Heliostat	▪ Strong and established float glass manufacturing industry ▪ India has developed technological expertise in flat mirror manufacturing.	▪ Low economies of scale for production of mirrors ▪ Insufficient/uncertainty in demand hindering investment ▪ Inadequate testing facilities.	▪ High Job potential ▪ R&D in coating technology, two axis tracking mechanism ▪ Export market ▪ Demand is expected to rise with cost reduction.	▪ No clarity in the road map of CSP as heliostat requires high capital investment.
Receiver	▪ Availability of raw materials ▪ Availability of skilled and low cost workers.	▪ Due to uncertainty in CSP demand, global players are not interested in setting up the manufacturing plant in India.	▪ Large cost reduction can be achieved if the receiver are manufactured indigenously ▪ Patenting and development of strong brand names.	▪ Particle receivers or beams down receivers are the competing technologies.

Based on the qualitative and quantitative factors mentioned earlier the study concludes that in the short-term (2012-17) India should domestically manufacture parabolic mirror and power block whereas it should import receiver and HTF. In the case of ST, the heliostat technology (comprising support structure, tracking mechanism, pedestal, foundation, and control systems) should be domestically made and receiver should be imported.

Table 4.18: Short-Term Make vs. Buy of the Different Critical Components of PT and ST Technologies

Component	Make	Buy
Parabolic Trough		
Parabolic Mirror	✔	
Receiver		✔
Heat Transfer Fluid		✔
Power Block	✔	
Solar Tower		
Heliostat	✔	
Receiver		✔
Power block	✔	

4.4.2 Long-Term Make or Buy

In the long-term (2017-32), if sufficient demand exists, all the technologies could be easily transferred and manufacturing could be locally established. As mentioned earlier, mirror, HTF and power block could be manufactured in India. In the case of ST technology, heliostat (glass and stainless steel) could be easily manufactured locally whereas establishing receiver-manufacturing facility would be dependent on the prevailing demand. In the long-term, at a minimum 3.2 GW and a maximum 13 GW of PT plants is projected to be installed in India. In the case of ST, the study projects 2.7-11 GW of installed capacity. Figure 4.11 highlights the range of PT and ST installations in the long-term.

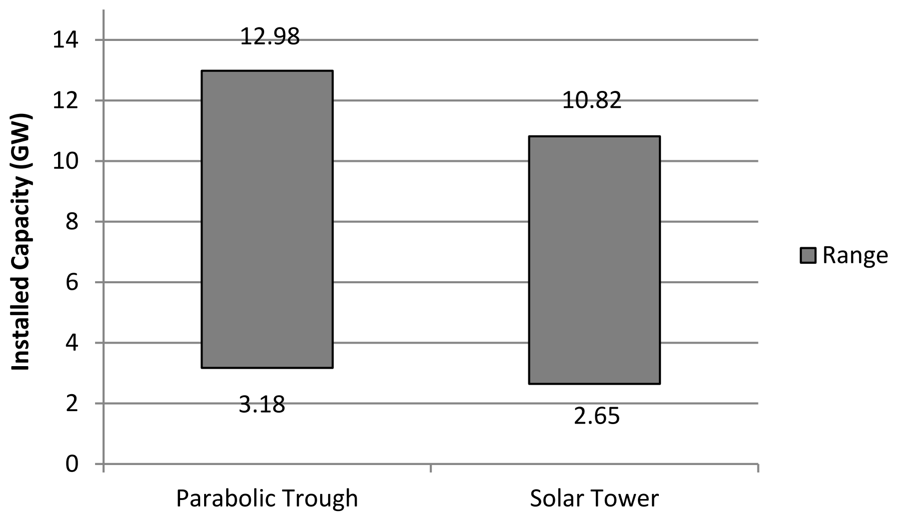


Figure 4.11: Technology Wise Estimate of the Range of Installed Capacity for CSP (in GW) During 2017-32

In the long-term, more heliostat glass is anticipated vis a vis parabolic mirror. There are two reasons for this: i) Higher share of ST (Refer **Annexure 7**) and ii) Larger g/W of material required. In the case of a receiver, PT requires more material as one receiver is required for each parabolic mirror whereas only one receiver (placed on the top of the tower) for the entire solar field is required in the case of ST. Table 4.19 summarizes the range of materials required in PT and ST technologies. Considering the material requirement, in the long-term, HTF along with Mirror/Glass for both PT and ST technologies could be indigenously manufactured, whereas, receiver for both the technologies could continue to be imported.

Table 4.19: Long-Term Material Requirement for PT and ST Technologies

Components	Material Requirement (2017-32) (in kt)	Estimated Global Consumption in 2012 (in kt)
Parabolic Trough		
Parabolic Mirror/Glass	334 - 1,240	49.3
Receiver - Stainless Steel SS-304	43 – 173	6.2
Borosilicate Glass	13 – 51	1.82
Heat Transfer Fluid	106 - 431	16.9
Solar Tower		
Heliostat Glass	345 – 1,402	0.085
Heliostat Carbon steel	747 – 3,037	0.18
Receiver - Stainless Steel - 316	8 - 31	0.003

4.5 Molten Salt Storage

Molten salt, storage tank, foundation, heat exchanger, heat tracing, and pumps are some of the major components of a molten salt storage system. Molten salt, pump, and storage tanks have been identified as the critical components of a molten salt storage system. Barring the domestic manufacturing capacity of molten salt mixture, technology depth, and raw material availability of storage tank and pump is high. Table 4.20 offers a short-term Make or Buy matrix for a molten salt storage system.

Table 4.20: Short-Term (2012-17) Make or Buy Matrix for Molten Salt Storage System

Component	Domestic manufacturing capacity	Price (INR Crore/ MW)		Technology depth	Domestic content (%)	Raw material availability	Raw material requirement (2012-17)
		Import	Domestic				
Molten salt	Low	1.72	N.A.	Low	0	High	N.A.
Storage Tank	High	0.61		High	100	High	N.A.
Pump	High	0.14		High	100	High	N.A.

The SWOT analysis for the critical components of a molten salt storage system is shown in Table 4.21.

Table 4.21: SWOT Analysis for Molten Salt Storage

Component	Strength	Weakness	Opportunity	Threat
Molten salt	▪ Raw materials are abundant	▪ Molten salt has a very high freezing temperature (220°C) ▪ Chemical industries are not very keen in manufacturing molten salt due to uncertainty in demand ▪ High material cost.	▪ Collaborations with research centres, academia and industry to produce low cost molten salt ▪ Low barrier to entry and as such existing monopolistic behaviour could be diffused.	▪ Super critical CO_2 and hypo eutectic alloys are the competing technologies ▪ Oligopolistic market structure as only a few manufacturers of these tubes are present across the globe.
Storage Tank	▪ Strong and well established storage tank market	▪ Only a small amount of cost reduction can occur in tank	▪ Additional market segment for existing tank manufacturers.	▪ Technology innovation is high so new material and tank design can

Component	Strength	Weakness	Opportunity	Threat
	▪ Availability of low cost and skilled labour ▪ Availability of raw material.	construction.		replace the existing technology.
Pump	▪ Strong and well-established pump manufacturing industries.	▪ Only small amount of cost reduction can happen with a rise in demand ▪ Lack of R&D in designing next generation molten salt pump which can operate at higher temperature ▪ Seals need constant replacement.	▪ Exporting molten salt pumps across the globe ▪ Patenting and development of strong brand names for molten salt pumps.	

In the short-term, based on a qualitative analysis, storage tanks and pumps should be manufactured indigenously whereas in the long-term molten salt too could be produced locally.

Table 4.22: Decision to Make or Buy Thermal Storage System in the Short-Term (2012-17)

Component	Make	Buy
Molten Salt		✔
Storage Tank	✔	
Pump	✔	

Exhibit 4.1

Manufacturing batteries for grid-scale energy storage in India

Energy storage would serve a major need to bridge the gap between available generation and customer loads during system peaks, and as a distributed resource on the customer-side of the meter. India is aggressively pursuing energy storage as a secure power resource for more than 300,000 telecom towers, and announced a USD 40 million contract in July 2013 for Li-ion battery energy storage systems to meet that need (US Department of Energy, 2013). The cost of battery-based energy storage can be around INR 8 crore/MW. This could reduce to INR 5 crore/MW due to economies of scale.

Table 4.23: Energy Storage Devices Manufacturers

Manufacturer	Technology
ABB Ltd	Battery-based energy module for micro-grid up to 5 MW
Build Your Dreams (BYD) company Ltd.	Batteries, Electric vehicles
Samsung SDI	Li-ion batteries, xEV batteries
AES Energy Storage	Battery based storage system
Mahindra REVA	xEV
Convergent Energy + Power	Zinc hybrid cathode battery
IMERGY Power solution	Redox flow battery
S&C Electric Company	Sodium sulfur battery

Table 4.23 shows the major global battery-based storage device manufacturers. High per MW cost and high investment requirement pose a major barrier for manufacturing battery-based storage

devices in India. Yet, the implementation of energy storage technology is of utmost importance for efficient renewable grid integration. Strong policy support and R&D may provide encouragement and an opportunity for Indian manufacturers to flourish in the market.

Table 4.24: SWOT Analysis Of Battery Based Energy Storage

Strength	Weakness	Opportunity	Threat
• Batteries cover an extremely wide range, making them suitable for almost all energy storage applications. Therefore, one installation can be used for multiple applications, which can render its use cost effective. • Fast response time • Low standby losses and comparatively high density and energy efficiency	• Limited lifetime; batteries have to be replaced periodically • High maintenance • Highly sensitive to heat • Comparatively low storage capacity in terms of hours of storage • High investment cost	• Large scale distributed generation and the connection of renewables to the grid will create the need for additional energy storage. • A new evolution in battery technology is the flow battery. Flow batteries are more advantageous than conventional batteries.	• There is concern about possible ecological damage caused by batteries. Batteries contain toxic materials that can weigh hard on the environment. • New upcoming technologies with substantial technological breakthroughs may pose a threat to batteries

Table 4.24 shows a SWOT analysis for battery-based storage devices. This analysis may help to deduce a strategic ‘Make or Buy’ decision for these storage devices during their implementation in the future. However, at present India does not have any manufacturing facilities for grid-scale battery storage devices, and hence imports these products. In the short to medium-term, the requirement is to improve R&D of batteries for grid-scale storage applications.

5 Renewable Energy –Policies and Regulations

Conducive policies and regulations are essential for promoting RE technologies. To support renewable energy technology development, two different policy approaches are adopted by policy makers. The first one is a 'Technology Push Policy' or Supply Side Policy, which directly supports the upstream value chain of renewable energy technology. The second emphasizes 'Market Pull Mechanism' or Demand Side Policy, which directly supports the downstream renewable energy value chain. The different support mechanisms are highlighted in Table 5.1 and defined in **Annexure 8**.

Table 5.1: Supply Side and Demand Side Support Mechanisms for Promoting Renewable Energy

Supply Side Policy	Demand Side Policy
▪ Financial support ▪ Export subsidies ▪ Local content requirement[61] ▪ Excise/Custom duty rebate ▪ Export tax rebates ▪ Production subsidies for manufacturing ▪ Tax incentives to manufacturers ▪ Import quota/restriction ▪ Anti Dumping Duty ▪ Market access restriction ▪ Certification and testing program ▪ Technical standards ▪ Research and development and demonstration program ▪ Compulsory licensing of intellectual property ▪ Land acquisition	▪ Feed in tariff ▪ Consumer subsidies ▪ Preferential credit ▪ Accelerated depreciation ▪ Production tax credit ▪ Renewable Purchase Obligation ▪ Government procurement ▪ Grid connection ▪ Financial incentives ▪ Tax incentives to developers ▪ Green power market ▪ Government auction or resource concession ▪ Renewable Energy Credit

Section 5.1 enlists supply and demand side policies across China, the US, Germany and Spain along with a summary of different demand side policies applicable to the wind and solar industries in these countries. Section 5.2 examines the supply and demand sides of RE policies in India. The section also reviews two major policies, which have a direct impact on the manufacturing sector – the NMP and National Clean Energy Fund (NCEF).

Section 5.3 examines policies for the textile, auto, information technology (all export oriented) and ultra-mega power (components for which are chiefly imported) sectors. The rationale here being that these policies have assisted in building these sectors, hence they could be applied to the RE industry. Finally, Section 5.4 highlights the existing policy gaps affecting RE component manufacturing, directly or indirectly.

5.1 Global Experience

This section examines the policy interventions made by China, the US, Germany and Spain. These countries were chosen as they have a mature market and policies, which support both, the manufacturing supply chain (upstream value chain – China, Germany, and the US) and installations (downstream value chain – Germany, Spain, and the US).

[61]Local content requirement or Domestic content requirements are used interchangeably.

5.1.1 Supply Side Policies

China

At the end of 2013, China had a cumulative installed capacity of 91.4 GW of wind (GWEC, 2014)and 10 GW of solar PV[62] (PV magazine, 2013c). It ranked first and fourth for major wind and solar installed capacities across the world, respectively. Five WTG manufacturers from China are among the top 10 global manufacturers. Nine out of the fifteen top PV module manufacturers (in terms of annual capacity) in solar PV are Chinese (REN21, 2013). These nine manufacturers accounted for roughly 31% of the global 35.5 GW PV module annual production capacities.

The renewable industry in China is primarily supported by long-term measures such as stable power procurement process and local content requirement. The major WTG manufacturers in China are Goldwind, Guodian United Power Technology Company, Sinovel, etc. Yingli Green Energy is the largest PV module manufacturer accounting for 6.7% of the global PV module production, followed by Trina Solar and Suntech Power, each accounting for 4.7% (REN21, 2013).

Policies adopted for supporting the upstream value chain for wind and solar energy in China are listed in Table 5.2.

Table 5.2: Support Mechanism for Wind and Solar Power in China (IEA/IRENA, 2013)

Support mechanism	Nature of support	Target sector
Financial Incentives	▪ A subsidy of 600RMB/kW for the first 50 MW size wind turbine produced by a company ▪ The Government of China provides loans at very low interest rates (1-2%) with an extended credit limit (up to 20years). The total amount of loans availed by solar manufacturers in 2010 and until the first half of 2011 is accounted for in the range of USD 34 to USD 40 billion (Grau, Huo, & Neuhoff, 2011).	▪ Wind, Solar
Preferential Tax Treatments for Renewable Energy	▪ Provision for 100% tariff and VAT credit on important components and raw materials that are necessary for manufacturing wind equipment but not produced domestically, for eligible domestic wind energy equipment manufacturers (Grau, Huo, & Neuhoff, 2011) ▪ Reduced Corporate Income Tax (CIT) rate of 15% is given for qualified advanced and new technology enterprises. Applicable fields include solar energy, wind energy, biomaterial energy, and geothermal energy ▪ Also, 10% of the amount invested in the qualified equipment is credited against CIT payable for the current year, with any unutilized investment credit eligible to be carried forward for the next five tax years if such equipment is qualified as special equipment related to environmental protection, energy, or water conservation and production safety ▪ Import tax exception for raw materials and components needed by wind power manufacturers ▪ The Enterprise Income Tax law (EIT) provides tax exemptions for 2 years and a 50% tax reduction for the next three years to the registered PV companies.	▪ Wind, Solar
Trade/Investment	▪ Promotion of domestic projects through competitive bidding,	▪ Wind

[62]Barring Spain and United States, no other country has installed a sizeable capacity (>25 MW) of CSP technology.

Support mechanism	Nature of support	Target sector
Restriction	requiring wind turbines to be manufactured with 70% domestically produced content. Local Content Requirement (LCR) was dropped in 2009 once the domestic industry was completely established.	
Market Entry Standard	▪ New wind turbine manufacturing companies should demonstrate a five years' experience in large-scale mechanical and electrical industry and establish a professional R&D team.	▪ Wind
Other Government Support	▪ Research and development on testing operations are limited to companies with design capacities while wind turbine manufacturers should meet the requirements of the wind power technology standards and follow the Environmental Impact Assessment law ▪ Chinese Ministry of Science and Technology through central government provided USD18 million for R&D on solar technologies for the period of 11th Five Year Plan ▪ The Chinese government initiated the International Science and Technology Cooperation Program in Renewable Energy to boost Chinese technological development. The program aims to introduce cutting-edge technologies in the national market, attract overseas scientists and develop exchange program with international research centres ▪ The government encourages early joint ventures with foreign manufacturers.	▪ Multiple RE technologies

United States of America

In 2013, the US had cumulatively installed a capacity of 61 GW from wind (GWEC, 2014), 12.1 GW from solar PV and 0.918 GW from solar CSP (SECI, 2014). It ranked second in cumulative wind and CSP installations and third in solar PV installation. The top wind turbine manufacturer of the world is GE and the second largest PV manufacturer is First Solar, both having their head offices in the US.

In the US, both the solar and wind energy sectors are supported by long-term goals, financial support schemes, tax credit, and funding for R&D (Davies, 2013). The states have played a prominent role in enacting renewable portfolio standards, public benefit funds, net metering policies, etc. Taking this cue, the federal agency introduced production tax credit for wind and other renewable energy resources. This was initially set at 1.5 cents/kWh and indexed to inflation (Martinot, Wiser, & Hamrin, 2005).Projects installed on or before December 31, 2013 are eligible for production tax credit.

Different types of tax incentives are available for WTG and solar manufacturers, which vary from state to state. A database of the State Incentives for Renewable Energy (DSIRE) is a comprehensive source of information for different incentives at state, local, utility, and federal levels. Some of the supply side policies in the US have been highlighted in Table 5.3.

Table 5.3: Support Mechanism for Wind and Solar Power in USA

Support mechanism	Nature of support	Target Sector
Financial Incentives	The Department of Energy's *Sunshot* initiative is a program to strengthen PV manufacturing across the country. It has set a goal to provide 14% of domestic electricity by 2030 and 27% by 2050. To achieve these targets	Solar

	the following efforts were undertaken (Platzer, 2012): • PV incubator program was started in 2007 to support commercial manufacturing and products • Advanced solar photovoltaic manufacturing initiative was started to reduce the domestic cost of production with up to USD112.5 million funding for five years • SUNPATH was another initiative started to scale-up domestic manufacturing of PV; it provided a funding of USD50 million for two years.	
Preferential Tax Treatment	Federal government provided limited, short-term incentives like section 48C- Advanced energy manufacturing Tax Credit (48C). This incentive provides 30% credit to new, expanded or re-equipped advanced energy manufacturing projects (Platzer, 2012).	Multiple RE Sources
Funding From Financial Institution	Conditional or closed loan guarantees for renewable energy deployment and manufacturing projects have supported the growth of renewable manufacturing sectors Section 1705 Loan Program provided loan guarantees for solar manufacturing and solar power generation projects. Under this section 82% of the loan guarantees have been for solar and the other remaining 18% support a variety of projects in other renewable sectors (Platzer, 2012).	Wind, Solar

Exhibit 5.1: American Recovery and Reinvestment Act

The American Recovery and Reinvestment Act (ARRA) of 2009 is the economic stimulus package passed by the Congress on February 13, 2009.It is a supplemental spending bill that contains USD 80 billion to support clean energy research, development and deployment in the US. Of this, USD 30 billion is available in the form of tax-based incentive and USD 50 billion is provided in direct appropriations. (IEA, 2013a)

Tax-based Incentive(IEA, 2013a)

- **Production tax credit:** Tax payers who invest in certain energy producing facilities may claim a tax credit equal to approximately USD 0.021/kWh of energy produced by qualifying facility from the date the project is placed in service
- **Investment tax credit:** ARRA also permits taxpayers to claim Investment Tax Credit (ITC) in lieu of the Production Tax Credit (PTC). Taxpayers who invest in qualifying advanced energy properties are entitled to a 30% Investment Tax Credit based on project costs
- **Cash Grants:** A new scheme also provides the option for developers to receive cash grants, of equal value to the ITC, instead of the PTC/ITC tax credits. Grants are available for renewable energy projects that are in service since 2009-10, or that began construction in 2009-10 and are in service before 2013 for wind, 2017 for solar and 2014 for other qualified technologies.
- ARRA also removes the subsidized energy financing penalty under ITC, allowing projects that apply for the tax credit to benefit from other state and local subsides
- ARRA extends 50% bonus depreciation (ability to claim 50% of the depreciable basis in the first year, with the remaining basis depreciated as normal according to the applicable schedules) to qualified renewable energy projects acquired and placed in service in 2009
- ARRA increases funding for Clean Renewable Energy Bonds, by USD 1.6 billion, for eligible renewable technologies owned by governmental or tribal entities, as well as municipal utilities and cooperatives
- **Manufacturing Tax Credit (MTC):** ARRA creates a new incentive for the creation or expansion of manufacturing facilities that produce clean energy components and systems. Up to USD 2.3 billion in tax credits are available for qualifying projects. MTC applicants receive a tax credit worth up to 30% of the capital costs for approved projects.

Appropriations for Clean Energy(IEA, 2013b)

- Approximately USD 1.6 billion in funding for research managed by DOE's Office of Science
- USD 4.5 billion for a smart grid program (authorized by the Energy Independence and Security Act of 2007)
- USD 6 billion for Innovative Technologies Loan Guarantee Program to accelerate the deployment of a range of commercial clean energy technologies
- Up to USD 6.5 billion in loans under management of the Bonneville Power Administration and Western Area Power Administration to accelerate the expansion of transmission lines that will facilitate renewable energy deployment
- USD 2 billion in grants available to support advanced battery manufacturing for facilities located in the US
- USD 500 million for a grant program supporting clean energy workforce training managed by the Department of Labour
- Over USD 110 million for the US National Renewable Energy Laboratory for advancing wind energy technologies, building new energy efficient facilities, and lab up gradation.

Funds allotted under ARRA to the Office of Energy Efficiency for Renewable Energy (EERE) research, development, and outreach programs and DOE's national laboratories are highlighted in Table 5.4.

Table 5.4: ARRA Funding in Research and Development (Department of Energy, 2013)

Project	Funding (USD)
Wind Energy	
Wind Turbine Design Facility	44.56 million
University Wind Research Facilities	22.98 million
Wind Technology Development	16.20 million
Massachusetts Wind Blade Testing Centre	24.75 million
NREL National Wind Technology Centre	9.95 million
Solar Energy	
Concentrating Solar Power	24.13 million
High Penetration Solar Deployment	42.05 million
Photovoltaic System Development	50.67 million
Advanced Energy Technology Facilities at National Laboratories	104.77 million
Facility and Infrastructure Improvements at the National Renewable Energy Laboratory	144 million

Germany

Germany has been the pioneer and key trendsetter in establishing major policies and dissemination of renewables. At the end of 2013, its cumulative installed capacity of wind and solar PV energy stood at 34.2 GW (GWEC, 2014)and 35.7 GW (Fraunhofer ISE, 2014), respectively. It was ranked third in wind and first in solar in terms of the cumulative MWs installed. It had a first mover advantage in wind energy and was supported by long-term targets and R&D. Enercon GmbH, Siemens, Nordex, etc. are major manufacturers of WTG. Germany is the second best in providing infrastructure support as well (GTAI, 2013b).

The primary reason for Germany taking a lead in the renewable sector – dissemination as well as manufacturing is the Renewable Energy Sources Act (EEG), which was established in 2000. The Act mandates priority purchase of electricity from renewables over conventional sources. Subsequently other programmes were launched (Grigoleit & Lenkeit, 2012). Germany has two major programmes for PV manufacturers - Joint Task Program and Investment Allowance Program.

Cash payment based on investment or estimated salary costs (to operate future businesses) is provided under the Joint Task Program. These grants vary from region to region depending on their economic development. The investment allowance is in the form of tax-free cash payment given to manufacturers who are located or are planning to establish a company in the eastern part of Germany (GTAI, 2013a). Figure 5.1represents a schematic plan of the types of incentives offered to the RE manufacturing industry in Germany.

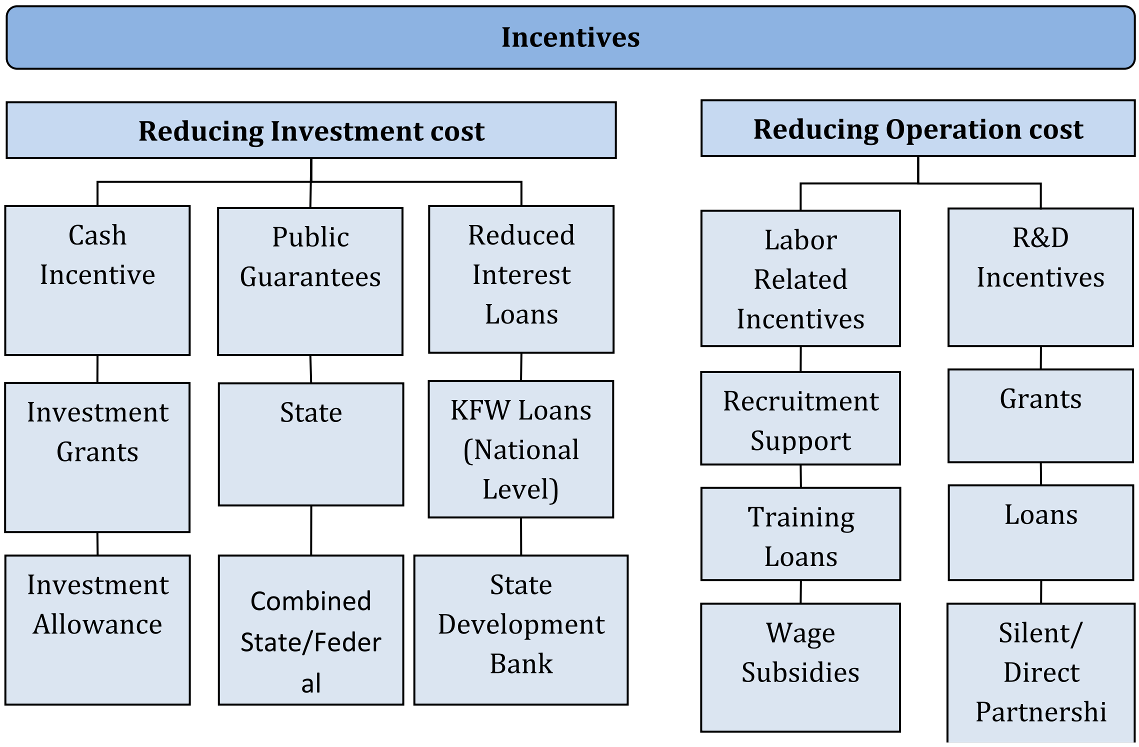


Figure 5.1: Support Mechanisms for Investment in Industries in Germany (GTAI, 2013)

A summary of the different support mechanisms applicable in Germany for wind and solar manufacturing is given in Table 5.5.

Table 5.5: Support Mechanism for Wind and Solar Power in Germany (CRISIL, 2013)

Support mechanism	Nature of support	Target Sector
Financial Incentives	▪ The market incentive programme offers the possibility to apply for investment grants ▪ The Federal Office of Economics and Export Control (BAFA) in Eschborn, processes and decides on applications for an investment grant. BAFA promotes measures for using renewable energy under the market incentive program, which is run by the Federal Ministry for Environment, Nature Conservation, and Nuclear Safety. In 2011, a total of 84,000 applications were received by BAFA and Euro 112 million of funding were disbursed ▪ *Joint Task Program* provides grants worth 15-30% of eligible expenditures for large enterprises located across lowest to highest developed economic regions. The maximum percentage (35-50%) of incentives is provided to small enterprises across these regions (GTAI, 2013a).	Wind, Solar
Funding From Financial	The market incentive programme offers the possibility to apply for a long-term low-interest loan including a redemption grant. KfW Renewable	Wind, Solar

Support mechanism	Nature of support	Target Sector
Institution	energies program offers an entrepreneur loan from 1.9-8.45% for large enterprises and between 1.2-8.35% for small-scale enterprises. The loan-term for these loans is for 5, 10, or 20 years with a repayment-free period of up to 3 years.	
Other Government Support	▪ Support for R&D, industrial clusters, and workforce training ▪ Research and development for PV projects is supported by the Ministry of Education and Research and the Ministry of Environment Nature Conservation and Nuclear Safety. Companies need to define R & D project with clear objectives and fixed timeline to obtain advantage of this program. More than EUR 5 billion is set aside annually for R&D projects in the form of non-payable project grants and these rates can reach up to 50% of respected project cost. Another support mechanism includes the EU's 7th research Framework Program (FP7) which provides financial support in the form of grants covering up to 75% of project expenditure for SMEs.	Solar

Spain

At the end of 2013, the cumulative installed capacity of wind and solar[63] power were 23 GW (GWEC, 2014) and 7.4 GW, respectively (REN21, 2013)(PV magazine, 2013b). Spain was ranked fourth in both wind and solar cumulative installations. Spain is one of the two countries, which have a sizeable share of CSP installations (~2 GW) as well. Wind capacity added in 2013 was 175 MW and approximately 440 MW of solar was added to the grid during the same period.

The major manufacturers of wind technology are Gamesa and Alstom. Abengoa is one of the major manufacturers in the CSP industry. Wind manufacturing was supported by local content requirement. In fact, the growth of Gamesa has been the result of the Local Content Requirements (LCR) provision by the local provinces (Kuntze & Moerenhout, 2012). Supported by high Feed in Tariffs (FiTs), the PV market started booming in the beginning of 2008 (Julien & Lamla, 2011). But, sadly, the large-scale commissioning of renewables has led to a debt of Euro 26 billion. This coupled with the debt crisis has resulted in energy sector reforms with sweeping retroactive changes which has currently resulted in the lack of private sector investments in renewables (The Economist, 2013)(Couture, 2013). Table 5.6 lists the policies, which are applicable to both wind and solar industry in Spain.

Table 5.6: Support Mechanism for Wind Power in Spain (CRISIL, 2013).

Support Mechanism	Nature of support	Target Sector
Preferential Tax Treatment	Corporate income tax credit and accelerated depreciation for some assets used to produce renewable energy; Local tax relief is also offered (ICTSD, 2012).	Wind, Solar
Trade/Investment Restriction	Many regional governments used LCR to attract wind and solar manufacturers to their regions.	Wind
Other Government Support	Initial public support was provided for wind turbine manufacturing; One of the two largest manufacturers was created under a PPP while the other was a joint venture with Government participation. Regional governments provided a dedicated training centre and funded support lines for wind energy sector, solar PV and thermal energy storage.	Wind, Solar

[63]Solar power includes power from both solar PV and CSP technologies.

	The *Renewable Energy Plan* for 2010-2020 was approved by the Spanish Government in November 2011, establishing a framework for the development of renewable energy in the country. This plan expects the share of renewable energy to reach 20% of gross final energy consumption by 2020 with the minimum contribution of renewable sources to transport sector at 10%.An investment of Euro 1.037 billion in R&D is proposed under the law (EERC, 2009).	

Table 5.7 highlights the impact of different policies on the cumulative renewable capacity added and the corresponding percentage of renewables in the total energy mix across these nations. One can observe that if hydropower (chiefly large hydro) is excluded, then, Germany and Spain have made impressive strides in adding renewable energy to its grid.

Table 5.7: Global RE Installed Capacity (GW) and Share (%) (IEA, 2013c)(REN21, 2013)

Country	Cumulative RE installed Capacity (in 2012)		RE share (%) in Total Generation (in 2011)	
	Hydropower (in GW)	Others (in GW)	Hydropower	Others
China	229	90	14.8	2.5
United States	78	86	7.8	5.1
Germany	5	71	3.8	18.6
Spain	17	31	11.6	19.8

5.1.2 Demand Side Policy

In this section, the different demand side supporting mechanisms have been summarized. This directly affects developers and/or system integrators who are part of the downstream of the total value chain. RPO/Green Energy Certificates (GEC), FiTs, emission reduction targets, and tax-based incentives are some of the support mechanisms on the demand side. The various demand side policies adopted globally are highlighted in Table 5.8.

Table 5.8: Demand Side Policies for Wind and Solar Energy Sectors (IRENA, 2012a)

Demand side policy	USA	UK	China	Germany	Denmark	Spain	India
Feed in tariff	-	√	√	√	√	√	√
Premium or adder system	-	-	-	√	√	√	-
Auction or tendering system	-	√	√	-	-	√	-
Tax-based production incentives	√	-	-	-	-	-	-
Spot market trading	-	√	-	√	√	√	-
Investment subsidy or tax credit	√	-	-	-	√	-	√
Tradable green certificate	√	√	-	-	-	√	√
Concessionary financing	√	-	√	√	-	-	-
Renewable portfolio standard	√	√	-	-	-	-	√
Project permitting process	√	√	√	-	√	√	√
Federal or state wise targets	√	√	√	√	√	√	√
Project siting guidelines	√	√	√	√	√	√	√
Priority access to grid	-	√	-	√	√	√	-
Grid code	-	-	-	√	√	√	√

The success of the policies in each of the countries depended on the clarity of their design and the expression of political commitment visible in the support mechanisms. Although, it has been commonly seen that an incentive or subsidy is often necessary for renewable energy development, it may not be a sufficient factor. For instance, in Greece, FiTs were high, but other elements led to a slower pace of development of the renewable sector (IRENA, 2012a).

National targets and specific plans for renewable energy development have been seen as important elements for building awareness and providing a strong long-term signal for investors. Almost all countries with significant renewable energy development have clear and binding targets for renewable energy additions.

Successful policy measures in the long-term also indicate linkages to technology and market development, including facilitating technology transfers and adoption. Policies that favour the development of local manufacturing capacities and ensure healthy competition have been instrumental in the long-term development of a renewable energy market in the respective countries.

5.2 Renewable Energy Policies in India

The total installed capacity of grid-connected RE in India was 30.2 GW as of January 31, 2014, which is approximately 13% of India's overall installed capacity (MNRE, 2015a). It has been a continuous endeavour of GoI to increase the share of renewable energy generation in the electricity generation mix. However, under the Constitution of India, 'power' is a 'concurrent' subject and hence the centre as well as state governments have authority to enact legislations related to the power sector. The central and state governments[64] have taken various measures to support the development of RE.

The Electricity Act, 2003 entrusted the responsibility of promoting RE power generation to the state electricity regulators. The enabling provisions in clause 86 1(e) of the Act were helpful in promoting the RE market in India. The National Electricity Policy and the National Tariff Policy set out under the Act also recognize RE generation and provide enabling provisions. The Central Electricity Regulatory Commission (CERC) has played a very important and proactive role in promoting RE by providing regulations on RE tariff setting, tariff determination for RE projects, establishment of a REC framework and measures on grid interconnection for RE projects. NAPCC has proposed a target of 15% RE in the total electricity generation mix by 2020, which provides an impetus to RE dissemination in India. To support clean energy technologies, GoI has also established a NCEF, which is furnished with revenue generated from imposing a cess of INR 50/tonne on domestic and imported coal. In FY15, the cess on coal was increased to INR 100/tonne and in the FY16 budget, this was further increased to INR 200/tonne to support green energy and environment sector projects (Live Mint, 2015). The salient features of the different enabling frameworks for RE development in India are listed in Table 5.9. Exhibit 2 gives an overview of the evolution of India's policies for the wind and solar energy sectors.

Table 5.9: Central Level Enabling Frameworks and Provisions for RE in India (WISE, 2013)

RE enabling measures at central level	
Electricity Act, 2003	▪ Provides suitable measures for connectivity to the grid for RE projects ▪ Defines provisions for RPOs/specifications ▪ Promotes renewable energy while specifying tariff ▪ Recommends preparation of National Electricity and Tariff Policy ▪ No license required for setting up power/RE power generation project ▪ Empowers state regulators to promote RE power, decide FiTs, define RE purchase obligations, and ensures connectivity to grid for RE

[64]**Annexure 9** describes the State level policies for Renewable energy

RE enabling measures at central level	
	project.
MOEF guidelines for diversion of forest land, 2004	▪ Diversion of forest land for establishment of wind power projects under the Forest (Conservation)Act, 1980 ▪ A lease rent of INR 30,000 per MW is charged by the state government as a lump sum one-time payment for the entire period of lease.
National Electricity Policy,2005	▪ Emphasizes competition between non-conventional sources of energy ▪ RE generation needs to be promoted by creating suitable measures for grid connectivity and by specifying progressively increasing RPO ▪ Advocates procurement of power by distribution licensees through competitive bidding.
Integrated Energy Policy, 2006	▪ Acknowledges the role of RE in the country's energy mix and promotes renewable energy generation ▪ Advocates energy production linked incentives for RE sector in lieu of investment-linked incentives.
National Tariff Policy,2006	▪ Appropriate Commission will fix a minimum percentage for purchase of energy from such sources taking into account availability of such resources in the region and its impact on retail tariff ▪ Procurement by distribution companies shall be done at preferential tariffs determined by the Appropriate Commission ▪ RE procurement by distribution licensees for future requirements shall be done, as far as possible, through competitive bidding process ▪ Central Commission should lay down guidelines for pricing non-firm power, especially from non-conventional sources, to be followed in cases where such procurement is not through competitive bidding.
National Action Plan on Climate Change,2008	▪ Mandates 15% RE in the electricity generation mix by 2020 – implying above 100 GW installed RE generation capacity by then ▪ Establish National Solar Mission for development of 22,000 MW solar power by 2022 ▪ Propose to set up National Wind Energy Mission during 12th FYP.
Central Electricity Regulatory Commission initiatives	▪ In line with the provisions under NTP, the Commission had issued a multi-year RE Tariff Regulations first time in 2009 and revised the same in 2012 ▪ The Commission's regulation brought clarity among state regulators on various tariff determining parameters ▪ Facilitates adoption of long-term RPO trajectory and established REC mechanism in India ▪ Actively promoting development of voluntary REC market and RPO compliance.
13th Finance Commission's Incentives to States promoting RE, 2010	▪ Grant of INR 50,000 million to be paid as an incentive to states who increase the share of electricity generated from renewable sources between FY11 to FY14 ▪ Grants to be awarded based on two-part formula relating to absolute achievements in MW and relative achievements with respect to RE potential in the state.
National Clean Energy Fund (NCEF), 2010	▪ NCEF was proposed to be utilized for the development and deployment of clean energy technologies in India ▪ It is furnished by revenue from imposing a cess of INR 50/tonne on domestic and imported coal ▪ Part of this fund may be utilized for development of grid infrastructure which is proposed under the Green Energy Corridor report prepared by PGCIL ▪ GoI has announced soft loans/interest subsidy for RE projects through

RE enabling measures at central level	
	NCEF in FY14 budget ▪ Coal cess has been increased to INR 200/tonne in FY16.
Supporting Infrastructure Development - Green Energy Corridor Plan, 2012	▪ PGCIL had published research report on 'Green Energy Corridor'. Plans for building transmission infrastructure of electricity envisaged RE capacity additions during 12th/13th FYP ▪ PGCIL has also proposed various grid strengthening plans to accommodate RE capacity addition of around 40,000 MW in the RE resource rich states by FY16/17 ▪ INR 425,570 million capital expenditure plan is proposed for RE rich states by FY16/17 for grid strengthening.
Tariff Based Competitive Bidding, MNRE Guidelines, 2012	▪ MNRE published tariff based competitive bidding guidelines in 2012-13 to promote competition, facilitate transparency and fairness in procurement process ▪ Competitive bidding framework is applicable only for solar power ▪ Competitive bidding guidelines are awaiting clearance from Ministry of Power.
Offshore Wind Power Policy – Draft, 2013	▪ Offshore wind power policy draft floated by MNRE in 2013 ▪ National Offshore Wind Energy Policy approved by the government in September 2015 ▪ MNRE authorized as the nodal ministry and National Institute of Wind Energy (NIWE) as the nodal agency. ▪ NIWE to carry out allocation of wind blocks, coordination and allied functions with related ministries and agencies.
Proposed National Wind Energy Mission	▪ A National Wind Energy Mission on the lines of NSM may soon be set up by the Centre in order to fuel growth in wind energy sector as enumerated in the 12th FYP document.

Exhibit 5.2

The impact of conducive policies on the growth of renewable energy in India

Evolution of wind energy Policies in India

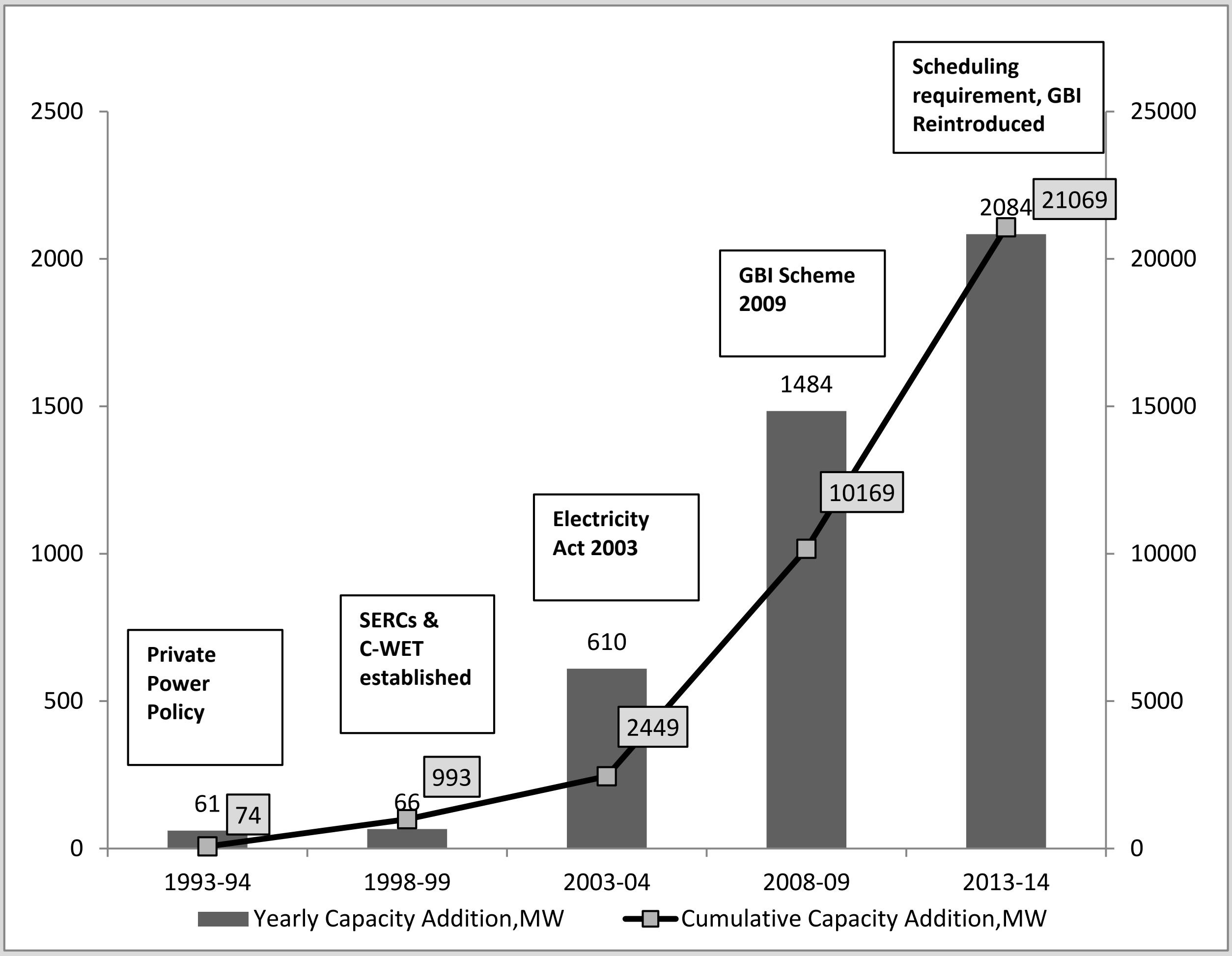


Figure 5.2: Cumulative and Annual Capacity Addition (MW) of Wind Power in India as of 31/03/2014

Wind energy is witnessing a high level of commitment from MNRE and several state governments. This has translated into short to medium-term policy certainty in the wind energy market. The domestic and global wind industry has taken advantage of a variety of support mechanisms available to deepen its engagement (IRENA, 2012a). The development of wind power in India began in the early 90's and the market has matured since the implementation of the Electricity Act 2003. With a cumulative installed capacity of 20,682 MW as on March 31, 2014, India is ranked 5th in wind power in the world.

Figure 5.2 highlights the annual and cumulative wind power installed capacity in India along with the important policies that were announced 1992 onwards. FiT, AD (withdrawn from April 2012 and reinstated in 2014-15), GBI and tax exemptions in addition to RPOs offered by various states have been the major driving force for wind power in India. Tamil Nadu (7,277 MW) has the largest wind power installed capacity in India followed by Maharashtra (4,065 MW), Gujarat (3,346 MW), Rajasthan (2,802 MW) and Karnataka (2,324 MW).

Evolution of Solar PV Policies in India

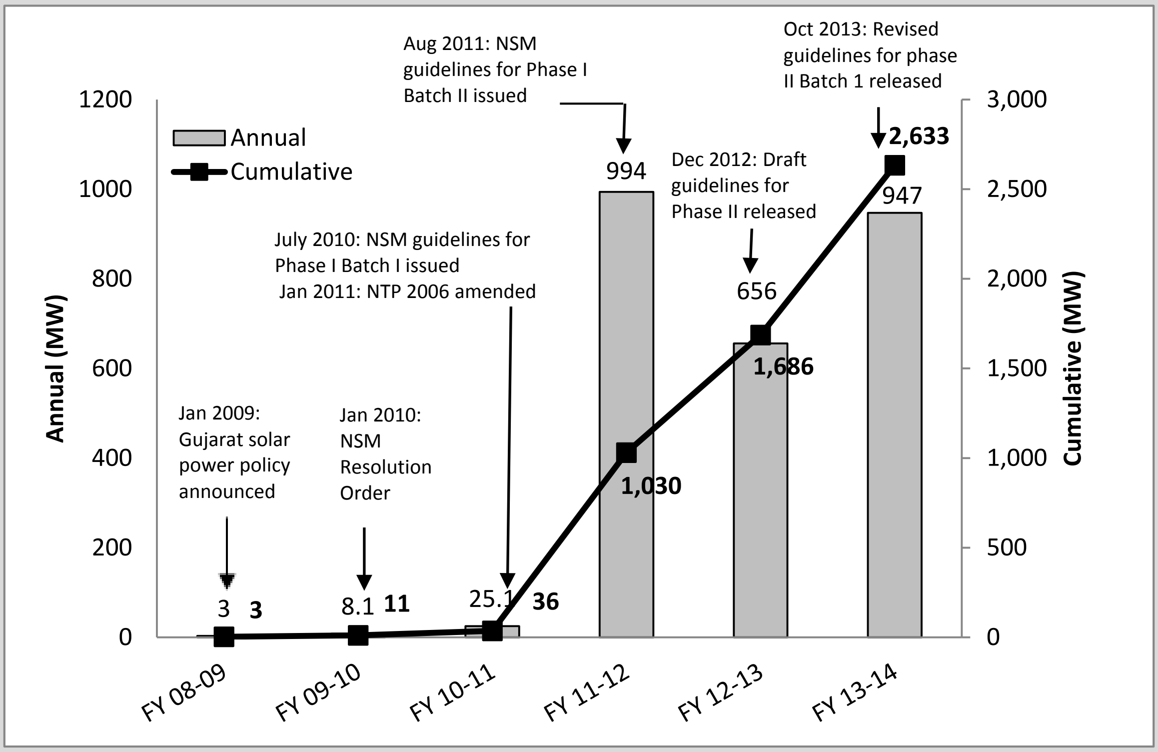


Figure 5.3: Cumulative and Annual Incremental PV Installed Capacity in India From 2008-14

NSM coupled with the state solar policies of Rajasthan, Gujarat, Karnataka and Maharashtra have been instrumental in adding utility-scale solar PV in India. The benchmark tariff of INR 15/kWh applicable for first 12 years and INR 5/kWh for the life of the system for the subsequent 13 years as established by Gujarat Electricity Regulatory Commission (GERC) was one of the prime motivators for generating investor interest in Gujarat's solar program (GEDA, 2010). In the case of NSM, a 25 year power purchase agreement with the National Vidyut Vyapar Nigam (NVVN), an arm of NTPC (a central public sector undertaking) was a major driver for developers.

Figure 5.3 highlights the annual and cumulative PV installed capacity in India along with the important policies that were announced during this period. As of March 2014, the cumulative installed capacity of solar was 2,633 MW (Resolve, 2014)(Balachandar, 2014). The solar installations have been growing at CAGR of 389% over the past five years. Gujarat (916 MW) has added the maximum amount of solar capacity followed by Rajasthan (730 MW) (Balachandar, 2014).

5.2.1 Supply Side Support Mechanisms

The renewable manufacturing sector directly benefits from different supply side support mechanisms viz. subsidy on capital expenditure, LCR, waiver of excise duty or sales tax, etc. Modified Special Incentive Package Scheme[65], Foreign Direct Investment, and SEZs have been some of the major initiatives promoted by the central government. Table 5.10 briefly highlights the different supply side policies that are very relevant to the promotion of renewable manufacturing.

Table 5.10: Support Mechanisms for RE Manufacturing in India (CRISIL, 2013)

Supply side policy		
Policies	**Description**	**Sector**
Capital Subsidy Scheme	▪ Special Incentives Package Scheme of Department of Information Technology was launched in 2007 ▪ The policy states that central government will provide capital subsidy or equity worth 20% of capital expenditure, during the first 10 years, for SEZ units and 25% of capital expenditure for non-SEZ units along with exemption from countervailing duty (Live Mint & The Wall Steet Journal, 2010) ▪ Government received 26 proposals worth INR 2,29,000 crore for investments in semiconductor fabrication units, ecosystem units and solar PV projects (Business Line,The Hindu, 2010) ▪ Only six applicants were able to obtain financial commitment (INR 2,500 crore for fab units and INR 1,000 crore for ecosystem unit) (Business Line,The Hindu, 2010) ▪ To date, none of the applicants have been able to make investment of INR 1000 or 2,500 crore respectively and as such no capital subsidy has been disbursed by the central government ▪ Modified Special Incentive Package Scheme (M-SIPS) was notified on July 2012. MSIPS is an investment-based scheme, which will be valid for three years. ▪ 25% capital expenditure of the Electronic System Design& Manufacturing (ESDM) unit in non-SEZ and 20% of the capital expenditure of the ESDM unit within SEZ is available as subsidy. This capex (capital expenditure) is available for the investment made within 10 years from the date of approval of the project (PIB, 2012). ▪ Reimbursement of Countervailing Duty (CVD)/ excise on capital equipment for non-SEZ unit ▪ Investment threshold for semiconductor fab unit is INR 1000 crore, whereas, polysilicon, ingots, cells and modules (c-Si technology) have thresholds of INR 650 crore, INR 400 crore and INR 100 crore respectively. Cells and modules for thin film technology have an investment ceiling of INR 300 crore (Department of Electronics and Information Technology, 2012) ▪ M-SIPS has received a response of INR 4,600 crore of which INR 750 crore correspond to Assembly, Test, Mark and Pack (ATMP) unit - Semiconductor manufacturing (PIB, 2013a).	Solar
Trade/Investment Incentive	▪ LCR to support and boost the development of domestic manufacturing base for Silicon cells and modules	Solar

[65]Sadly, introduction of M-SIPS hasn't found enthusiasm among the solar component manufacturers. This could be partially blamed on its predecessor SIPS scheme and the supply glut prevailing in the global market.

Supply side policy		
Policies	**Description**	**Sector**
R&D Incentives	▪ The income tax department provides for a weighted deduction for in-house R&D activity, which entitles RE manufacturers to claim 200% of the expenses other than expenses on land and building incurred for the in-house R&D activity.	All RE technologies
Department of SCIENCE & Technology and Innovation	▪ Technology Development Board (TDB) aims at accelerating the development and commercialization of indigenous technology and adapting imported technology for wider domestic application. The board provides financial assistance in the form of equity, soft loans, or grants (DST, 2009). ▪ Advanced composite program (TIFAC, 2009) is a unique program under TIFAC (Technology, Information, Forecasting, and Assessment Council), Department of Science, and Technology. The program has attempted to source knowledge from various centres of excellence across the country and brought the industries closer for technology absorption, development, and dissemination.	All RE technologies
National Manufacturing Policy 2012	▪ GoI has prepared a National Manufacturing Policy, 2012 to increase the share of manufacturing in India, its GDP, accelerated development, inclusive growth, and provision of gainful employment in the manufacturing sector. ▪ The proposals in the policy are generally sector neutral, location neutral, and technology neutral except incentivization of green technology. ▪ Solar, wind, renewable energy are considered as strategic industries.	All RE technologies
Foreign Direct Investment	▪ 100% FDI is allowed in RE ▪ As of June 2013,cumulative FDI in non-conventional energy source stood at INR 13,425.78 Crore (DIPP, 2013) ▪ 100% FDI is allowed in the manufacturing sector	All RE technologies
Special Economic Zone (SEZ) Policy	▪ To provide speedy clearance, infrastructure support, fiscal incentive and tax exemption for increasing export from India, the SEZ Act was announced in April 2000 ▪ To date, 588 SEZs have formal approvals, 49 have in-principal approvals and 386 are notified SEZs ▪ 173 SEZs are export oriented ▪ Six non-conventional energy based SEZ had formal approvals, four are notified SEZs and two are exporting SEZs ▪ Three power/alternate energy/solar-based SEZs have formal approvals, two have obtained in-principal approvals, three are notified SEZs and two are export-oriented SEZs. (Ministry of Commerce and Industry, 2013)	All RE technologies
EXIM Policy	▪ Green technology is listed as a focused-group scheme. Under this scheme, export of RE product to all countries is entitled for an additional duty credit equivalent to 2-5% of Freight On Board (FOB) value of exports ▪ Export Promotion Capital Good (EPCG) scheme provides 0% duty to green energy technology. Export Obligation (EO) will be 8 times the duty saved. The Export Obligation Period (EOP) will be 8 years reckoned from authorization issue-date. For exporters of green technology products, specific EO will be 75% of EO	All RE technologies

Supply side policy		
Policies	**Description**	**Sector**
Trade Investment Restriction	▪ Custom duty rebates for wind components ▪ Local rules make it very difficult to import complete wind turbine into India as all turbine installed in the Indian market have to receive provisional type testing and certification by the Centre for Wind Energy Technology (C-WET), a research and development institute within MNRE, to be eligible for grid connectivity and to avail financial incentives. In addition, foreign manufacturers are required to establish a local manufacturing facility and provide after sales service.	Wind
Duty Relaxation	▪ No Excise duty for renewable energy ▪ Custom duty rebates for wind/solar components, ▪ Reduced or nil VAT for RE technologies in the states	Wind &Solar
IREDA NCEF Refinance scheme	▪ It aims to bring down the cost of funds for Renewable energy projects by providing refinancing at a rate of 2% up to 30% of the debt granted by scheduled commercial banks/financial institution at concessional rate of interest, with funds sourced from NCEF. ▪ Scheme will be in operation for a period of five year beginning 2013-14. ▪ Activities include manufacturing, generation, infrastructure for evacuation, etc. ▪ The rate of interest on refinance is 2% per annum. The refinance will be provided subject to the condition that the rate of interest on the refinanced component of the loan from the lending institution to the borrower does not exceed 5% per annum. ▪ Refinance from IREDA shall be repayable within a period of 10 years plus a moratorium of one year.	All RE technologies

Exhibit 5.3

Domestic Content Requirement and its effectiveness

In JNNSM, Domestic or Local Content Requirement has come under wide criticism in the international arena, especially by the US[66]. In Phase I, Batch I, it was mandatory for projects based on c-Si technology to use modules manufactured in India. This was extended to c-Si cells too in Phase I Batch II. However, thin film technologies and concentrator PV cells were left outside the purview [67](Johnson, 2013). Despite the DCR stipulation, approximately, 65% of projects under NSM have engaged thin films whereas only 35% of non-NSM projects have used thin films (Agrawal & Jain, 2014).

DCR has not resulted in increased jobs nor have they improved competitiveness. This resulted in the use of imported thin film technology which was cheaper than c-Si modules and came with concessional finance from the US Export-Import Bank – 4-5% interest and longer tenure (15 to 20 years) as compared to 14-15% offered by Indian Banks. The concessional finance came with a rider

[66]In Feb 2014, United States Trade Representative filed an official challenge at the World Trade Organization on the local content requirement clause in the National Solar Mission. USTR had launched a similar challenge early last year with little effect (Jopson, Donnan, & Kazmin, 2014).

[67]As Moser Baer was the only major company engaged in manufacturing thin film modules in India. It was thought that any clause favouring thin film adoption from indigenous manufacturer would lead to monopolistic behaviour. Hence, GoI chose to leave thin film technology outside DCR ambit. Solar thermal technology was also associated with local content requirement. Developers engaging this technology were required to ensure 30 per cent of local content (Johnson, 2013)

that the technology was to be adopted from US-based suppliers (Johnson, 2013).

Thus, DCR has had limited effectiveness in the uptake of c-Si modules manufactured domestically, in fact developers have preferred to opt for the imported thin film variant[68].

National Manufacturing Policy

The objective of the NMP, launched in 2011 is to increase the manufacturing sector's contribution to the GDP to at least 25% by 2022, to create 100 million additional jobs and appropriate skill sets, increase domestic value addition and technological depth in manufacturing, support policy for global competitiveness and sustainability of growth (DIPP, 2011). Barring incentives for green technology, the proposals in this policy are generally sector neutral, location neutral, and technology neutral. The policy is based on the principle of industrial growth in partnership with the states. The central government creates an enabling policy framework, provides incentives for infrastructure development on a Public Private Partnership (PPP) basis through appropriate financing instruments, and state governments encourage the adoption of the measures provided in the policy.

Some of the suggested strategies in NMP for increasing the manufacturing sector's contribution are:

- Welcome foreign investment and technologies
- Create comprehensive exit policy for sick units
- Rationalize business regulations and employment laws
- Create National Investment and Manufacturing Zones
- Enable statutory clearances through the web
- Encourage policy and market-based interventions for sustainable development and green manufacturing
- Establish Technology Acquisition and Development Fund (TADF) for acquisition of useful technologies including green/renewable energy technologies
- Apportion incentives for renewable energy under the existing schemes of GoI and state governments
- Identify renewable energy like solar, wind, etc. as a strategic industry which would need sector specific policy intervention
- Develop easy financing for the SME sector
- Leverage infrastructure deficit and government procurement.

NMP also highlights the role of National Investment and Manufacturing Zones (NIMZ) and SEZs in supporting the manufacturing sector. NIMZ is developed as an integrated township with state-of-the-art infrastructure and land-use based on zoning. Announced in April 2000, the SEZ policy provides quality infrastructure along with attractive fiscal package both at the central and state levels. A brief outlook of NIMZ is as follows:

- NIMZ norms were issued in March 2013
- Nine NIMZs have been identified across the country to begin under the National Manufacturing Plan
- Central government has approved the plan for setting up NIMZ in Tumkur, Karnataka
- Master plan for the first zone of Delhi-Mumbai Industrial Corridor has been notified.

[68]One other factor that affected the domestic industry was global oversupply which lead to large price reductions that outpaced reductions in cost. Major Indian manufacturers including Tata Solar, Moser Baer operated at 10-15 per cent and zero per cent in modules and cells respectively. Under these conditions, R&D and equipment enhancements were non-existent which further made the domestic PV industry less competitive (Johnson, 2013)(Sahoo & Shrimali, 2013).

Annexure 9 provides a detailed overview and comparison of NIMZ and SEZ.

National Clean Energy Fund (NCEF)

NCEF is a non-lapsable corpus under the Public Accounts of India introduced in the budget of 2010-11 and is being collected since July 2010. **Its objective is to fund research and innovative projects in clean energy technologies.** It is collected through the levy of a clean energy cess of INR 50/tonne of coal produced domestically and imported to India. From FY16, the cess has been increased to INR 200/tonne. It is collected by the Central Board of Excise & Customs (CBEC), while the Plan Finance II (PF-II) Division of the Department of Expenditure, Ministry of Finance acts as the Secretariat for the NCEF and is the agency responsible for disbursing NCEF funds. Projects are eligible to receive support in the form of a loan or viability gap funding to the tune of 40% of the total project cost wherein a minimum financial commitment of not less than 40% of the total project cost has to come through project organization. Projects funded by any other arm of GoI or those that have received grants from any other national/international body are not eligible for funding under the NCEF.

Projects to be considered under NCEF are appraised and evaluated at three levels; initially appraised by the sponsor Ministry; secondly by Ministry of Finance, Planning Commission and other relevant Ministries/Departments; and finally by an Inter-Ministerial Group (IMG) consisting of high ranking officials from Ministry of Finance, Planning Commission, sponsoring and other relevant Ministries.

The operation of NCEF has been affected by several problems and as a result, the Fund's performance has been far from satisfactory. The proposals that have been brought forth by sponsor ministries until date have generally lacked quality and innovativeness and failed to progress the stated objective of NCEF. Moreover, the majority of NCEF's corpus remains unutilized now. A conservative estimate by the Centre for Budget and Governance Accountability (CBGA) based on a review of IMG decisions has been that at least 80% of the corpus currently remains unutilized. This indicates that the sponsor ministries lack the capacity to develop proposals of the quality and size required to tap the full potential of the fund. Also, nearly half the proposals appraised by IMG were rejected or not approved in their entirety, as they were found ineligible under the existing guidelines. CBGA also concluded that the approval ratio would have been lower if IMG had strictly adhered to the 40% funding limit and other requirements in the guidelines.

A funding support of INR 100 crore from NCEF directed at interest cost reduction of 2% for renewable energy projects is expected to result in an additional capacity of around 600 MW in case of solar PV projects, 800 MW in case of wind projects and 350 MW in case of solar CSP projects. These capacity additions could save about 0.4 million tonnes of coal per annum (10.5 million tonnes of coal over the life of a power project) in case of solar PV capacity additions, about 0.6 million tonnes of coal per annum (14.5 million tonnes of coal over the life of a power project) in case of wind capacity additions and about 0.25 million tonnes of coal per annum (6.0 million tonnes of coal over the life of a power project) in case of solar CSP capacity additions(CRISIL, 2013). Table 5.11 provides a list of projects that have or are in the process of availing funds from NCEF. Approximately INR 4,422.16 crore has been allocated from the NCEF corpus.

Table 5.11: List of Approved Project by NCEF (Society for Environmental Communications, 2013)

Ministry/ Department	Project	NCEF amount approved (INR Crore)
MNRE	Solar water heaters	64.14

MNRE	Solar photovoltaic system in six states	85.88
MNRE	Financing through NABARD	46.8
MNRE	Biomass cook stoves	6.55
MoEF	Green India Mission	200
MoP	Fuel gas based aqua ammonia power cycle	8.00
MoP	Establishment of 1,200 KV National Test Station	39.40
MNRE	Bihar Saurkranti Sichai Yojna	17.64
MNRE	Funding for off grid PV systems to be installed under NSM in nine villages of North 24 Paragana district of West Bengal	44.64
MNRE	Installation of PV plants with an aggregate capacity of 50MW	70.90
MNRE	Financial support for extending subsidy for installation of PV lights and small systems through NABARD	73.71
MNRE	Installation of PV plants of 4 MW capacity at different railway locations	15.20
MNRE	Pilot grid connected solar thermal power projects under NSM	1,020.00
MNRE	Viability Gap Funding for 750 MW of PV under solar mission	1,875.00
MDWS	Solar energy based dual pump piped water supply in 74 backward districts	221.30
Total		4,422.16

Exhibit 5.4

Attracting RE investments through cross-sectoral policy interventions

Technology Up gradation Fund Scheme (TUFS), 1999

To resuscitate the textile and jute industry in India, the Ministry of Textiles launched the Technology Up gradation Fund Scheme (TUFS) in April 1999. The key feature of TUFS is the reimbursement of 5% of the interest charged by the identified financial institutions on sanctioned projects. Wind turbines, like any other modernization/expansion project of the textile industry qualified to be treated as TUFS compatible, are also entitled to the 5% interest subsidy on the capital invested.

The Ministry of Textiles had originally allowed wind power projects to come up under TUFS since 2003. Further, Ministry of Textiles, on November 1, 2007, through a resolution continued the Technology Up gradation Fund Scheme for textiles and jute industries with effect from 01.11.2007 to 31.03.2012 and has further broadened the scope of the areas under up-gradation of technologies. Textile and jute plants were allowed to obtain reimbursements for 25% of the cost of machinery in energy saving devices and captive power plants (including non-conventional sources).This scheme has been currently discontinued for wind turbines.

Karnataka Semiconductor Policy, 2010

The state of Karnataka came with a semiconductor policy with an aim to retain its edge in design by attracting new investments and capacity expansion from existing companies. The policy provides incentives to the manufacturing industry at multiple levels. A few policies are summarized below (Government of Karnataka, 2010):

- Semiconductor hubs must be located closer to the Airports/Ports as transportation costs account for 30% of the total costs.
- Government of Karnataka has set-up a financial incentive scheme under 'Karnataka Fund for Semiconductor Excellence'. In this scheme, INR 10 crore is available to the private companies covering up to 50% of their R & D expenses, subject to a limit of INR 10 lakhs per unit.
- Development of solar farms in a Joint Venture/PPP mode in Bijapur, Gulbarga, Raichur and Bellary districts with support from Karnataka Power Corporation Limited and Karnataka Renewable Energy Development Limited.
- Investment promotion subsidy under which 25% of the sanctioned amount will be released every year on a refund basis towards payments made by the unit towards gross VAT, Employees State Insurance (ESI), Employee Provident Fund (EPF) and electricity tariff. In the case of enterprises, which do not use power and are not covered under VAT, EPF or ESI, the investment subsidy will be released against loan dues. This incentive is available to enterprises availing term loan to an extent of minimum 50% of the cost of fixed assets.

5.2.2 Demand Side Support Mechanisms

This section briefly highlights the different demand side support mechanisms applicable for renewable energy dissemination in India, and details of the various support mechanisms can be found in **Annexure 10.** The key incentives by the Centre and the states that have helped the growth of renewable energy demand in India are summarized in Table 5.12.

Table 5.12: Support Mechanism for RE Market Development in India (GWEC, 2012b)

Policy	Detail	Type
Feed in Tariff	▪ 13 and 14 SERCs have declared FiT for the purchase of electricity generated from wind and solar power projects respectively. List of state-wise FiT is given in **Annexure 11** ▪ All the SERC's have adopted a 'cost plus' methodology to determine the tariff	State

Policy	Detail	Type
Renewable Purchase Obligation/Specification	▪ 26 SERCs have specified the mandatory purchase obligation under Section 86, 1 (e) of the Electricity Act, 2003, for purchase of fixed percentage of energy generated from RE sources ▪ The Renewable Purchase Obligation (RPO) percentage varies from 0.5% to 10.25%, depending on the local renewable resources. The solar RPO target ranges from 0.25% to 1.9% across different states ▪ RPO obligation can be fulfilled through direct purchase via bilateral contracts and tradable REC mechanism, which can further generate revenue for RE projects.	State
(REC)	▪ Launched in 2010, REC is a tradable certificate where one certificate is equal to 1 MWh of renewable energy generated ▪ Purchased by DISCOM, Open Access and Captive Consumer to fulfil the RPO obligation ▪ As of April 2014, a total of 1,23,05,349 RECs were issued of which 63,54,206 RECs have been redeemed.	Central
Accelerated Depreciation	▪ Till March 2014, wind energy projects were eligible to claim accelerated depreciation of 35% (15%+20%) in the first year of operation. Currently, wind power sector project can avail 100% (80%+20%) depreciation in the first year of operation ▪ Solar energy projects can claim accelerated depreciation of 100% (80%+20%) in the first year of operation (CERC, 2013).	Central
Generation Based Incentive	▪ GBI of INR 0.5/kWh has been reintroduced for wind energy projects and INR 800 crore has been allocated in FY14 Budget. GBI will be effective on projects installed from 1 April, 2012 onwards ▪ GBI will be provided for a period of not less than 4 years and a maximum of 10 years with a cap of INR 1 crore per MW. The total disbursement in a year will not exceed one fourth of the maximum limit of the incentive i.e. INR 25 lakhs per MW during the first four years. The GBI scheme will be applicable for the 12th FYP period which has a target of 15,000 MW wind power capacity addition ▪ Solar GBI is provided to projects of capacity 100 kW to 2 MW connected to the distribution grid below 33 KV, which is eligible under RPSSGP (Rooftop PV and Small Solar Power Generation Program) scheme ▪ The quantum of GBI is kept fixed which is a difference between the CERC tariff for 2010-11 (INR 17.91 per KWh) and a reference tariff of INR 5.5 per KWh ▪ The first 100 MW capacity projects registered with IREDA are eligible for GBI ▪ MNRE proposes to launch new program in Phase II for states, which could not be covered in the earlier allocation under RPSSGP scheme.	Central
JNNSM	▪ Under JNNSM, GoI has set an ambitious target of deploying 22,000 MW of solar energy by 2022 ▪ Aimed at reducing the cost of solar power generation in the country through (i) long-term policy; (ii) large-scale	Solar (Central)

Policy	Detail	Type
	deployment goals; (iii) aggressive R&D; (iv) domestic production of critical raw materials, components and products ▪ Targets to achieve grid tariff parity by 2022 ▪ Targets in NSM are scheduled in phases. Project allotment for Phase I was scheduled for 2010-13, which was further divided into two batches. In Batch 1, PPAs were signed for a capacity of 610 MW, 140 MW for solar PV and 470 MW for CSP technology. Currently, 130 MW of solar PV, and 50 MW of CSP have been commissioned. 420 MW of CSP projects have obtained an extension till March 2014 (Mercom Capital , 2013) ▪ In Batch II, 340 MW of solar PV was allotted of which 300 MW has currently been installed. The rest - 40 MW might get extended or cancelled (Mercom Capital , 2013) ▪ Phase II targets capacity addition of 10 GW of grid-connected solar power in India from 2013-17 ▪ In Phase-II Batch-1, a total of 750 MW of solar PV projects were allotted by competitive bidding process ▪ A new process called Viability Gap Funding (VGF) was introduced in which selected project will sign PPA at the rate of INR 5.25 per unit for 25 Years with SECI and is eligible to receive VGF financing of 30% of project cost or INR 2.5 crore/MW /project, whichever is lower.	
Grid connectivity	▪ As per the Electricity Act 2003, the respective State Transmission Utility (STU) is responsible for the creation of grid inter-connection infrastructure for RE connectivity at its own cost. However, due to the poor financial health of the STUs and the time required to create such infrastructure, states adopt different practices for creation of the required infrastructure.	State
Wheeling, Banking & third party sale	▪ Favourable provision for wheeling, banking and third party sale by wind and solar power producers ▪ For wind, wheeling charge for the different states is in the range of 2% (MP and MH) to 7.5% (WB) of the energy fed to the grid. The states of Karnataka, Tamil Nadu, and Andhra Pradesh charge 5% of the total energy fed to the grid. UI charges are also applied during the time of injection and withdrawal (EAI, 2013) ▪ For wind, Tamil Nadu and Karnataka allow 5% and 2% of the total renewable energy fed to the grid as bankable energy and can be availed anytime during the financial year. Rajasthan and Maharashtra provide 6 months (Apr-Sep) and 12 months of banking period respectively. UI charge is also applied during the time of injection and withdrawal. The state of Andhra Pradesh doesn't permit banking (EAI, 2013) ▪ The wheeling charges for solar in Karnataka is zero and banking charge is 2% (REConnect, 2013). The wheeling charges for solar in Gujarat is 4% of the energy fed and transmission losses at 7%-10% (for 5 MW and above) are also applied. Gujarat state does not allow banking in case of any third party sale of solar power (GERC, 2010). Andhra	State

Policy	Detail	Type
	Pradesh does not levy wheeling and transmission charges for solar (Ramesh, 2012).	
SNA Project Facilitation	▪ State Nodal Agencies (SNAs) facilitate project development right from resource assessment to the final commissioning. ▪ SNA through its initiative undertakes resource assessment studies ▪ SNA supports the developer by facilitating development of infrastructure at identified sites and also verifies the legal statutory clearances sought by developers from different departments ▪ MEDA in Maharashtra has created the Green Cess (tax) fund. This is a dedicated fund in Maharashtra for the development of RE and a part of this fund is utilized to create infrastructure for grid connectivity with proposed wind farms. Similar tax (cess) is being collected in Karnataka.	State
Capital Subsidy	▪ Maharashtra has the provision for capital subsidy to the extent of 11% for wind energy projects set up by the cooperative sector. The state also has provision for capital for wind power projects under Green Cess Fund (GCF) ▪ Rajasthan provides soft loan equal to 1/3 of capital cost to developer at low interest rate ▪ A 30% capital subsidy on the project cost is available from the centre for off-grid solar projects.	State/Center
VAT Exemption	▪ Tamil Nadu has reduced VAT from 14.5% to 5% (Government of Tamil Nadu, 2013) ▪ Madhya Pradesh Solar Policy 2012 states that the equipment purchased for installation of solar power plants will be exempted as per VAT rules and entry tax (IREEED, 2013) ▪ Chhattisgarh has a solar policy where there is a provision for exemption of VAT for all equipment/materials required for solar power project through Commercial Tax Department (CREDA, 2012) ▪ Karnataka offers 5.5% VAT for all the renewable energy components (KREDL, 2009) ▪ Gujarat and Maharashtra offer 5% VAT for all renewable components (MNRE, 2012d) ▪ In Rajasthan, No VAT is applicable for RE projects.	State
Investment in Infrastructure	▪ Gujarat has created a solar energy park (Joshi, 2012). ▪ Provision of 2,024 hectare of land for establishing the complete 'solar ecosystem' ▪ Single window facility to developers for infrastructure facilities like land, water, power evacuation system and road	State
Exemption on Electricity Duty	▪ Renewable energy project is exempted from electricity duty by state government	State

Tax/Duty provisions

Power plants engaged in generation of power using renewables are offered a 10 year tax holiday provided the generation begins before March 31, 2017. Yet, the cost on taxes forms a major part of the engineering, procurement and construction costs ranging from 10-20% of the total system costs (KPMG, 2013). However, the government has provided exemptions on Basic Custom Duties (BCD) for solar cells and modules. The BCD exemption is also applicable to chemicals and electronic parts used in the manufacture of solar cells (Ministry of Finance, 2013). This was one of the primary reasons why India saw a major import of cells and modules, as can be observed in Figure 5.4.

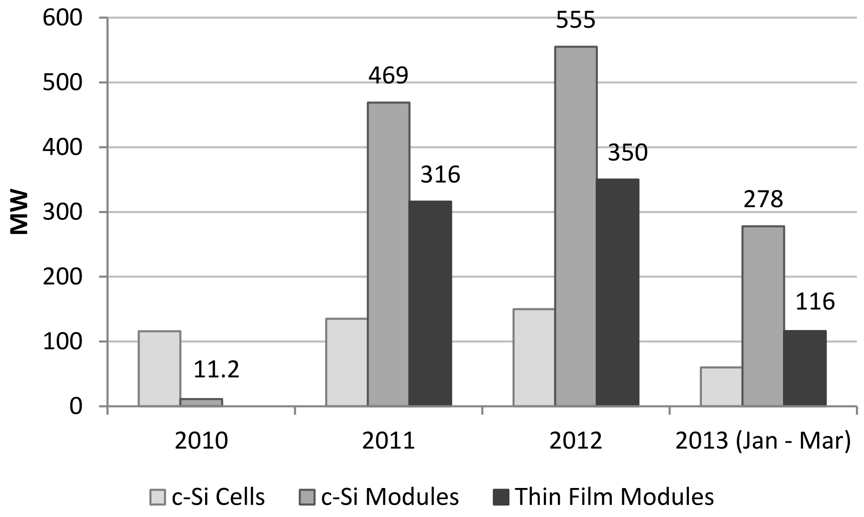


Figure 5.4: Import of Solar Cells and Modules in India during 2010-13 (PV Magazine, 2013e)

A few states such as Rajasthan and Madhya Pradesh have 0% VAT whereas states such as Maharashtra, Tamil Nadu, and Gujarat have 5% and Karnataka has 5.5% VAT charges, respectively. The tax structure applicable at the state and the central level in India for renewable energy components/parts have been summarized in Table 5.13.

Table5.13: Tax Structure for RE Components at State/Central Level (CRISIL, 2013)

Taxes applicable on components	Rajasthan	Maharashtra	Gujarat	Karnataka	Tamil Nadu	Madhya Pradesh
Local VAT	0%	5%	5%	5.5%	5%	0%
Central Sales tax against C-Form from these states to other state	0%	2%	2%	2%	2%	0%
Central Sales tax without C-Form	0%	5%	5%	5.5%	5%	0%

5.3 Incentives Offered to Other Industries in India

In 2013, the total investment in the renewable sector in India came down to USD 6.1 billion, 15% lower than the previous year's figures of USD 7.2 billion and more than 50% lower than the investments (USD12.6 billion) recorded in 2011 (BNEF, 2014). In 2013, China with around USD 54.2 billion followed by the US at USD 33.9 billion saw the first and second largest investments. In India, the wind and solar sectors saw an investment of USD 3.3 and USD 1.0 billion, respectively (BNEF, 2014). The investments in these technologies in 2011 stood at USD 5.9 billion and USD 4.7 billion, respectively, however, a decrease was also observed in 2012(UNEP, 2012). The lower investments in wind were attributed to the expiry of AD and GBI[69]. 'Policy uncertainty'[70] and the anti-dumping duty petition filed by Indian Solar (PV) Manufacturers Association, coupled with

[69]GBI was effective from April 1, 2012.
[70]Phase II of NSM was expected to begin in April 2013, but the cabinet approved the Phase II guidelines only on October 3, 2013. Source:http://www.downtoearth.org.in/content/cabinet-clears-phase-two-solar-mission.

allegation of discrimination on solar equipment imports from the US by GoI[71] have resulted in lower investments in solar technology (Bridge to India, 2013c).

In India, a few sectors such as textile and apparel, auto, Information Technology (IT) and ultra-mega power, etc. have been provided incentives that have encouraged them to grow during their nascent stage. Textile, auto, and IT are export-oriented sectors whereas major components for ultra-mega power project are chiefly imported. The total planned investment in textile for FYP 2012-17 is around USD 2.9 billion, whereas the sector saw an FDI of USD 1.22 billion between 2000-13 (IBEF, 2013d). The auto sector has seen an FDI of USD 8.1 billion between 2000-13 and the IT sector has seen Private Equity – Venture Capital funding of USD 5.1 billion in 2011-12 (IBEF, 2013b)(IBEF, 2013c). Incentives offered by the government have helped attract investments by the private sector. Similar support mechanisms could also be extended to the renewable energy manufacturing industry. Table 5.14 provides a summary of support mechanisms offered to these sectors.

Table 5.14: Support Mechanisms for Different Manufacturing Sectors in India (CRISIL, 2013)

Type of support	Textile Sector	Auto Industry	IT Sector	Ultra Mega Power Sector
Financial Incentives	INR 5,000 crore venture fund with SIDBI to enhance availability of equity to MSME sector among others		Subsidy of 20% on capital expenditure incurred in setting up such units within Special Economic Zones (SEZs) by the Department of IT and Electronics. The subsidy will be hiked to 25% if units are set up outside SEZs	
Preferential Tax Treatments/Duty Structure Related Incentives	Full exemption from basic duty to automatic silk reeling and processing machinery and its parts Concessional rate of 5% basic customs duty to new textile machinery and 7.5% basic duty on second-hand machinery, Reduction of basic customs duty on wool waste and wool tops from 15% to	Concessional import duty on specified parts of hybrid vehicles which has been extended to lithium ion batteries and other parts of hybrid vehicles Excise duty on specified parts of hybrid vehicle reduced to 6% from 10% and excise duty on lithium ion battery packs for supply to electric vehicle or hybrid vehicle manufacturers has	All central taxes and duties incurred in setting up or operating semiconductor fabs will be reimbursed for a period of 10 years	Zero per cent customs duty for components imported for large power plants (> 1000MW capacity) Concessional duty of 5% for plants under 1000MW capacity Tax holiday for 10 years. In Budget 2013-14, uniform duty structure for all forms of coal has

[71]Source: http://www.ustr.gov/about-us/press-office/press-releases/2013/february/us-challenges-india-restrictions-solar

Type of support	Textile Sector	Auto Industry	IT Sector	Ultra Mega Power Sector
	5% Full exemption from basic customs duty to aramid yarn and fabric used for the manufacture of bulletproof helmets.	also been reduced to 6% from 10%. Full exemption from basic customs duty and special CVD with concessional excise duty or CVD of 6 % on some parts of hybrid vehicles is being extended to specified additional items and lithium ion batteries imported to make battery packs for electric or hybrid vehicles.		been announced– 2% basic customs duty and 2% countervailing duty (in lieu of excise).
Incentives Directed at R&D	Weighted deduction at 150% of expenditure incurred on skill development in manufacturing sector to overcome shortage of skilled manpower and an extension of weighted deduction of 200% for R&D expenditure in an in-house facility beyond March 31, 2012 for another 5 years.	The overall incentives package for the auto-manufacturing sector covers R&D activities, hybrid vehicles, and skill development.	Capex eligible for incentives for entities operating in this sector includes not only cost incurred on plant, machinery and equipment, tools etc. but also expenditure incurred on captive power plant, utility machines and R&D including cost of IPRs, copyrights etc.	
Other Government Support	Dormitories for women workers in the mega clusters of handloom and power loom Three Weavers' Service Centres INR 500 crore pilot scheme for promotion of Geo-textiles in the North East		Financial support for the development of electronic manufacturing clusters	The SPV facilitates various clearances, allocations, land acquisition in its name and finally transfers it to the identified developer along with various clearances, tie ups, etc.

5.4 Gaps in Indian Context

India continues to be placed very low in various global surveys in terms of 'ease of doing businesses. For instance, obtaining a construction permit is a very time-consuming process in India. According to the World Bank and International Finance's 'Doing Business 2013', India ranks 182[72] out of 185 countries in terms of dealing with construction permits. In India, 34 procedures are involved as compared to 8 in Thailand, Colombia and Spain and 6 in Hong Kong and New Zealand. Further, it takes 196 days to get construction permits in India as compared to 26 in Singapore, 27 in USA, 43 in Bahrain and 46 in UAE (World Bank, 2013). Moreover, India ranks a low 173 in terms of procedure and time taken in starting a new business and ranks 184 in enforcing contracts. (FICCI, 2013c)

However, in a conference hosted by the Confederation of Indian Industry (CII) and the US-India Business Council (USIBC) on July 11, 2013, Anand Sharma, the Minister for Commerce and Industry emphasized the steps taken by the government to spur business and investments in the country. Setting up NIMZ across India and the single-window approval mechanism for investments are the two prominent features adopted by India (IANS, 2013) .

Interestingly, on the renewable front, India has made good strides and is ranked 9 out of 40 countries in a renewable energy country attractiveness index published by EY (EY, 2013). In the wind index it ranked 6th; in onshore it ranked 10th and in offshore it ranked 22nd. Moreover, in the overall solar index it ranked 3rd, with 8th and 6th positions respectively for solar PV and CSP. The demand and supply side measures put forth by GoI are the prime reasons for India's performance.

However, domestic renewable manufacturing, especially in solar PV has been slow over the past few years. A bulk of cell and module manufacturing capacity remains idle (PV Magazine, 2013e) (Subramaniam, 2013). Different sources place this value at 50-80% range (Limaye, 2012). Although, the Indian government has various support incentives for the renewable manufacturing sector, the performance has not been as expected. Skewed policy which left out thin films from DCR ambit in the JNNSM, the global supply glut in c-Si cells and modules, poor infrastructure (quality of electricity supply) and high costs of electricity and fuels are some of the major challenges affecting the PV industry(Johnson, 2013). Some of the major gaps that are hampering the domestic RE manufacturing industry are highlighted below:

5.4.1 Financing

High costs and shorter tenure of financing and general scepticism in technology (especially in the case of solar) are major challenges for both manufacturing as well as deployment of renewable energy in India (FICCI, 2013b) (CEEW & NRDC, 2012)(CSPToday, 2013). Bankability of PPAs, lack of experience of (solar) developers, uncertainty in implementation of regulatory mechanisms such as enforcement of RPOs, and the REC mechanism and absence of reliable irradiation and plant performance data are some of the factors, which act as barriers to obtain finance. Moreover, the cost of financing in India is very high. This leaves very small margins for project developers who are already working with some of the lowest renewable tariffs in the world (Mercom Capital, 2012). This has led to many project developers looking for long-term, low-cost, and more reliable sources of project finance internationally.

In addition to higher interest rates (12-14%), which leads to viability issues in a project, while financing RE projects, especially wind power, banks don't take an exposure of more than 60% on

[72]Overall rank in ease of doing business is 132, last among South Asian countries and only above Philippines among fast developing countries.

non/limited recourse project financing. Most banks are reaching a sectoral cap in the power sector and renewable energy technologies do not have any specific sectoral limits sanctions by the Reserve Bank of India. The working capital requirement is high in case of wind power projects. The higher interest rates (12-14%) for working capital make Indian products less competitive in the global market, which offers borrowing rates of 3-4%. Wind turbine suppliers are also involved in infrastructure creation for projects and need to stay invested for longer durations, even up to 4-5 years. Costly working capital creates a lack of a level playing field with global players.

USA's EXIM bank or the Export-Import Bank of China provide low cost (1-2%) and longer tenure financing (15 to 20 years) with a caveat that the developer import project components from the manufacturers in their countries(Bayaliyev, Kalloz, & Robinson, 2011). Developers such as Azure Power, Green Infra, Mahindra Solar and Kiran Energy are among many others who have financed their projects using international financing sources in the past (EXIM USA, 2011). Financing come with a stipulation – in the case of Azure, it received a loan of USD16 million from EXIM bank for the import of modules from First Solar, the largest manufacturer in the US, to build a 5 MW solar thin film plant (CdTe) in Rajasthan (EXIM USA, 2011).

For wind power, it is often noticed that the existing EXIM line of credit is inadequate for export.. Besides, Indian exporters also have to incur extra logistics cost since the shipping route is via Dubai/Singapore. To increase wind turbine export from India, establishing a portfolio fund like the US-EXIM or China–EXIM may prove helpful.

5.4.2 Support to Domestic Industry

DCR was introduced under JNNSM Phase I to support solar PV manufacturing in the country. For solar PV, the JNNSM DCR guidelines state, *"In Solar PV projects to be selected in first batch during FY10-11, it will be mandatory for projects based on crystalline silicon technology to use the modules manufactured in India. For Solar PV Projects to be selected in the second batch during FY12, it will be mandatory for all the projects to use cells and modules manufactured in India. PV Modules made from thin film technologies or concentrator PV cells may be sourced from any country, provided the technical qualification criterion is fully met"* (MNRE, 2010a).

In Phase-II, Batch 1 of NSM the projects implemented under Part -A (375 MW) have to be in accordance with the DCR guidelines, i.e., both the solar cells and modules used in the project must be made in India.

When JNNSM was launched, India already had 15 companies engaged in cell manufacturing and 20 in module manufacturing, using c-Si PV technology (ISA, 2010). On the other hand, Moser-Baer was the only thin film manufacturer in India. Therefore, to avoid monopoly, DCR on thin film technology was exempted (Johnson, 2013).

This resulted in majority of installations using low-cost financed imported thin film[73] modules, acting against the domestic solar cell manufacturers, majority of who were producing crystalline PV cells and modules. Currently, approximately 42% of the total module capacity used in India is based on thin film technology whereas, globally, 13% of the total PV installations in 2012 used this technology (Woods, 2013)(REN21, 2013).

Moreover, India does not have a provision for assistance (fiscal incentives or low interest loans) to those buying from domestic manufacturers. Such a provision has supported the development of

[73]First Solar, a US based thin film manufacturing firm, has the highest - approx 21% share of the supply of PV modules in India (Subramaniam, 2013) .

indigenous manufacturing capacity in countries like China (Renewable Energy World, 2009)(South China Morning Post, 2013). In addition, manufacturers also face delays in setting up facilities due to a complex regulatory system for permitting land clearances.

In India, the provision for anti-dumping duty like those existing in the US and Europe on imports of PV products from China is missing (Wingfield, 2012) (European Commission, 2013b). However, the Directorate General of Anti-Dumping Duties (DGAD), Ministry of Commerce has found preliminary evidence of dumping of solar cells and modules by China, the US, Taiwan and Malaysia and has initiated an investigation (PIB, 2013b).

The provision of DCR in the wind sector proved to be very effective in the development of wind manufacturing industry in China. It was lifted in 2009 only after the domestic industry was well established. DCR could prove to be critical for the establishment of a robust wind manufacturing industry in India as well (CRISIL, 2013).

5.4.3 Clarity on Taxation

The inverted duty structure in India favours the import of finished goods as opposed to domestic manufacturers relying on imported raw materials. Under the inverted duty structure, the cost of importing raw materials to manufacture products becomes much higher than the cost of importing the finished goods. Thus, the extension of a buyer's credit and zero import duty on completely built modules have put imported thin film technologies at a cost advantage as compared to the crystalline PV manufactured by domestic manufacturers(CRISIL, 2013). However, GoI has recognised these flaws and have made necessary changes (PV Magazine, 2013e) (Bridge To India, 2013b).

The wind energy manufacturing industry faces issues linked to CVD, which is levied in lieu of, and equivalent to Excise Duty (ED) on basic value of imports. CVD is levied equivalent to ED to bring import prices at parity with domestic market prices. As per Excise Notification 6/2006, Clause 84, List 5, there is a provision for ED exemption for wind-operated generators and its components. However, the tower is not considered as part of the generator and hence if it is imported, a CVD of 12.36% becomes an additional cost for the manufacturer (CBEC, 2012). In the set-up of excise also, certain equipment like parts of sub-parts for wind turbines do not qualify. Hence, the manufacturer has to pay ED for input goods but it cannot claim it on the output as ED is exempted. This becomes an additional cost for the manufacturer. There is a lack of a stable and consistent tax/duty structure that could support manufacturers.

The domestic industry continues to suffer from cost disadvantage of higher local taxes such as VAT, Octroi, and entry tax. With the implementation of the Goods & Services Tax (GST), manufacturers could get relieved from multiple tax regimes but there is still no clarity about the benefits, which are applicable for RE component manufacturers and developers. The same applies to the Direct Tax Code, which could become operational in FY15 (KPMG, 2012).

5.4.4 R&D and Others

The promotional measures for R&D and workforce development need to evolve. The operational incentives for workforce recruitment, training support and wage subsidies, and subsidies for R&D projects at the national level, during various stages have to be awarded. RE technologies require large investment in R&D and hence seek government facilitation. This is a critical area for development in India. In countries like China, R&D expenditures on big turbines have been earmarked for VAT refunds and the Ministry of Science and Technology (MoST) has subsidized wind energy R&D expenditures at varied levels over time through initiatives like the establishment of a renewable energy fund (Lema, Berger, & Schmitz, 2013). Such incentives directed at R&D would be required for the growth and development of renewable energy manufacturing in India.

Although, India has created NCEF in 2011 with an objective of funding research and innovative projects in clean energy technology, it is observed that the utilization of funds from NCEF has been rather low and disbursements, so far, are aligned more with on-going programs/missions of various ministries/departments than with the stated objectives of the fund. This poses a potential risk of diluting the focus of NCEF with adverse implications for research and innovation in India's clean energy sector (NIPFP, 2013).

Budget 2013-14 has proposed an investment allowance[74] at the rate of 15% to a manufacturing company that invests more than INR 100 crore in plant and machinery during the period April 1, 2013 to March 31, 2015. However, according to FICCI, "The threshold for minimum investments needs to be reduced from INR 100 Crore to INR 10 Crore to encourage investments by smaller investors and MSMEs. Further, the allowance should be increased from two years to five years" (FICCI, 2013c).

5.4.5 Support for Storage Systems

India does not have specific policy initiatives directed at incentivizing grid-scale storage technologies. Countries like the US and Germany have offered incentive support for the growth and development of this industry as storage remains critical to the development of both, renewable energy generation as well as manufacturing. The issue of load balancing and intermittency can also be effectively addressed by storage technologies. While the US has supported the storage segment with investment tax credits and investment grants, Germany has supported the industry through soft loans and cash subsidies (CRISIL, 2013). Policies for energy storage in different countries are highlighted in **Annexure 12**.

5.4.6 Skill and Capacity Development

The availability of skilled work force and capacity building are areas, which need to be adequately addressed. Although, the National Skill Development Commission (NSDC) affiliated skill development institutions were included in the negative list of service tax in 2011-12, the provision was removed in 2012-13 (FICCI, 2013c).

The recent notification from the Central Board of Direct Taxes (CBDT) on the approval of weighted deduction for skill development under section 36 CCD is a welcome step to encourage participation in skill development. However, it excludes corporate that are conducting in-house training in facilities that are not approved by the National Council for Vocational Training (NCVT) or State Council for Vocational Training (SCVT).

Further, as the definition of "company" provided in the guidelines does not include "companies engaged in skill development", stand-alone skill development providers are not eligible for the deduction. Thus, only company programs offering training become eligible. Besides, the definition of "training institutes" excludes NSDC's training partners, Sector Skill Council (SSC) certified institutes and any private institution conducting training for the sector, which are not certified by NCVT or SCVT.

In addition to the gaps mentioned above, the regulatory and procedural complexities have also led to delays in setting up manufacturing facilities and renewable power development, thus

[74]A tax incentive to encourage capital investment in which the deduction of specified percentage of capital costs, including depreciation, from taxable income is allowed.

discouraging investors. A number of institutions are involved in the promotion of RE in India. For instance, India is the only country in the world with a separate Ministry for Renewables. Other institutions involved in this sector include the Ministry of Power, Ministry of Commerce and Industry, Ministry of Science and Technology, Ministry of Environment and Forests, Solar Energy Corporation of India (SECI), Centre for Wind Energy Technology (C-WET), Central Electricity Regulatory Commission (CERC), State Electricity Regulatory Commission (SERC), Power Grid Corporation of India Limited (PGCIL), National Load Despatch Centres (NLDC), State Load Despatch Centre (SLDC), Distribution Companies (DISCOM), State/Central Pollution Control Board, etc. These institutions are involved at one or the other stage in obtaining licenses, no objection certificates, clearances, and renewable power deployment.

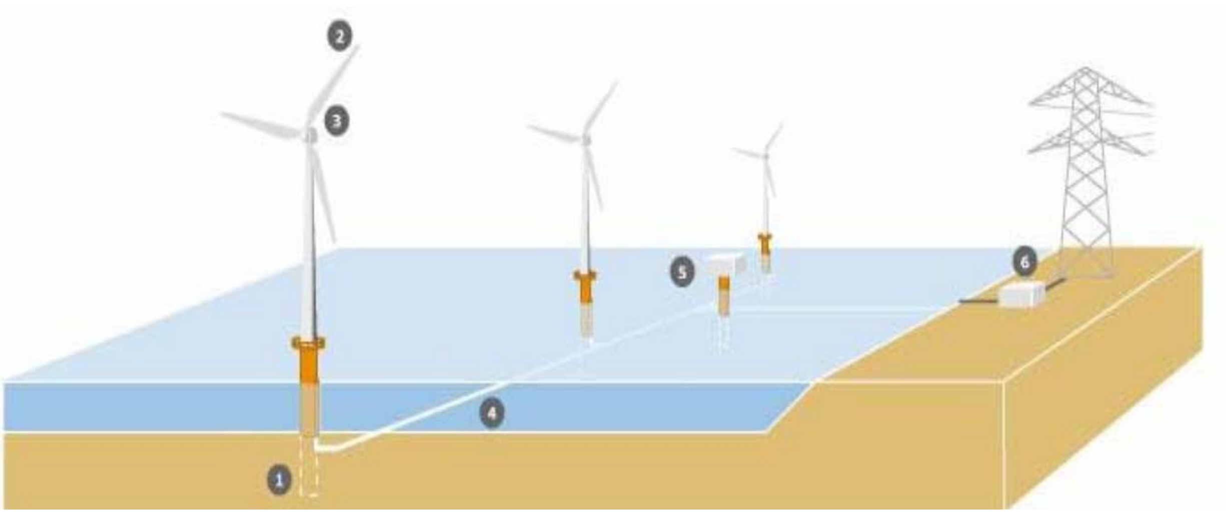
6 Offshore Wind – An Emerging Opportunity for Indian Wind Industry

Experts around the world believe that offshore is the future of the wind industry (Earnest & Wizelius, 2011). The technology is already mature in Europe and is being developed in China, South Korea, and Japan. Countries such as the US and India are showing enthusiasm to address the increasing energy needs.

6.1 Basics of Offshore Wind

The term offshore means "away from the mainland and in the ocean". The potential for offshore wind is much higher than that of onshore wind, however, the cost and technical challenges remain high. Although, the basic principle of an offshore wind turbine is same as that of onshore, a different approach is required for installation, operation, and maintenance, addressing the inaccessibility of the seas and rough weather conditions.

A typical offshore wind farm is shown in Figure 6.1



1.Piles	4.Connecting cables
2.Blades	5. Offshore substation (transformer 33kV)
3.Nacelle	6. Onshore substation

Figure 6.1: An Offshore Wind Farm (Greenpeace International, 2005)

The Piles (1) are driven into the seabed once a suitable place for the wind farm is decided. Erosion protection measures, similar to sea defence, are placed at the foundation base to prevent damage to the sea floor. The top of the foundation is painted in a bright colour to make it visible to ships and has an access platform to allow maintenance teams to dock. Once a turbine is assembled, sensors on the turbine detect the wind direction and turn the head, known as the nacelle, to face the wind, so that the blades can collect the maximum amount of energy. The movement of the wind over the aerodynamically shaped blades (2) makes them rotate around a horizontal hub, which is connected to a shaft inside the nacelle (3). This shaft, via a gearbox, powers a generator to convert energy into electricity. Subsea cables (4) take the power to an offshore transformer (5), which converts the electricity to a high-voltage (33kV) current before transporting it 10–15 kms to connect to the grid at a substation on land (6). An overview of the offshore wind technology – balance of plant is provided in **Annexure 13.** The global offshore wind technology developments has moved up significantly and the offshore wind turbine size has increased from 450 kW to 7-8 MW in the last 23 years since the Vindeby offshore wind farm was built in shallow waters, off the coast of Denmark (GWEC, 2014). The project costs have decreased by 30% in the past decade and projects are now built up to 40 m water depths and 100 km away from the coastline (GWEC, 2014). The major offshore wind turbine technology providers in the global market are Siemens, Vestas, Senvion (RE Power), Bard etc.

Advantages

- *More robust wind environment*
  Offshore sites generally have higher wind speeds than onshore sites and lower wind shear because the ocean surface offers no man-made or natural features of the earth's surface as possible obstructions. This also means high returns on investment in offshore.

- *More available area for siting*
  There are many hurdles to obtain potential sites for onshore wind farms such as bureaucratic hindrance, difficulty in obtaining agricultural or tribal land and price issue with owners. Offshore have more sites comparatively, with less siting problems.

- *Logistics*
  Although offshore turbines are bigger than their onshore counterparts, logistics is not a constraint unlike in onshore projects. Once the turbine components reach a seaport, they can easily be shipped on barges for installation, unlike onshore where manoeuvring over rural roads may be a difficult task.

- *High capacity turbines*
  High capacity turbines can be used at offshore sites since size is not a constraint. This leads to more power capture, more efficiency, and more energy yield.

- *Less visual impact and noise*
  As compared to onshore wind turbines, offshore turbines are located far from human settlements and have less visual impact, especially shadow flicker that can bother people living near onshore farms. Noise is also not a problem at sea, unlike on land.

- *Closer to load centres*
  Many important cities are often located near the coast and offshore wind turbines can play an important role in supplying power to these regions.

6.2 Global Offshore Wind Supply Chain

6.2.1 Market Status

As of December 2013, almost 7046 MW of offshore wind power was installed globally, representing about 2.2% of the total installed wind power capacity; more than 68.5% of it is installed in Europe. During 2013, of the total 35.2 GW of wind capacity installed globally, offshore's share was 1.63 GW (4.6%). The EU offshore wind market alone contributed 1.56 GW (96%) of the total annual installed capacity in 2013. An estimate by GWEC puts the global offshore wind installations at 70-80 GW (about 10%) of the cumulative installed wind power capacity of 700+ GW in 2020. Several countries such as Japan, Korea, US, Canada, Taiwan, Spain, Portugal, and India are now showing some interest in offshore wind in their seas. (GWEC, 2014). The global cumulative installed capacity in different countries is shown in Figure 6.2.

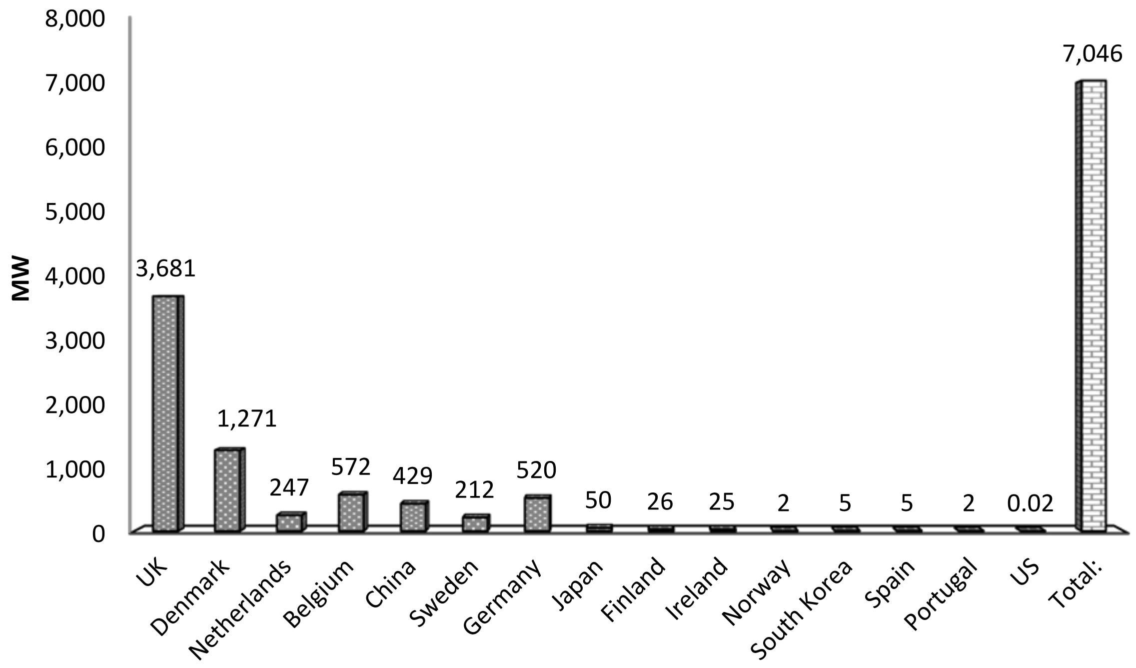


Figure 6.2: Global Cumulative Offshore Installed Capacity (GWEC, 2014)

6.2.2 Supply Chain

The supply chain for offshore is typically different from that for onshore, with several different types of expertise required. Although the wind turbine is a major cost component of the offshore wind farm, ports, vessels, and substructures form a large part of capital expenditure and play an important role in offshore wind development. The main components of the offshore supply chain are shown in Figure 6.3.

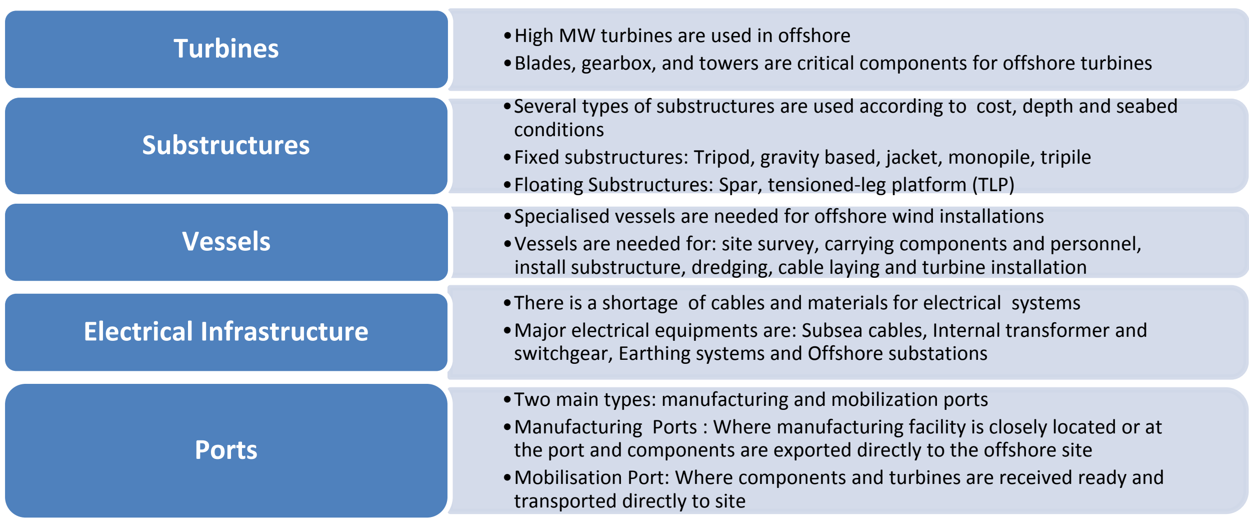


Figure 6.3: Offshore Supply Chain (EWEA, 2011)

The major global players in the offshore supply chain are shown in Table 6.1.

Table 6.1: Global Offshore Wind Component Suppliers

Component	Major Global players
Turbine	Siemens, Vestas and Senvion (earlier RE power) with about 95% market share
Foundations	Sif Group and Smulders from the Netherlands, Bladt from Denmark, Weserwind and Cuxhaven Steel from Germany
Vessels	A2SEA, BARD Engineering, MPI Vroon, Seajacks International, HOCHTIEF, DBB, and RWE Innogy
Electrical equipment	ABB, Alstom, Siemens, SEAS transmission, AEI Cables

6.2.3 Costs- A Major Challenge to Offshore Wind Development

The costs of offshore projects are invariably higher than those of onshore projects because of the extra costs for logistics, foundations, cable laying and other developmental activities. High costs are a major challenge and can be reduced with improved technology and great progress along the learning curve. High costs are compensated to some extent by high CUFs offered by offshore wind farms.

Figure 6.4 shows the average costs and the range of costs per megawatt for offshore wind farms in Europe, Asia and USA. The average costs are derived from the data available for commissioned and upcoming projects and are 2–3.5 million Euros, about 2 to 3 times the costs of onshore wind farms.

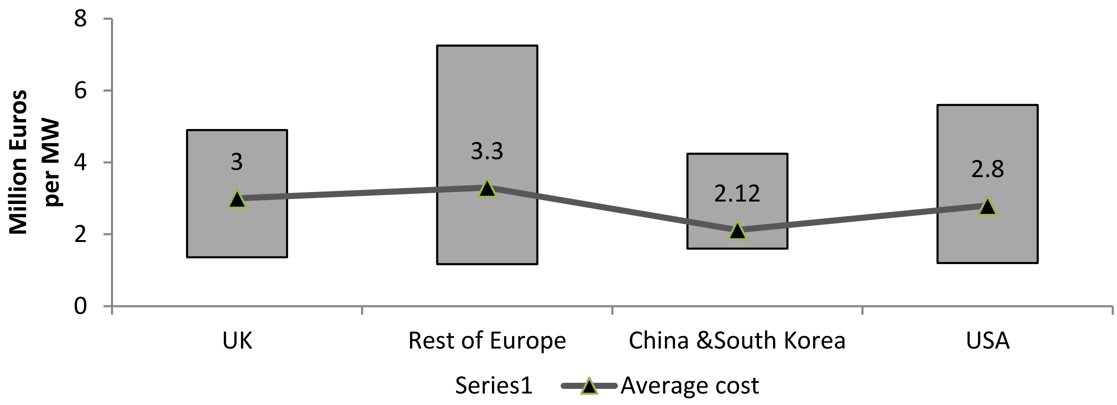


Figure 6.4: Costs of Offshore Wind Farms (WISE Research)

Note: The costs are derived from data available in the public domain for commissioned and upcoming projects. Total project capacity for which costs were available for each region is as follows: UK, 4.8 GW; Rest of Europe, 4.5 GW; Asia (China and South Korea), 5.9 GW and USA, 0.5 GW

The breakdown of costs for offshore wind turbine is given in Table 6.2**;** the turbine shares a major cost (44%). India's mature wind turbine market can use this emerging opportunity to its advantage.

Table 6.2: Breakdown of Capital Costs of Offshore Wind Project (IRENA, 2012b)

Component	Share of total cost (%)	Sub-components	Cost share of sub components (%)
Wind turbine	44	Nacelle	2
		Blades	20
		Gearbox	15
		Generator	4
		Controller	10
		Rotor Hub	5
		Transformer	4

Component	Share of total cost (%)	Sub-components	Cost share of sub components (%)
		Tower Other	25 15
Foundations	16	-	-
Electrical infrastructure	17	Small array cable Large array cable Substation Export cable	4 11 50 36
Installation	13	Turbine installation Foundation installation Electrical installation	20 50 30
Planning and development	10	-	-
Total	100%	-	-

6.3 Review of Offshore Wind Energy Policies

Offshore wind market has been historically dominated by Western European regions responsible for 96% of the total installations in 2013. In 2013, approximately 1.63 GW of offshore wind capacity was globally added bringing the cumulative installations to 7.04 GW. Approximately 4.95 GW of the capacity was installed by Denmark and UK alone. In the Asian region, China (428 MW) has installed the most number of installations followed by Japan (49.7MW). (GWEC, 2014).

Offshore wind energy policies are covered separately (from other renewable technologies) due to the uniqueness and complexity of its value chain. Moreover, the technology is still in its infancy in India and the policies are still evolving. As a matter of fact, India released the draft offshore wind energy policy on May 29, 2013. The following section examines the global offshore policy followed by a review of the draft offshore wind energy policy of India.

6.3.1 International Offshore Wind Energy Policies

Table 6.3 highlights the offshore wind energy policies for Belgium, China, Denmark, Germany, the Netherlands, Spain, and United Kingdom - the key offshore wind power markets in the world(World Bank, 2010) (Hamilton, 2013) (European Commission, 2013a).

Table 6.3: Summary of Offshore Wind Energy Policy of Different Countries

Country	Policy
Belgium	• Quota system: Renewable electricity generation is promoted through a quota system based on quota obligations. Electricity suppliers are obliged to prove, by submitting certificates, that a certain statutory and continuously increasing proportion (quota) of electricity they supply is generated from renewable sources. A certificate is issued for every MWh of electricity produced from offshore wind energy by the Federal government. o Cost of 1 green energy certificate is €107 per MWh for electricity generated from first 216 MW of installed capacity, €90 per MWh for electricity produced from an installed capacity beyond 216 MW; • Offshore Domain Concessions for Wind and Ocean Energy Production: Contributions by National Transmission Service Operators (TSO) of up to EUR 25 million worth of undersea cables for each concession.
China	• Rules for the Interim Measures for the Management of Development and Construction of Offshore Wind Power was issued in July 2011 • 12th Five Year Special Planning- Wind Power Technology Development plans the construction of two offshore and coastal wind power base

Country	Policy
	• In September 2010, the National Energy Administration organized a public bidding for four offshore wind projects, totalling 1 GW, in Yancheng, in east China's Jiangsu province. The bid winning FITs ranged from CNY 0.62 to CNY 0.74 (USD 0.10-0.12) per KWh. • FITs for demonstration is slightly higher.
Denmark	• Created a committee for future offshore wind turbine locations for identification of suitable area for offshore • Single window clearance • Owners are eligible for a subsidy that combined with the market price is approx. DKK 0.453 per kWh (USD 0.0815/kWh). The subsidy is payable for 42,000 full load–equivalent hours. If production is subject to a grid tariff, it is eligible for additional compensation of up to DKK 0.007 per kWh (USD 0.00126/kWh). • Provided grid connection by the utility at no cost to the project • Ports are owned by respective municipalities. Any upgrades made to them are approved by the municipality.
Germany	• Permission for offshore wind project in territorial sea is granted by regional authority, while in the EEZ it is the federal authority • The primary consent for a wind farm in the EEZ is the *Marine Facilities Ordinance*, which will also require the facility to comply with the requirements of the *Maritime Federal Responsibilities Act.* • There are no payments for system usage in Germany. The utility is responsible for grid connection, maintenance, and reinforcement. A wind farm owner pays for the transmission line up to the nearest suitable grid connection point. The Infrastructure Acceleration Law has placed the grid connection point for offshore wind farms inside the wind farm for a limited duration. Hence, the utilities are now financially and legally responsible for expanding the grid infrastructure to connect the offshore wind farm. • In 2006, the German government deemed two German TSOs, TenneT and 50Hertz, legally responsible, in their respective areas, for planning, consenting, designing, building, and operating offshore transmission connections for all offshore wind projects whose construction began prior to 2015. Investments in offshore transmission assets are incurred by the TSOs and recovered through transmission tariffs from the customers of all four German TSOs. • Guaranteed tariff of €19 cent/kWh for 8 years or €15 cent/kWh for 12 years. • KfW program for offshore wind to support financing of offshore wind project of up to 70% of the project cost but not to exceed € 700 million • Financial support by government for research and development • Incentives and financial support for port up gradation

The Netherlands	• Target of 6000 MW of offshore wind energy capacity addition by 2020
	• The SDE+ (*Subsidieregeling duurzame energieproductie+*) provides a feed-in subsidy covering the difference between production costs (annually calculated per technology) and income (i.e. energy price, which is determined annually). This subsidy is applicable for 3200 Full load hour.
	  o stage 1: €ct 8.75 per kWh (4 April 2013 to 13 May 2013)
	  o stage 2: €ct 10.0 per kWh (13 May 2013 to 17 June 2013)
	  o stage 3: €ct 11.25 per kWh (17 June 2013 to 2 September 2013)
	  o stage 4: €ct 13.75 per kWh (2 September 2013 to 30 September 2013)
	  o stage 5: €ct 16.25 per kWh (30 September 2013 to 4 November 2013)
	  o stage 6: €ct 18.75 per kWh (4 November 2013 to 19 December 2013)
	• Tax regulation mechanisms II (Energy Investment Allowance, EIA scheme): This tax benefit enables entrepreneurs based in the Netherlands to write off investments in renewable energy plants against tax. The maximum investment eligible for EIA:
	  o Installation > 25 kW
	    ▪ Wind onshore and wind offshore in national waters max. € 600 per kW
	    ▪ Wind offshore max. € 1000 per kW
	• Offshore Green Deal – This was signed between the Ministry of Economic Affairs, Agriculture, Innovation, and Netherlands Wind Energy Association for development of offshore wind energy in North Sea region.

Spain	• Competitive price among applicants for the same site, with a maximum feed-in tariff of

Country	Policy
	€ct 16.4/kWh • Minimum project size - 50 MW
United Kingdom	• Up to £120 million (USD 192 million) for the development of an offshore wind industry under Low Carbon Industrial Strategy • Capital grants up to £10 million (USD 1.6 million) for round 1 offshore wind power project • Renewable generated electricity is exempted from climate change levy tax • 1 MWh from offshore wind farm receives 2 ROCs (Renewable Obligation Certificates) • Introduced phasing in offshore wind accreditation after 31/03/2011 where generator can register the installed capacity of their project in up to five phases • Offshore wind farm operators can choose to construct their own transmission connections or opt for the offshore transmission owner (OFTO) to do so • For wind farms in the United Kingdom, there are typically two types of PPAs: o Purchase of "brown" electricity only (in the electricity market; brown refers to the source of the majority of this power) o Purchase of combination of "brown" electricity, ROCs (Renewable Obligation Certificates—UK tradable "green certificates"), and LECs (Climate Change *Levy Exemption Certificates*—UK tax incentive).

6.3.2 Draft Policy for Offshore Wind in India

To carry forward the development of offshore wind energy in India and to overcome the existing barriers and to create technological and implementation capabilities within the country, the MNRE prepared a draft policy for offshore wind (MNRE, 2013c).

The National Offshore Wind Energy Agency (NOWA) will be the nodal agency and facilitate in getting clearances for offshore wind energy project. The geographical coverage area of offshore wind project will be 12 nautical miles from baseline. However, the research and development activities may be carried out in Exclusive Economic Zone (EEZ).

The objective of offshore policy is to promote deployment of offshore wind farms, promoting investment in energy infrastructure, spatial planning, and management of EEZ for renewable energy, promoting research and development and creating skilled manpower.

Following are the salient features of the policy:

- Preliminary Resource Assessment, Environment Impact Assessment (EIA) and Oceanography Survey for demarcation of offshore wind energy blocks.
- Offer for blocks will be made through an open International Competitive Bidding (ICB) process.
- NOWA will be the contracting authority to lease the seabed.
- Single window procedure for statutory approvals.
- A designated nodal agency/distribution utility of state will enter into Power Purchase Agreement (PPA) with offshore wind power generation project developers.
- Fiscal incentives such as tax holiday for the first ten years of offshore wind power generation, concession in customs duty and exemption in excise duty for procurement of technology and equipment, may be available to the manufacturers of the offshore wind turbines. Besides, nil service, tax for services like conducting Resource Assessment/EIA/ Oceanographic Study by third party, utilization of survey vessels and installation vessels could also be available.

- GoI may call for proposals for development of offshore wind energy project/s in specific block/s. Such projects may be exempted from paying any lease fee for a specified period, after which the ownership of project will be transferred to it.
- Testing of whole offshore wind turbine generator will be rendered by CWET.

6.4 Resource Potential in India

India has a long coastline of over 7,500 kms with several major load centres and important cities close to the sea. Also, India has rights over a vast Exclusive Economic Zone (EEZ) of over 2 million sq km. To tap this vast offshore wind resource, researchers from India and abroad, have conducted studies on wind resource assessment for Indian waters.

1. Risø National Laboratory, Denmark

Risø DTU has prepared offshore wind maps for Europe and has identified wind speed and density at various heights: 10m, 25m, 50m, 100m, and 200m. For India, they have mapped the data using Synthetic Aperture Radar (SAR) and scatterometer satellite (QuikSCAT) data at 100m. The resolution of this data was 0.01 degree by 0.01 degree or roughly 1km by 1km. The mean wind speed near the Tamil Nadu coast was found to be 4–5 m/s whereas it was up to 7.6 m/s further offshore, indicating wind resources from 200–500 W/m^2. These statistics were for heights above 10m. Sites identified with high wind resource fall in the area between Rameshwaram and Kanyakumari (Charlotte B. Hasager, 2011).

2. Indian National Centre for Ocean Information Service (INCOIS)

INCOIS concluded that wind speeds of 6–8 m/s are prevalent along the coast at 80 m height and that Tuticorin (Tamil Nadu) has wind speeds greater than 8 m/s for 200 days in a year whereas coastal region near Gujarat has wind speeds greater than 8 m/s for 100 days in a year (Gomathinayagam, 2011) (Chary, 2011).

3. Centre for Wind Energy Technology (C-WET)

C–WET in a concerted effort with Risø DTU released a wind atlas in 2010 (C-WET and Riso DTU, 2010). They carried out meso-scale modelling using the Karlsruhe Atmospheric Meso Scale Model (KAMM) and micro scale modelling for 52 locations using the Wind Atlas Analysis and Application Programme (WAsP). For offshore maps, only meso-scale data were used and points up to 100 km from the coast were included. The C-WET studies show the average speeds in the range of 7–8.5 m/s at 50 and 80m hub heights and the wind power densities in the range of 350–500 W/m^2, indicating fair to good wind resource at these heights (C-WET and Riso DTU, 2010).

4. World Institute of Sustainable Energy (WISE) (WISE, 2012) (WWF India and WISE, 2013)

WISE has conducted a GIS-based offshore wind resource assessment with the help of globally available wind dataset at a high resolution for the states of Tamil Nadu and Kerala. The studies concluded that a sizable gross offshore wind power potential exists in both the states. The gross offshore wind potential at 80 m height for Tamil Nadu was estimated at 127 GW.(WISE, 2012) While for Kerala, the offshore wind potential at 80 m height was estimated at 41 GW.(WWF India and WISE, 2013)**.** The assumptions included sea depth <30 m, Distance to coast < 25 km, and Wind Power Density > 200 (W/m^2) for both studies.

6.5 Barriers to Offshore Development in India

A major barrier to offshore wind development and deployment is the high costs. Studies indicate that the costs haven't decreased despite the achievement of large economies of scale. Moreover, since it is a new venture globally, the risk perception for offshore is quite high.

The barriers for offshore wind can be divided into four types, pertaining to (i) Resource assessment, (ii) Permits and clearances, (iii) Supply Chain and (iv) Finance, infrastructure and Human Resources. These have been described in Table 6.4.

Table 6.4: Barriers to Offshore Wind Development

(i) Resource Assessment ➢ Rough weather and sea conditions as compared to onshore, therefore high risks in resource assessment ➢ High costs of offshore met masts, also much higher costs incurred on seabed assessment and bathymetric studies and Environment Impact Assessment ➢ Lack of reference data, especially over a long-term ➢ Accounting for sea surface roughness and atmospheric stability ➢ Wake effect or losses not accounted for offshore ➢ Proper mapping of fishing and shipping channels and marine mammal movements needs to be done to determine development restrictions	**(ii) Permits and Clearances** ➢ Naval, Coastguard and Air force clearances may be required stage-wise as India has high threat perceptions from its neighbours when compared to the European countries ➢ Possibility of government interference in the case of any schedule or plan change because of technical reasons from environmental angle, although prior approval may have been taken ➢ There will be restrictions on the nationality of personnel and vessels operating in view of defence, IB regulations & recent cases of marine offence by foreign ships ➢ Fishing community has to be taken into confidence for development because of their livelihood and political influence
(iii) Supply Chain ➢ Offshore wind uses large turbines under a different set of conditions from onshore, therefore, dependence on imports would be more initially ➢ High modulus carbon fibre which is expected to be in short supply would be required for wind turbine blades ➢ Subsea cables are in short supply world over, which may take at least 4 years to ease (EWEA estimate) ➢ Copper for cables, transformers, generators etc. may be a supply constraint in the future ➢ Large casting and forging for bearings, shafts and gearing systems are not manufactured in India. For this reliance will be on foreign manufacturers and suppliers ➢ HVDC power stations to be installed will need heavy electrical equipment and foreign expertise ➢ Mostly, large turbines use direct drives and permanent magnet generators. China holds a monopoly ➢ Corrosion-resistant materials for towers. ➢ Planning needs to be accurate in order to avoid cost overruns, because of the weather-dependent schedule ➢ Installation vessels for WTG, sub-sea cable and foundation structures will be a challenge in view of the fact that not all vessels suitable for offshore oil platform installation will be suitable for wind farm installation ➢ No turbine installation vessels in India as of date ➢ Lack of suppliers of foundations and vessels in India	**(iv) Finance, Infrastructure and Human Resources** ➢ High capital expenditure is the single biggest factor that deters investors from investing in offshore wind ➢ Risks involved in offshore wind are much higher compared to onshore. Some risks may not even be factored into costs ➢ High interest rates prevailing in India ➢ Bottlenecks in clearances, environmental impact assessment etc. pose additional risks ➢ Development of dedicated ports is required for an offshore industry. Initially ports can be used for mobilization, but later manufacturing ports will need to be developed ➢ Grid availability at port and connection via subsea cables will be a challenge. Balancing mechanisms would be required to incorporate large amounts of wind energy into the grid ➢ Space requirement for vessels and assembly on ports ➢ Rail and road access to ports ➢ Operations and maintenance would be much more difficult than for onshore; suitable facilities such as crew boats and helipads for helicopters will be needed in the port. ➢ Technical expertise would be needed for all activities, ranging from resource assessment to planning, construction, installation and operation ➢ Safety is a major issue for offshore wind. Hazardous conditions and rough weather make offshore wind operations a challenging task

6.6 An Emerging Supply Chain Opportunity

While countries like US are yet to enter the offshore wind domain, plans for offshore wind in India seem certainly ambitious. With the announcement of the draft offshore wind policy by GoI several state government and private agencies are showing interest in this area.

India already has a mature wind turbine manufacturing and wind power industry and many major load centres such as Mumbai, Chennai etc. are near potential offshore zones. Offshore wind clearly presents an excellent opportunity for Indian wind industry to grow and leapfrog to advanced technologies. Moreover, for domestic manufacturing substructures present a major opportunity as it has low technical barriers to entry and requires less technical expertise.

The skills, occupations, and qualifications required in the offshore wind sector are highly diverse. Generally, the availability of human capital is limited throughout the supply chain from R&D to O&M. According to the EWEA report 'Wind Energy-the Facts', engineers and experienced and qualified project managers are particularly scarce. The demand for high–level skills (university, postgraduate, and professional education) is relatively high compared to other sectors. The skills, occupations, and qualifications required in offshore wind sector are shown in Table 6.5.

Table 6.5: Skills, Occupations, and Qualifications Required in Offshore Wind Sector

Skills	Occupations	Qualifications
• Control System and Design • Construction/Cabling • Manufacturing of turbines and foundations • Planning and Development • Construction, installation, operation and maintenance	• Electrical ,Civil, Mechanical, Electronics, Structural ,Ocean Engineers • Environmental Specialists • Health and Safety Specialists • Construction Project Managers • Fabrication engineers • Service Engineers • Wind turbine operations • Offshore operation specialists	• Computer Aided Design (CAD) experts • Graduates, Masters, PhDs • Engineering • Project management experience • Health and safety experience • Knowledge of steelwork and structural engineering • Knowledge/experience in SCADA systems

The offshore wind energy sector will not only provide an excellent supply chain opportunity and better quality employment, but will also lead to a well-rounded industrial development of India. It will open huge opportunities in several disciplines ranging from oceanography, naval architecture, structural engineering, foundation engineering to electronics and logistics. It is also likely to open research and development opportunities across several disciplines in the future.

7 Conclusion and Recommendations

The Government of India has made the growth of renewable energy in India a top priority. It has a vision to make India a self-sustainable industry in renewable energy and pursue a low carbon growth path. Key developments favouring renewables have been announced in the budget 2014-15. Incentives favouring renewable sector have also been announced in the ambitious 'Make in India' programme. Recently, the government also released its first detailed assessment of the solar potential which is 749 GW (MNRE, 2014c) which is three times the current power generation capacity (Sustainable business, 2014). Therefore, in order to accelerate the RE development it has announced ambitious targets for Solar (100GW) as well as Wind energy deployment (60 GW) by 2022 (PIB, 2014a).

7.1 Key Drivers of Future Growth

The ambitious targets set by the government for wind and solar capacity additions will require long-term policy certainty and a clear roadmap for development. The key drivers for promoting renewables manufacturing and accelerating deployment of these technologies are shown in Figure 7.1

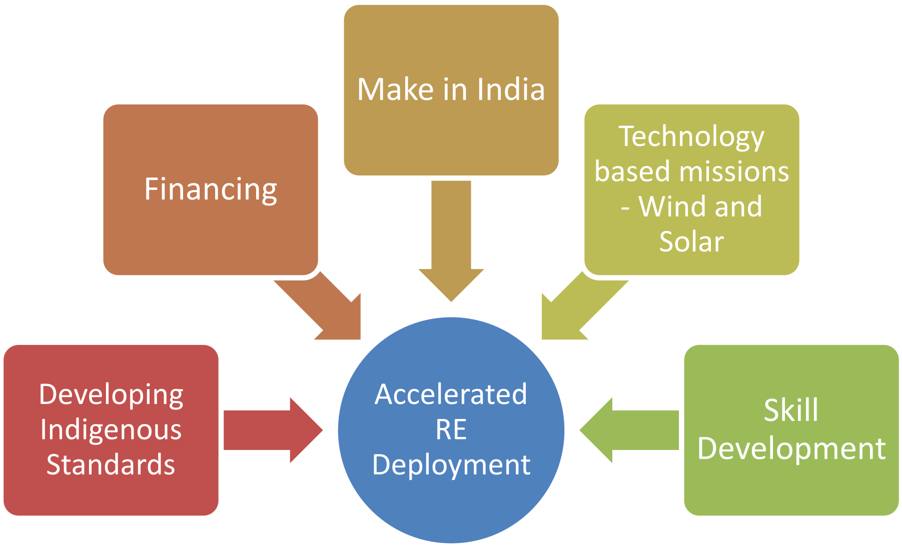


Figure 7.1: Drivers of Accelerated RE Deployment

Make in India is a prologue to the NMP and a clarion call to domestic as well as foreign investors. Renewable Energy is already recognized as an important sector under the Make in India programme. In addition Government of India has offered specific benefits to OEMs and component manufacturers, such as **introduction of scheme like M-SIPS** (which offers subsidies to manufacturers of electronics components) and **for other industries like casting, forging and composites especially Carbon and glass fibre.**

The JNNSM in its first phase has led to a high deployment of solar technology as well as low costs of energy. India envisions attaining market leadership in the second and third phase of the mission. Similarly, a **National Wind Energy Mission** is on the anvil; it must be brought in after an integrated approach in consultation with policy makers, manufacturers, service providers and other institutions.

Financing of renewable energy is a critical challenge due to high cost of debt, high-risk perception and less awareness on renewable technologies. It is therefore **essential to ensure that funds are made available to OEMs and for purposes of research, development, and induction of new and disruptive technologies**. Financing to manufacturers can be provided on the lines similar to China where a subsidy to the tune of 600 RMB/kW (equivalent to INR 61 lakhs /MW[75]) for the first 50 MW size wind turbine produced by a company is provided. Similarly, funds are available to manufacturers in the US as well, such as the Edison Innovation Clean Energy Manufacturing Fund in New Jersey State. These grants can be used for manufacturing site identification, procurement, design and permits. Moreover, construction and project completion loans are available at low rates of 2% (New Jersey Economic Development Authority, 2012). A **Renewable Energy Manufacturing Fund** for India can also be proposed on similar lines.

Export promotion, especially for wind which is now a mature technology in India should be provided through EXIM Bank by providing long-term export finance at LIBOR+1% to 2% with 3 years moratorium period and payback period of 10 to 15 years. Lines of credit should be project-specific, depending on the specific project requirements of the recipient country and procedures must be simplified. More funds need to be allotted to the banking sector to finance exports from India. For wind power, it is often noticed that the existing EXIM's line of credit is inadequate for export. For China, the line of credit extended goes up to USD 2 billion for 4-5 years period, while for India it is only USD 200 million for one year. Indian exporters also have to incur extra logistics cost, since the shipping route is via Dubai/Singapore. To increase wind turbine export from India **establishing portfolio fund like US-EXIM or China–EXIM** may prove helpful.

India does not have its own standards and specifications for wind technology suited to the Indian climatic conditions. For certification of new turbine model, the NIWE needs a global certification as it does not have the capacity or the expertise to develop certification standards. Even after international certification, NIWE takes a long time to certify it again and include it in the Revised List of Models and Manufacturers (RLMM) list. Indian wind turbines need to be developed according to Indian climatic conditions, and, there is a need to develop **indigenous standards and benchmarking for wind turbines.** For Solar technology, the National Institute of Solar Energy (NISE) is the body identified by MNRE for testing and certifying PV modules. CBTL, TUV Rheinland and UL are also approved by MNRE for testing modules and balance of system. It costs approximately INR 25-27 lakhs per project for testing which acts as a deterrent. Also, India doesn't have India specific standards for modules. In addition, **Certification of modules, which is currently not mandatory, should be mandated.**

Availability of skilled manpower and capacity building are areas, which need to be adequately addressed. As per Construction Industry Development Council (CIDC) estimates, only 3-5% of the total blue-collared workers in the Indian power sector have received formal training. A Power Sector Skill Council (PSSC) has been proposed to ensure adequate capacity of skilled and certified manpower in various segments of the power industry including renewables. The PSSC will identify critical roles where major skill gaps exist, develop curriculum and courses, execute training of instructors and build affiliation and accreditation processes to impart skills that increase employability and technical expertise (Global Peers Management Group). Key institutions such as NIWE and NISE can be strengthened through capacity building programmes in cooperation with private sectors. Renewable sector specific courses for technicians, engineers, as well as master's and doctorate level courses can be introduced for ensuring availability of skilled manpower in this sector.

[75] 1 RMB = INR 10.21 as of Jan 2015

7.2 Key Regulatory Interventions to Promote RE Manufacturing

The study identifies challenges faced by RE manufacturing in four key areas: (a) Taxes and Duties (b) Support to domestic industry (c) Materials (d) Technology, Research and Development. These issues and required interventions are as follows:

a) Taxes and Duties

Key interventions in challenges related to taxes and duties are given in Table 7.1

Table 7.1: Issues and Suggested Interventions for Taxes and Duties

Issues	Short-term Impact[76]	Long-term Impact[77]	Applicable Technologies	Suggested Interventions	Relevant Agencies
High excise and custom duties on critical raw materials	Medium	High	Wind	▪ Reduce duties on crucial raw materials such as glass fibre, CRGO/CRNO steel, etc.	▪ Ministry of Finance/ Central Board of Excise and Customs
Service tax credit paid on imported sub-parts is not available, since the final product is exempted from excise duty	Low	Medium	All technologies	▪ Exemption of service tax on supporting services related to (i) installation; commissioning/repairs and maintenance of such exempted products and (ii) evacuation of power from a generation site to the state grid should be exempted from service tax. ▪ Exemption of service tax on import of service (reverse charge mechanism)	

b) Support to Domestic Renewable Industry

Gaps in providing support to domestic industry and suggested interventions are given in Table 7.2.

Table 7.2: Gaps in Support to Domestic Industry and Suggested Interventions

Issues	Short-term Impact	Long-term Impact	Applicable Technologies	Suggested Interventions	Relevant Agencies
Local content requirement	Medium	High	Solar PV and CSP: Short-term and long-term; Onshore and Offshore Wind: Long term	▪ Follow Brazil's BNDES (Brazil Development Bank) example: Subsidized financing or tax breaks if local content requirements are fulfilled. ▪ Include LCR in government tenders	▪ Ministry of New and Renewable Energy, ▪ Ministry of Finance
Export promotion	Medium	Medium	Onshore Wind: Short-term; Solar PV and CSP: Long-	▪ Establish portfolio fund like US-EXIM or China – EXIM	▪ Ministry of Finance, ▪ EXIM Bank

[76] Short-term: Up to 2017
[77] Long-term: Up to 2032

Issues	**Short-term Impact**	**Long-term Impact**	**Applicable Technologies**	**Suggested Interventions**	**Relevant Agencies**
			term	▪ EXIM Bank should provide long-term export finance at LIBOR+1% to 2% with 3 years moratorium period and payback period of 10 to 15 years ▪ Lines of credit should be project specific for renewables	
Auxiliary industry promotion	Medium	High	All technologies	▪ Promote renewable energy cluster development ▪ Units in cluster that manufacture RE equipment will receive 5% interest reimbursement of the nominal interest,10% capital subsidy, exemption from capital gains tax, simplified procedures and easier exit norms ▪ Units in cluster will also be able to access Technology Acquisition Development Fund which subsidizes technology acquisition of maximum amount of INR 20 lakhs ▪ Promotion of the following supplier industries to the wind sector: (i) casting and forging (ii) electronics/power electronics (iii) composites, especially glass and Carbon fibre ▪ Promotion of following supplier industries in the solar thermal technology: (i) Manufacturing and bending of mirror (ii)Reflective structure in heliostat technology (iii) Moisture content in the steam should be reduced	▪ Department of Industrial Policy and Promotion, Ministry of Commerce and Industry
Logistics challenges for	Medium	High	Onshore wind	▪ Clear norms up to 9 axle and 80 ton capacity multi-	▪ Ministry of Road

Issues	Short-term Impact	Long-term Impact	Applicable Technologies	Suggested Interventions	Relevant Agencies
huge structures, turbines and tower				axle trucks	Transport and Highways

c) Materials

Material issues and suggested interventions are given in Table 7.3.

Table 7.3: Material Issues and Suggested Interventions

Issues	Short-term impact	Long-term Impact	Applicable technologies	Suggested interventions	Relevant Agencies
Glass fibre in India is largely imported	Low	Medium	Onshore Wind	▪ Promote research and development in glass and carbon fibre in joint coordination amongst government institutions such as TIFAC, NCT Pune or ICT Mumbai and industry players such as Suzlon India ▪ Low excise duty on manufacturing of specialty fibres ▪ Promote quality and production of epoxy resin ▪ Inclusion of development of CRGO steel as a high value project of national importance ▪ Promote rare earth exploration and extraction using modern technologies ▪ Develop processes for extraction of rare earth metal Nd from spent nuclear fuel. Such research activities must be taken up in material research laboratories of premier research institutions in India ▪ Development of nano-composites can reduce reliance on rare earths, research in this field should be promoted ▪ Recycling of e-waste	▪ Ministry of Mines, ▪ Department of Science and Technology, ▪ TIFAC, ▪ IITs, ▪ Indian Rare Earths Limited (IREL)
Material used in epoxy resin biphenol-A (Phenol) is chiefly imported	Low	Medium			
Less availability of CRGO/CRNGO (electrical steel) for generators	Medium	High			
Less availability of (CrMo)steel used in large bearings	Low	Medium			
Less availability of S 355 structural steel for towers	Low	Medium			
Low availability of rare earths such as Dy and Nd for permanent magnets. Rare earth monopoly is held by China	Medium	High			

Issues	Short-term impact	Long-term Impact	Applicable technologies	Suggested interventions	Relevant Agencies
				should be promoted as it can also be a source for rare earths	
Research in PV technology	Medium	High	Solar PV	▪ In PV, research on smart coating on glass could lead to substitution, In EVA; technology, which reduces shrinkage effect, needs to be explored.	▪ Department of Science and Technology, ▪ IIT Bombay ▪ IISc Bangalore
Material for absorber and HTF in CSP technology	High	High	Solar CSP	▪ Coating configuration and material for both absorber and receiver tubes needs to be studies. Advanced heat transfer fluid (low temperature applicable for Indian GHI) and low cost materials for thermal storage work also need to be researched	▪ Department of Science and Technology, ▪ IISc Bangalore

Sources: (Economic times , 2012) , (Ministry of Textiles, 2011), (Working Group on Chemicals and Petrochemicals, 2012) and (C-STEP and C-Tempo, 2012)-CSTEP

d) Technology, Research and Development

Issues in technology, research and development and suggested interventions are given in Table 7.4.

Table 7.4 : Technology and R&D Issues and Suggested Interventions

Issues	Short-term impact	Long-term Impact	Applicable technologies	Suggested interventions	Relevant agencies
Blade, tower and gearbox are not designed in India	Medium	High	Onshore and offshore wind	▪ Initiating a programme to acquire and generate long-term (10-15 years equivalent) data bank for structural materials such as glass/Carbon fibre reinforced composites, concrete and steel structures etc., under high stress and appropriate environmental conditions will be useful in WTG component design and development ▪ R&D programme for aerodynamics can be carried out between industries and Hindustan	▪ Ministry of New and Renewable Energy, ▪ Department of Science and Technology, ▪ NIWE ▪ Council of Scientific and Industrial Research (CSIR)

Issues	Short-term impact	Long-term Impact	Applicable technologies	Suggested interventions	Relevant agencies
				Aeronautics Limited (HAL) ▪ Tower design evaluation and load testing is done at Structural Engineering Research Centre (SERC) and Centre for Wind Energy (NIWE), however, in depth knowledge of loads on towers under different operating conditions, tower dynamics, material specifications and economics of design are areas that need to be strengthened ▪ Institutes for blade testing, courses in tower welding, concrete technology for towers and foundation and gearbox designing should be introduced in India	
Current way of utilization of NCEF poses potential risk of diluting the focus with adverse implications for research and innovation in the clean energy sector in India	High	High		▪ NCEF guidelines are too broad-based, the need for the fund should be clarified ▪ Setup a dedicated NCEF team with appropriate expertise and accountability	▪ Ministry of Finance, ▪ Ministry of New and Renewable Energy
India does not have its own wind standards and specifications suited to Indian climatic conditions	Medium	High		▪ Develop wind turbine standards suitable for lower wind regimes of India	▪ Ministry of New and Renewable Energy, ▪ NIWE, ▪ Bureau of Indian Standards
NIWE does not have the capacity or expertise for certification of new turbine model	Medium	Medium		▪ Strengthen NIWE through training and development of staff with knowledge of latest technologies and policies ▪ Engage NIWE in induction of technologies, testing and standardization,	▪ NIWE
Research in	Low	High	Solar	▪ R&D of Perovskite need to	▪ IISc

Issues	Short-term impact	Long-term Impact	Applicable technologies	Suggested interventions	Relevant agencies
Perovskite technology (PV)				be pursued as the materials are abundantly available and these have exhibited high efficiency (>15%) within a short duration of three years	Bangalore ▪ IIT Bombay
Using diamond encrusted nano saw to cut Silicon ingot and reduce waste	High	High	Solar	▪ Roughly, 50% of silicon is wasted while sawing ingot into wafers. This could be reduced by using nano saw, which is encrusted with diamond.	▪
PV Module reliability testing	High	High	Solar	▪ Understand the reliability of c-Si and Thin Film installations in Indian conditions and the impact of dust and humidity over a lifetime.	▪ National Institute of Solar Energy
Evaluation of PT systems at sub MW levels	Low	High	Solar	▪ Research on technology that takes into consideration various organic fluids at sub MW levels and at low operating temperatures (150 – 250 ^{o}C)	▪ IISc Bangalore
Research on ST technology (CSP)	Low	Medium	Solar	▪ Research on using superheated CO_2 and air brayton cycles for 1MW to 10 MW system size	▪ IISc Bangalore
Grid integration of large scale renewables is an issue in India	Low	Medium	All technologies	▪ Promotion of offgrid and decentralized solutions using small wind or solar must be encouraged ▪ Green energy corridor plan should be expedited	▪ MNRE, ▪ Power Grid Corporation of India Ltd.
Limited knowledge exchange among renewable industry stakeholders	Medium	Medium	All technologies	▪ Knowledge exchange platform to share R&D and other developments among various stakeholders	▪
Less availability of skilled manpower	Medium	Medium	All technologies	▪ ITIs and other technical Government institutes should provide training for technicians and trainers ▪ Develop curriculum and offer Graduate, Masters and Post Graduate programmes in renewable energy technologies and specific programmes on	▪ Ministry of Human Resources and Development ▪ Directorate General of Employment & Training, MNRE

Issues	Short-term impact	Long-term Impact	Applicable technologies	Suggested interventions	Relevant agencies
				wind and solar technologies	

Sources: (Rathod, 2006), (NIPFP, 2013), (SERIIUS, 2014)

7.3 Recommendations for Critical Components

The Make or Buy was analysed in section 5 of the report after a thorough consideration of various factors followed by a SWOT analysis. The recommendations and suggested policy interventions to the critical components identified by the exercise are given as follows.

Onshore Wind

Component manufacturers have their own set of challenges, which requires differentiated treatment with respect to incentives to be extended. Technology, raw material, R&D, infrastructure, and logistics are the key areas in which challenges are faced by the wind turbine component manufacturers. The make or buy decision and policy intervention required is shown in Table 7.5.

Table 7.5 : Component Wise Interventions for Onshore Wind

Component	Make	Buy	▪ Policy Recommendation
Blades	✔		▪ Ministry of Road Transport and Highways notification S.O. 728(E) to include trucks and trailers of higher capacities than mentioned ▪ Relaxation of import duty on glass/carbon fibre and on epoxy resin ▪ Cross-sectoral coordination between Department of Science and Technology, MNRE and Ministry of Textiles for research and development of specialty fibres (includes glass and carbon fibre). This could also be included in the National Fibre Policy ▪ Collaboration with HAL for R&D in the field of aerodynamics
Gearbox	✔	✔	▪ Promotion of research and development ▪ Encourage knowledge and technology exchange from EU countries
Generator	✔		▪ Reduce duties on CRGO/CRNGO steel
Tower	✔		▪ Ministry of Road Transport and Highways notification S.O. 728 (E) to include trucks and trailers of high capacities than mentioned?? ▪ Establish design centres for tower testing with radiography/ultrasonic testing, material testing etc. ▪ Reduce customs duty on S 355 (structural) steel used in tubular towers
Large bearing		✔	▪ Promote wind/power sector /heavy industries as large bearings do not have sizable market currently in India (NMP)
Hub and Main shaft (casting and forging)	✔	✔	▪ Promote technology transfer and joint ventures with foreign companies (NMP) ▪ Promote manufacturing clusters for forging and casting operations (NMP)

Solar PV

While the wind industry has matured, solar industry is in the growth stage, the areas of intervention for components of solar PV is highlighted in Table 7.6.

Table 7.6: Component Wise Intervention for Solar PV

Component	Make	Buy	Policy Recommendation
Cell	✔	✔	▪ Reduce CVD and additional CVD from 16% to 0% ▪ Promote R&D in innovative technology i.e. 'gas to wafer'
Glass	✔		▪ Assistance in finding sources of low Iron content silica (raw material) ▪ R&D to develop substitutes and improve productivity ▪ Reduction in price of power for industrial consumer
Encapsulant	✔		▪ Promote market growth to produce solar grade EVA ▪ Collaboration between academia-industry and government to promote solar grade polymer development ▪ Low interest loans to meet working capital needs
Backsheet	✔		▪ Skill development and capacity building needs to be addressed ▪ Specific policies to promote R&D and production
Silane		✔	▪ Promote technology transfer and joint ventures with foreign companies

Solar CSP

The areas of intervention for components of solar CSP is highlighted in Table 7.7

Table 7.7: Component Wise Intervention for Solar CSP

Component	Make	Buy	Policy Recommendation
Parabolic Mirror/Glass	✔		▪ R&D in the development of new mirror manufacturing techniques and substrate coating technology ▪ Establish standards and testing facilities ▪ Reduction in Basic Customs Duty for low Iron sand
Receiver -Stainless Steel (SS-304)		✔	▪ Promote technology transfer and joint ventures with foreign companies ▪ Low interest loans to developers to meet working capital needs
Heat Transfer Fluid		✔	▪ R&D in the development of HTF with boiling point > 450°C. ▪ Encourage knowledge and technology exchange
Heliostat Glass	✔		▪ Reduction in Basic Customs Duty for low Iron sand ▪ Establish Standards and Testing facilities ▪ Promote manufacturing cluster for improving supply chain of heliostat (tracking device, structure, control system)
Receiver - Stainless Steel (SS-316)		✔	▪ Reduction in Basic Custom Duty, CVD and Additional CVD from current effective duty of 25.85% ▪ Establish standards and testing facilities
Power Block	✔		▪ Establish standards and testing facilities ▪ Promote market growth
Molten Salt		✔	▪ Promote market growth ▪ Promote R&D in development of HTF with good thermochemical properties ▪ Promote technology transfer and joint ventures with foreign companies ▪ Lower custom duties
Storage Tank	✔		
Pump	✔		▪ Promote R&D in development of seals ▪ Skill development for the manufacture of seals

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Annexure 1: Renewable Technologies

The issues of energy security, environmental concerns, and power shortages together with availability of mature and indigenous technologies for wind and solar power have allowed renewable sources to play a pivotal role in India's energy mix. A brief overview of wind and solar power technologies, components and the manufacturing supply chain follows.

A1.1 Wind Power

A1.1.1 Wind Technology

Wind turbines transform the kinetic energy of the wind into electrical energy. The maximum power that a wind turbine can extract can be expressed as:

$P=1/2*\rho*A*v^3*C_p$

Where, ρ is the density of the air (which is 1.2 Kg/m^3 at sea level), A is the swept area (in m^2) of wind turbine rotor, V is the velocity (in m/s) of wind at particular site, C_p is the power coefficient, the share of the power of the wind that can be utilized by the rotor. Its maximum value can be 59.3% according to Betz law. For a real turbine, C_p is lower due to aerodynamics and mechanical losses. On most of the turbine, practical value that can be attained is in the range of 0.45 to 0.50 at a wind speed of 6-8 m/s (Earnest & Wizelius, 2011). The overall efficiency for a wind turbine is the product of the turbine rotor's power coefficient and the efficiency of gearbox and generator.

Figure A1.1 shows the working of a wind turbine generator. The rotor converts the kinetic energy of the wind into rotational energy, which is then converted to electrical energy. Although fewer or more blades are possible, rotors have three blades for maximum efficiency. The rotor is generally oriented such that the blades are upwind of the tower, although downwind orientation has sometimes been used. Positioning of the rotor is provided by a yaw system (which turns the entire nacelle on the vertical axis).

The rotor is connected to a main shaft, which in turn connects (typically) to a gearbox. The gearbox provides an increase in speed such that the speed of the gearbox's output shaft is matched to the speed requirements of the generator. The generator, which is the next step in the process, performs the conversion of mechanical energy to electrical energy.

Generators can be classified in several ways, e.g. synchronous generators (they may be either electrically excited synchronous generator or permanent magnet synchronous generator) or Asynchronous generators (doubly fed induction generator, squirrel cage induction generator or wound rotor induction generator). The electrical power produced by the generator is generally of 690 V (ac). This power is fed to the electrical substation block, which consists of the down tower panels, electric cables, transformer, and electric switchyard.

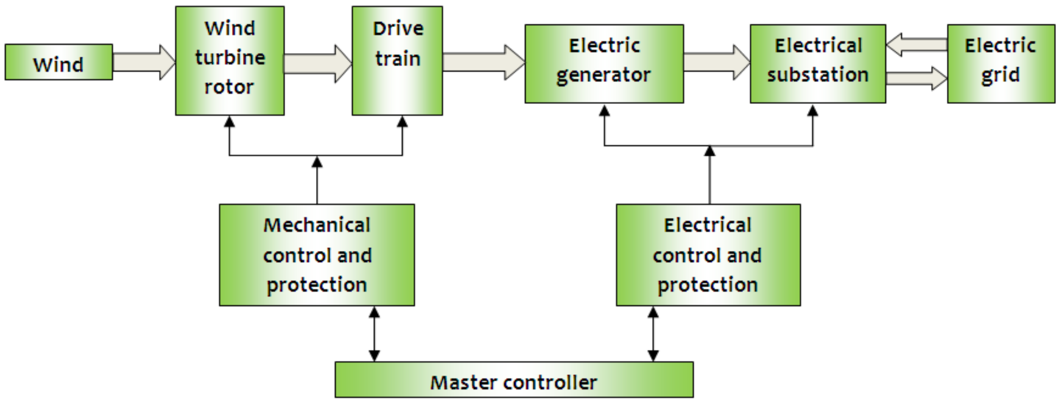


Figure A1.1: Wind Turbine Working (Earnest & Wizelius, 2011)

A mechanical control and protection governs the controlling and the regulation of the power harnessed by the wind turbine rotor, which is transferred to the drive train.

The electrical control and protection block consists of the power regulation and protection equipment which regulates the mechanical power converted into electrical power by the generator and which is fed into the grid through a substation.

The master controller is the brain of the wind turbine, which completely controls the operation of the wind turbine. Both the mechanical control system and the electrical control system come under the master controller. The master controller consists of a microcontroller with custom designed software. The entire drive train, generator, and associated equipment are contained in a nacelle, which is located on top of a tower. From a substation a transformer steps up the voltage to the grid value and the grid system transmits the electric power to the end use.

A1.1.2 Major Components

In wind turbine, there are more than 8000 components, and an analysis of each component is not possible. The study focuses only on major components and critical components, which have been identified by various literature and industry.

The wind turbine has three major components. These are rotor, nacelle, and tower. Each of these has various mechanical, electrical, and electronic subcomponents. Some important subcomponents of geared and gearless wind turbines have been depicted in Figure A1.2 and Figure A1.3 respectively.

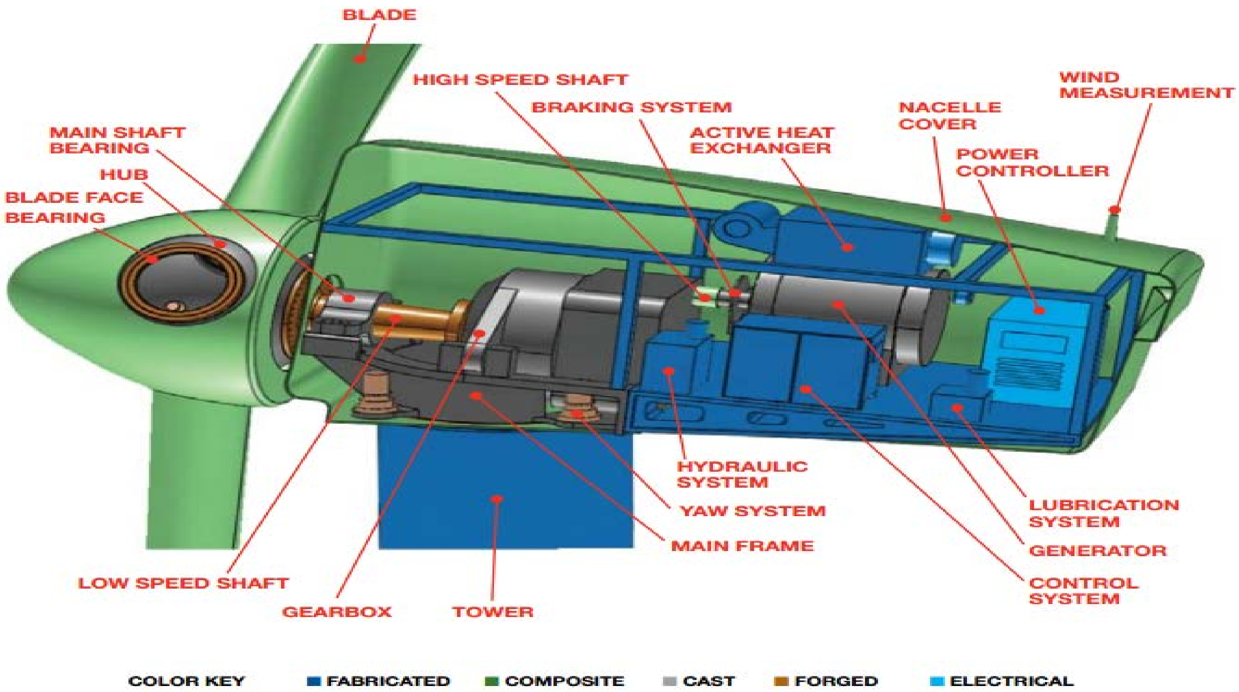


Figure A1.2: Geared Wind Turbine Schematic (AWEA, 2011)

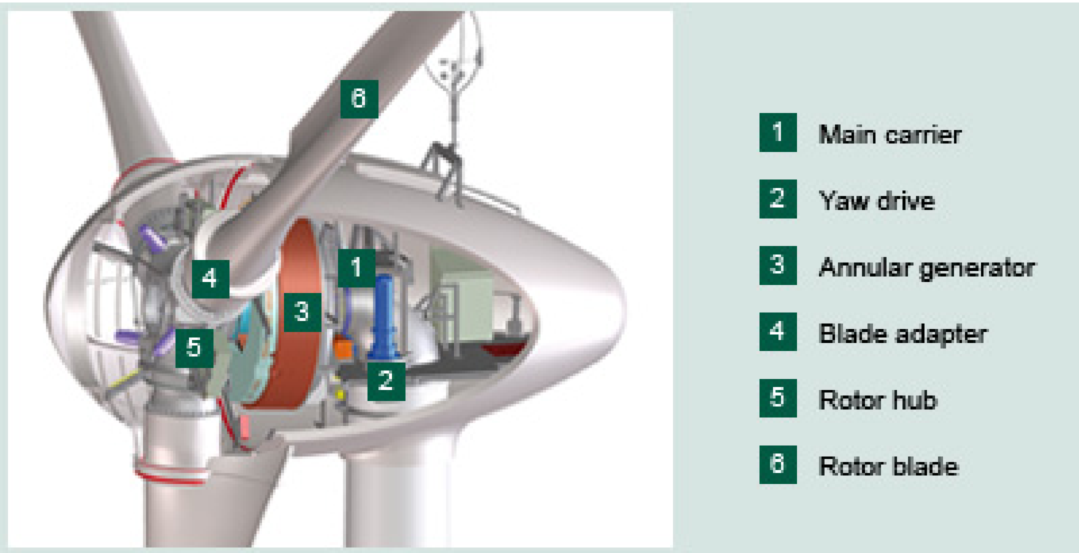


Figure A1.3: Gearless Wind Turbine (Enercon GmbH, 2014)

Rotor: The wind turbine rotor consists of a blade, hub, nose cone, pitching system, and lightning protection arrangement. It collects the energy from the wind. The rotor blades are set in rotational motion to turn the main shaft connected through a gearbox to an electrical generator to produce the electrical energy.

Table A1.1: Rotor Components and Their Functions

Subcomponent	Function
Rotor Blades	Blade converts the kinetic energy of wind into mechanical energy by utilizing the principle of lift and drag. Two types of blades according to their regulation are used - stall regulated and pitches regulated (NREL, 1999).
Pitch Drive	Pitch system controls the pitch (angle) of the blades to achieve the optimum angle for the wind speed and desired rotation speed (Singh G. , 2010).

Subcomponent	Function
Hub	The hub holds the blades and other components of rotor inside it and transmits the transverse motion of the blades into torque to the gearbox of a geared turbine or to the multi-pole electrical generator in the case of direct drive wind turbine. (Earnest & Wizelius, 2011)
Nose cone	Nose cone is used to keep the rotor equipment safe and protected from environmental condition. It encloses the inner hub (Gamesa, 2007).
Lightening protection	It is a steel conductor attached with a blade or nacelle top for protecting the whole wind turbine with lightning stroke (Earnest & Wizelius, 2011).

Nacelle: The nacelle holds the entire drive train of a wind turbine - a series of electrical and mechanical components required to convert the mechanical power received from the rotor hub to electrical power. The nacelle holds the electric panel, electronic control panel, cooling system and yaw system. The drive train inside the nacelle consists of all the rotating components - rotor, main shaft, bearing, gearbox, brakes, coupling and electrical generator. The nacelle cover/canopy encloses all the major parts of turbine and shield from the environmental condition like rain, sun etc.

The major components of nacelle assembly are shown below:

Table A1.2: Nacelle Components and Their Functions

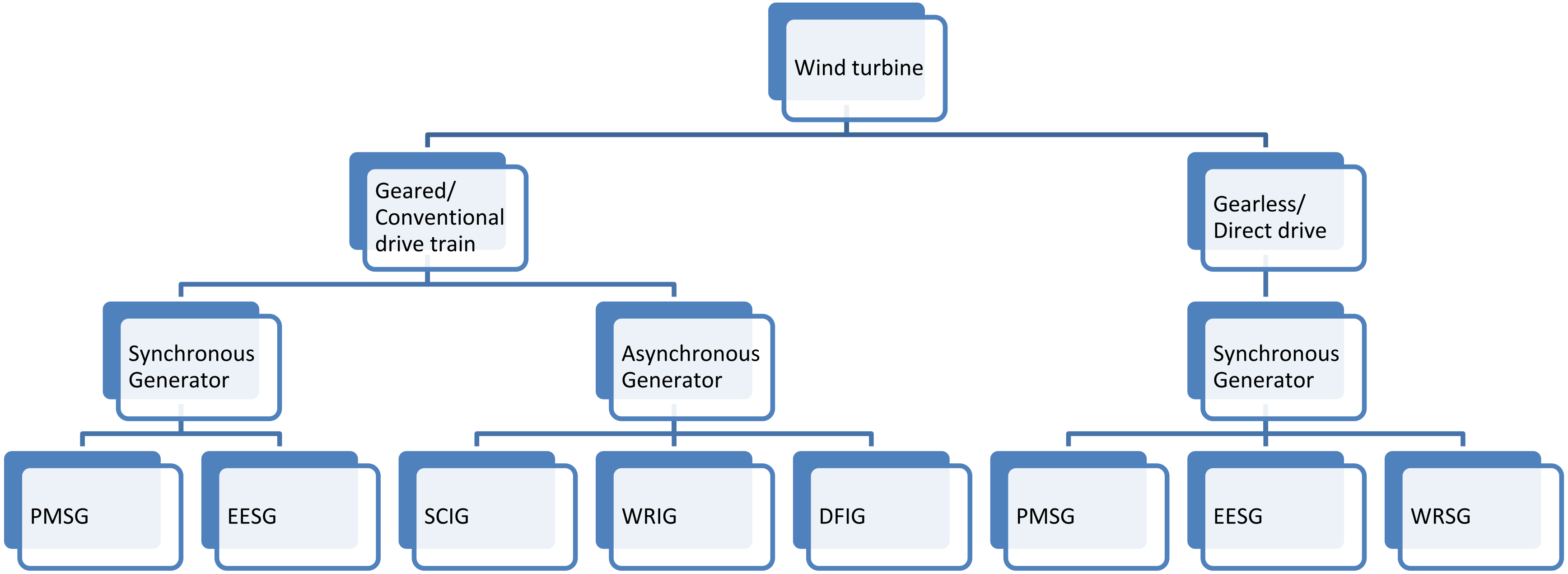
Subcomponent	Function
Shaft system	Shaft system transmits rotational energy of the rotor hub to the gearbox and from the gearbox to the generator. A shaft that is directly connected with rotor is called low speed shaft. High-speed shaft is also present in geared turbine to connect gearbox and generator. It is used to act as a mechanical fuse for gearbox and generator in case of misalignment and grid fault. (Earnest & Wizelius, 2011)
Gearbox (in Geared turbine)	The gearbox is used to increase the speed of slow rotating main shaft and pass it on to the high-speed shaft. One end of the gearbox is connected to the turbine rotor by means of a low speed main shaft, and the other end is connected with a generator via high-speed shaft. (Sterzinger & Svrcek, 2004)
Bearing	Although bearings are used in most of the moving parts of the turbine, the main shaft, and gearbox bearing is the large and crucial bearing. Bearing is used for smooth rotation of moving parts (NTN, 2008)
Coupling and dampers	The primary function of coupling is to transmit the torque between two shafts without any misalignment. These connect two shafts together collinearly (Earnest & Wizelius, 2011). Dampers are necessary to minimize vibrations.
Generator	The generator converts the mechanical energy of the rotating shaft into electrical energy. The generator's rating, or size, is dependent on the swept area of the wind turbine rotor and wind speed.
Cooling system	In wind turbine operation, heat is generated through various moving parts; to prevent damage of components and provide suitable working environment cooling system is used. (Sterzinger & Svrcek, 2004)
Hydraulic system	The hydraulic unit has to maintain and control the specified hydraulic pressure in all the hydraulic circuits. The moment pressure level drops, the wind turbine may come to a halt until the fault is rectified. (Rexroth Bosch Group, 2003) (Sterzinger & Svrcek, 2004)
Yaw system	The yaw system consists of yaw drive, the yaw bearing and the yaw brake located between the tower top and nacelle. It is deployed to control power generation through nacelle movements.
Nacelle main frames and Nacelle enclosure	All the major components except wind sensor assembly are mounted on nacelle mainframe. The main frame has to carry the major weight of nacelle as well as transmit the Thrust load to the tower.

Subcomponent	Function
	Nacelle enclosure protects all the components inside the nacelle from rain, dust etc.
Wind sensor assembly	The wind sensor, wind vane and anemometer assembly mounted on top of the nacelle measure the direction of the wind, speed of the wind, and send this data to controller. (Sterzinger & Svrcek, 2004)

Tower: This is one of the biggest, heaviest and the most expensive components of wind turbine. Wind turbine tower comes in different shapes, forms, and material. The selection of tower is dependent on environmental condition, strength, and economics. Platform, control cables, and ladder are also attached with the tower.

Table A1.3: Tower Components and its Functions

Subcomponent	Function
Tower	This component is typically made of rolled, tabular steel, concrete, built, and shipped in section because of its size and weight.
Flanges and bolts	These items join tower segments.



PMSG- Permanent magnet synchronous generator	*EESG- Electrically excited synchronous generator*	*WRSG- Wound rotor synchronous generator*	*SCIG- Squirrel cage induction generator*	*WRIG- Wound rotor induction generator*	*DFIG- Doubly fed induction generator*

Figure A1.4: Wind Turbine Classification and Combination According to Drive Train and Generator Type

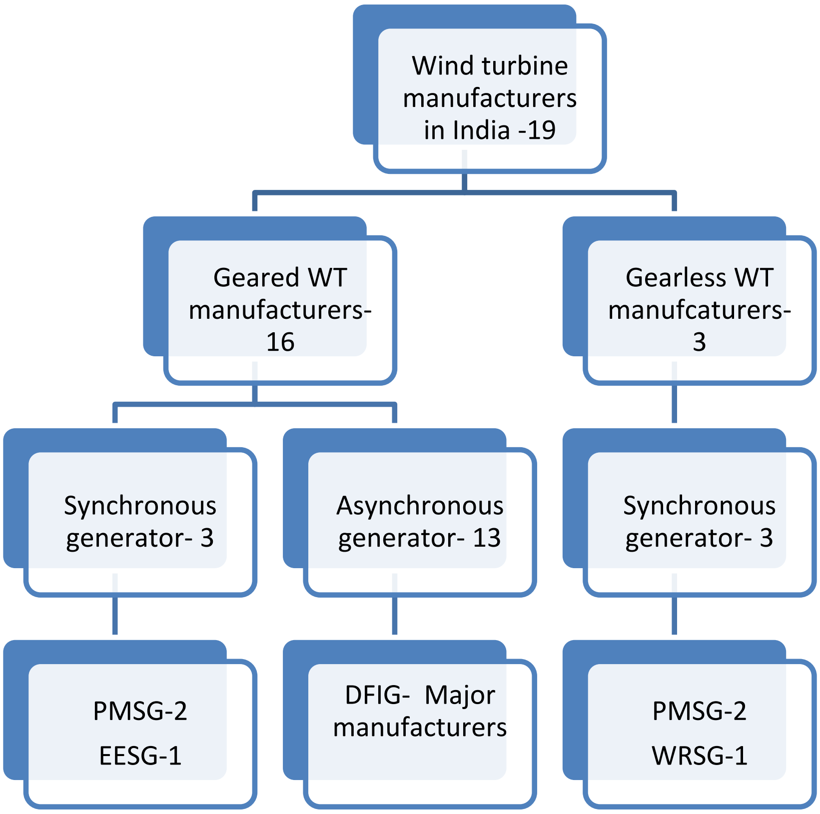


Figure A1.5: Bifurcation of Indian WTG Manufacturers by Drive Train and Generator Type

A1.2 Solar Power

Energy from solar can be harnessed using photovoltaic and thermal technologies. The word Photovoltaic (PV) comes from a synthesis of words Photon and Voltaic, which means light, and generation of electricity respectively. PV systems can directly transform solar energy into electric energy in a clean and quiet manner. A PV system consists of PV cells made of semiconducting devices able to generate electricity from sunlight.

In a thermal system, the rays of solar energy are concentrated on a receiver carrying HTF. This heat is transformed to mechanical energy by rotating a turbine, which is coupled to a generator to produce electricity (OECD/IEA, 2010). The following sections briefly describe the two technologies at a greater length.

A1.2.1 PV Technology

PV cells can be distinguished into crystalline PV cells and thin film PV cells. In a crystalline PV system, cells are assembled together to form a PV module, while in thin film technology, cells are laser scribed after the deposition of semi-conducting thin film on the substrate. Although thin films have low efficiency, advantages of low cost, low processing temperature and high performance (higher kWh output per kW_p installed capacity) due to low temperature coefficient and higher spectral sensitivity make them a preferred substitute (AppleSun, 2013). The crystalline or thin film modules are connected to form a PV array. The output of a PV system ranges from a few watts to several Megawatts (MW) (IEA, 2010b). In addition to a PV module, a PV system comprises a Junction Box, Mounting system, Inverters, Charge controllers, Protection relays, Energy meters, Weather monitoring station, DC Switches and Transformers. Figure A1.6 shows the schematic representation of a PV system.

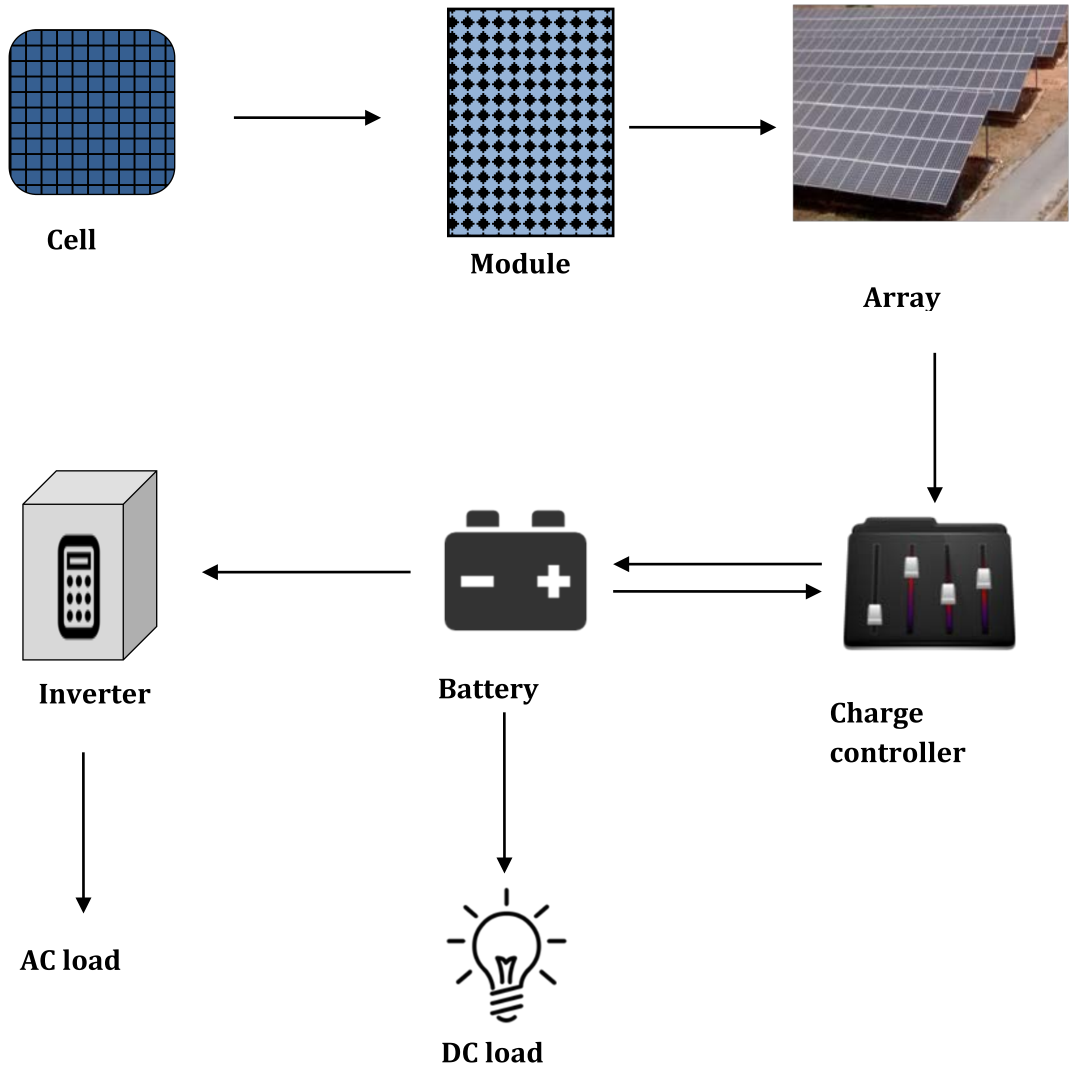


Figure A1.6: Photovoltaic Cells, Modules, Panels and Arrays (Leonics, 2013)

PV Working Principle

Photovoltaic effect refers to the generation of electricity from PV cells when exposed to sunlight. In a crystalline PV module, cells are made of several layers of semiconducting material like Silicon where one of these layers is positively doped into p-type semiconductor i.e. Boron (because Boron has a tendency to attract the electrons) and other with n-type i.e. Phosphorous (acts as a negative junction).

Amorphous Silicon (a-Si), Cadmium Teluride, Copper Indium Galium diSelenide are some of the popular thin film technologies. In an a-Si module, the tin oxide layer (Transparent conductive oxide) acts as P-layer and the Aluminium/Silver back coating acts as the N-Layer with deposited silicon as the intrinsic layer (Ullal, 2008). When exposed to light, some of the photons are absorbed by the semiconductor atoms. This results in the negative electron parting away from the silicon atom, and creating a positive 'hole' within. For generating electricity, these holes and electrons need to be separated by giving opposite charges to layers. When the electrical contacts on the front and rear are connected through an external circuit, the freed electrons can only return to the positively charged holes by flowing through this circuit, thus causing electricity to flow (RES group, 2013). Figure A1.7 shows how photovoltaic effect generates current.

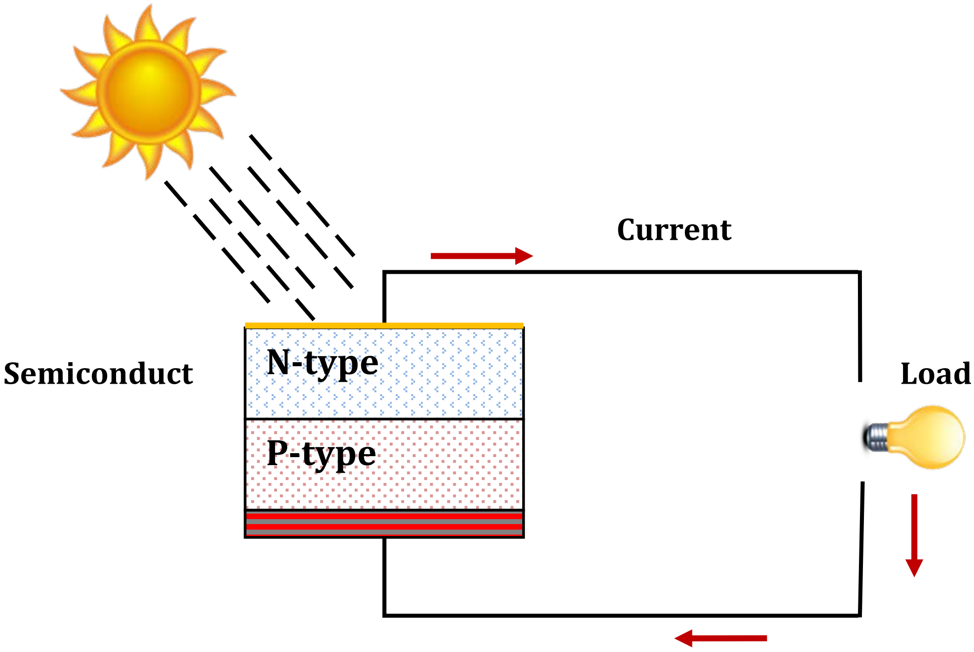


Figure A1.7: Photovoltaic Effect (Mechanical Engineering, 2013)

Crystalline Silicon PV

The making of a crystalline Silicon (c-Si) module begins with purification of silica sand and comprises several steps. It involves reducing raw silicon by purification of sand. Silicon is then obtained in the form of ingot, which is cut into wafers. The wafer is doped with positive and negative materials to (P-type and N-type junction) respectively to form a cell. Consequently, these cells are connected and laminated to form a module, which is assembled in an array and combined with a few electrical components viz. junction box, cable etc. to make a PV system (Green Rhino Energy, 2013b). Mono and multi-crystalline silicon are used in making cells and subsequently modules. The cell efficiencies vary between the two with mono crystalline Silicon having a higher efficiency compared to the multi-crystalline Silicon. Different steps involved in the supply chain of crystalline silicon PV technology are mentioned below. Figure A1.8 provides a schematic of a crystalline silicon PV supply chain.

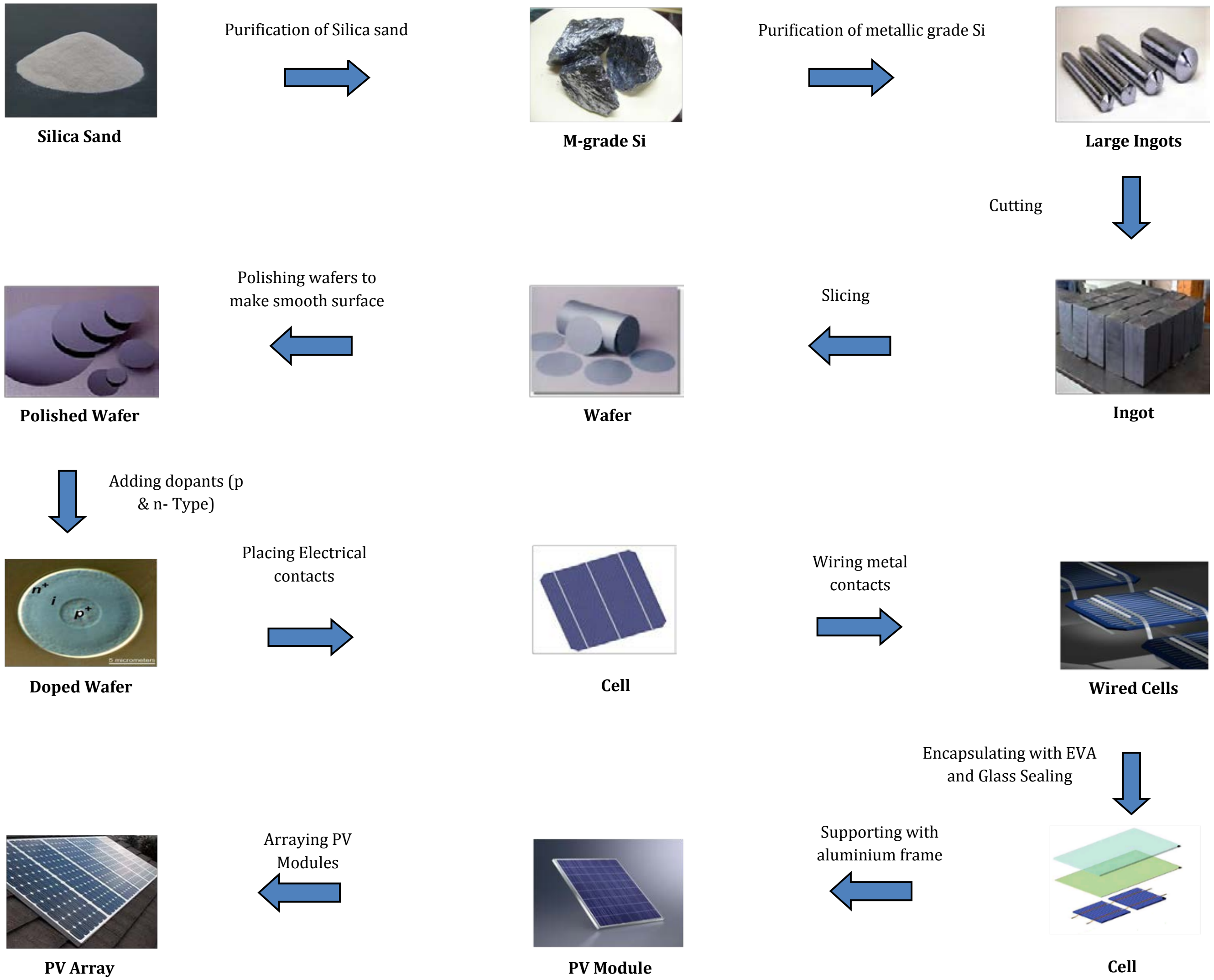


Figure A1.8: Supply Chain Overview (Sinovoltaics, 2011)

Components and Functions

A series of components are involved in making a crystalline PV system. An overview of these components and their respective functions in the PV system has been discussed in Table A1.4.

Table A1.4: c-Si Components and Functions (Green Rhino Energy, 2013c)

Component	Function
Crystalline silicon cell	Effectively uses sunlight directly to generate electricity.
Encapsulant	Holds the components in place, provides electrical insulation, reduces moisture ingress, protects cells from mechanical stress, and protects material from corrosion.
Glass	As a fundamental part of c-Si PV module, it plays an important role in assuring efficient and effective solar energy conversion. The glass is combined with Anti-Reflective (AR) coating that increases the light transmission properties and lowers the maintenance costs[78] of PV system.
Back sheets	Is used to cover the backside of a module. It protects the solar cells from humidity, harsh physical and chemical environments and guarantees total electrical insulation.
Frame	Is used to fix and encapsulate a module. It enhances the intensity and operating life of a module.
Tabbing Ribbon	Is used to interconnect cells and provide a way to transfer power from the solar cells to a power output.
Sealant	Is used for sealing and bonding PV module components and provides long-term protection and bonding from moisture, mechanical & thermal shock and vibration.
Junction box	Is a container for electrical connections generally intended to conceal them from sight and deter tampering. A junction box includes terminals for joining wires from one point to another.
Solar cable	Is used to interconnect solar panels and other electrical components in a PV system. These cables are designed to be ultra violet and weather resistant.
Mounting structure	Is used to fix solar panels on surfaces like roofs, empty plots etc
Solar tracker	Is a device that orients PV panels to sunrays in such a manner to achieve maximum solar intensity.
Inverter	A PV inverter is used to convert the variable direct current (DC) output of a photovoltaic solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network.

Amorphous Silicon Thin film PV

The supply chain of amorphous silicon thin film cell is more vertically integrated vis-à-vis crystalline Silicon technology. The processes involved are less complex. Various steps and components are involved in the manufacturing of a-Si thin film. The modules are manufactured in one single step; from raw silicon and silane and other compounds by depositing the PV material and other chemicals on a substrate. This can be glass, plastic or steel. The cell contacts are established to form an electric circuit. Lastly, this is wired and framed depending on application. Figure A1.9 presents the different process of establishing tandem-type thin-film silicon photovoltaic module.

A typical high-volume production is done with 'turn-key' manufacturing equipment, usually consisting of the following multi-stage processes: Transparent Conductive Oxide film ablation

[78] AR coating promotes hydrophobic properties, hence produces the self cleaning effect

(laser scribing), deposition of photoelectric conversion films, laser scribing of a-Si PIN[79] layer, deposition of rear electrode (reflective film), and laser scribing of back coating for cell isolation. The rest of the thin-film panel production process involves panel cleaning, sealing, wiring, frame, and terminal box mounting (Mount, 2013). The key manufacturing step in a tandem-junction PV panel is the deposition of the µc-Si (Microcrystalline Silicon) film. The flow chart below in Fig A1.9 shows the manufacturing process involved in the preparation of a-Si tandem type thin film module.

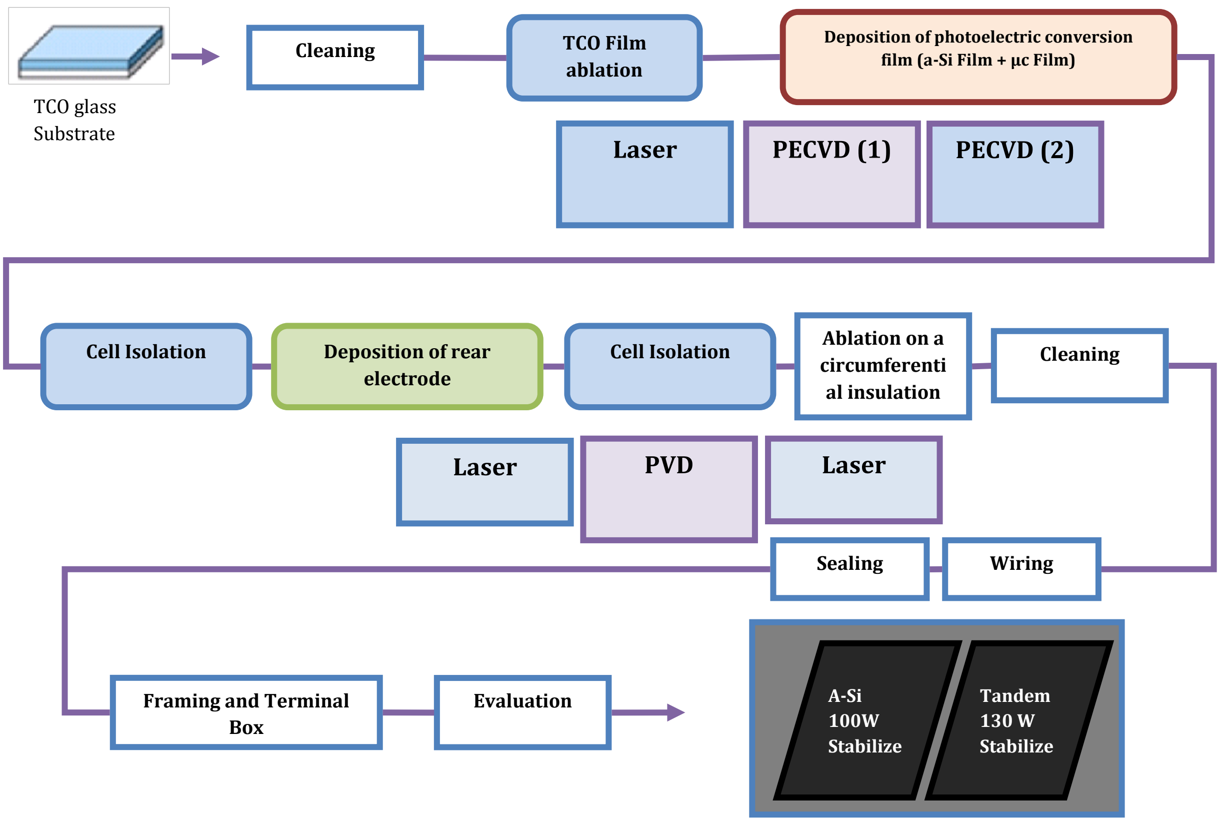


Figure A1.9: Supply Chain of Tandem-Type Thin-Film Silicon PV Module Production (Shimizu, 2010)

Before deposition of silicon thin film layer, the glass substrate is coated with textured **Transparent Conductive Oxide (TCO)** film. The TCO coating used is typically **Tin oxide or Zinc oxide** deposited via sputtering or using an organo-metallic precursor such as **diethyl zinc (DEZ)**. A glass etching treatment is done to improve the light scattering properties of the ZnO films while preserving their good transparency and electrical properties (Weisheit, 2013). The TCO layer acts as the positive electrode. Physical vapour deposition[80] (PVD) sputtering is used for coating back contact layer of **Silver/Aluminium** using **Argon gas** which acts as a negative electrode.

Amorphous silicon in silane is passivated by Hydrogen to reduce the dangling bond defect and forms hydrogenated amorphous Silicon a-Si:H. a-Si:H can be deposited on substrates by decomposition of **silane** gas to form a cell (at temperatures as low as 70°C). This temperature range allows using a wide range of low cost **substrates like glass, stainless steel, flexible plastic**

[79] PIN pattern refers to positively doped semiconductor layer-intrinsic layer-Negatively doped semiconductor

[80]Physical vapor deposition is a vacuum deposition method used to deposit thin films by the condensation of a vaporized form of the desired film material onto the desired surface.

foils, ceramic etc (Zeman, 2012). Dopants are added to the SiH_4 vapour within the chamber to dope the a-Si:H intrinsic layer e.g. Diborane (B_2H_6) for P-type and Phosphine (PH_3) for N-type.

The substrate is then divided into cells using laser-scribing machine. PV cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents, and power levels. PV modules consist of PV cell circuits sealed in an environmentally protective laminate using encapsulant and backsheet. Ethyl vinyl acetate is most commonly used **encapsulant** and **backsheets** are made up of tedlar, tefzel or Mylar. PV modules are assembled as a pre-wired, field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of number of PV modules (Florida Solar Energy Center, 2013).

Components and Functions

An overview of a-Si thin film PV components and their respective functions are discussed in Table A1.5.

Table A1.5: a-Si Thin Film PV Components and Functions (Hockley & Thwates, 2005)

Component	Function
Substrate	Float glass is commonly used. The optical properties of the glass determine the performance of thin film.
Critical gases	▪ Silane (primary feedstock gas for the PECVD process) ▪ Diborane in mixture with Hydrogen or silane (dopant gas to form p type material) ▪ Phosphine in mixture with Hydrogen or silane (dopant gas to form n type material) ▪ Hydrogen: Secondary process gas to permit tailoring of gas reactions and deposition ▪ Argon: Secondary process gas for back contact deposition
Other cleaning gases	Cleaning gas mixture of NF_3 and SF_3/F_2 to remove deposited material from system following the process and sample removal.
TCO	TCO texturation favours light trapping in the cell
Back Coating	Aluminium/Silver back coating acts as a negative electrode.

A1.2.2 Concentrating Solar Power

Concentrating Solar Power (CSP) technologies use mirrors to reflect and concentrate sunlight onto receivers that collect solar energy and convert it to heat. This thermal energy can then be used to produce electricity via a steam turbine or heat engine that drives a generator.

A CSP plant mainly consists of solar field, storage system and power block. A receiver, mirrors, support structure, heat transfer fluid, and solar trackers are part of the solar field. Storage system consists of storage tank and molten salt. Heat Exchangers, Steam turbine, Generators, Pumps, Condensers, and fossil boiler (optional) are the components of a power block.

CSP is subdivided into two types, in accordance with the concentration principle:

Line-focusing systems: PT collector and Linear Fresnel collector are the types of line focusing systems. These systems track the sun position in one dimension (one-axis-tracking)

Point-focusing systems: ST and solar dish are the two types of point focusing system. These systems track the sun in two dimensions (two-axis tracking) and have the higher concentration ratios compared to line focusing systems.

Four CSP technologies operating across the globe are:

1. PT Collector
2. Linear Fresnel Reflector
3. ST
4. Dish Stirling Systems

This study focuses on PT collector and ST technologies.

Parabolic Trough Collector

Figure A1.10 shows a schematic of PT collector solar power plant. The plant consists of a solar field, where solar energy is converted to thermal energy of the HTF, the power block, where the thermal energy of the HTF is used to operate a conventional steam turbine/generator to produce electricity and an optimal thermal storage system, which permits operation of the power block during cloud cover and when there is no sun-light. The solar field consists of rows of highly reflective parabolic mirrors mounted on support structures, which can be tilted about an axis (normally aligned in the North – South direction) to track the sun as it moves from east to west.

The collectors track the sun during the day to ensure that the reflected rays from the mirror continuously focus on the linear receiver. HTF is heated as it circulates through the receiver and passes through a series of heat exchangers in the power block where the fluid is used to generate high-pressure superheated steam. The superheated steam is then fed to a steam turbine/generator to produce electricity. The spent steam from the turbine is condensed to water in a condenser, returned to the heat exchangers via condensate, and feed water pumps to be transformed back into steam. Condenser cooling is provided by mechanical draft wet cooling towers. After passing through the heat exchangers, the cold HTF is re-circulated through the solar field (Solar Paces, 2012).

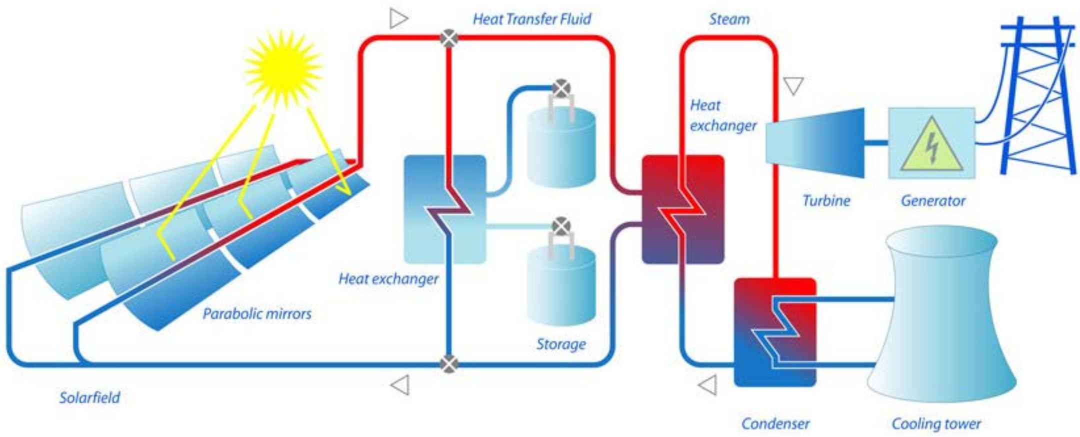


Figure A1.10: Schematic of CSP (Schott Solar, 2013a)

Parabolic Trough – Components and Sub Components

The supply chain of PT involves a lot of complex processes. In addition to the number of steps, several components are engaged in a PT system. Receiver, mirrors, support structure, heat transfer fluid (HTF), trackers, heat exchangers, steam turbine, generators, pumps, and condensers are the primary components of a PT system. All the components are categorized into three major components - solar field, thermal storage, and power block.

Figure A1.11 depicts the list of sub components of the PT system.

The support structure is made of steel or Aluminium on which mirrors and receivers are mounted. Parabolic mirrors are made from low Iron content clear glass sheets, which are thermally bent and coated with Silver and Copper substrates. Receivers are one of the most complex components of PT. They have to absorb as much light while reflecting as little thermal energy. Stainless Steel (SS) 304 material is used for the preparation of a receiver. Mo-Al_2O_3 or Ni- Al_2O_3 compounds are coated on the SS tube using physical vapour deposition process. These tubes are covered by concentric glass made from borosilicate glass (imported from China). The HTF: synthetic oil (Dowtherm or Therminol VP-1), flows in and out of the receiver through header pipe. Thermal energy acquired by HTF while flowing through the receiver is transferred to the feed water through heat exchangers to produce superheated steam, which drives the steam turbine coupled to a generator. The components and their respective functions are mentioned in the succeeding paragraphs.

Solar Field	**Thermal Storage**	**Power Block**
Receiver	Molten salt	Turbine
Mirror	Hot Tank	Generator
Support Structure	Cold Tank	Condenser
Tracking	Foundation	Pumps
Piping	Heat Exchanger	Heat Exchanger
HTF	Pump	Cooling Tower
HTF Pump	Heat tracing	Fossil Boiler
Heat Exchanger		Balance of Plant

Figure A1.11: Components of a PT System

Solar Field

Solar Field comprises receiver, mirrors, support structure, HTF, solar trackers, piping and heat exchanger. An overview of functions of solar field components is highlighted in Table A1.6.

Table A1.6: Solar Field Components and its Functions

Component	Function
Mirror	A linear two-dimensional concentrator which focuses the incident solar radiation on an absorber tube.
Receiver	Absorbs the solar radiation impinging on it and then transfers thermal energy onto the HTF.
Heat Transfer Fluid	It is a fluid, which transmits the heat from absorber tube to power block.
Support Structure	Is made of galvanized steel or Aluminium. The main function of support structure is to ensure the precise alignment of the mirrors over the entire length of the collector.
Tracker	Tracks the motion of the sun across the sky ensuring that the maximum amount of sunlight strikes the mirror throughout the day.
Piping	It is a system of pipes used to convey fluids from one location to another. Piping in the CSP plant is used for the interconnection of the solar field and power block.
Heat Exchanger	It transfers the heat from one medium to another.

Thermal Storage

The thermal energy storage can be defined as storage of thermal energy at high or low temperatures. The thermal storage system consists of storage tank and molten salt. Thermal storage components and their respective functions are highlighted in Table A1.7.

Table A1.7: Thermal Storage Components and its Functions

Component	Function
Molten salt	Is a eutectic mixture of 60% Potassium nitrate and 40% Sodium nitrate. The major function of molten salt is to store the thermal energy (Fabrizi, Trough Molten Salt HTF Field Test Experience, 2007).
Hot tank	Stores the thermal energy accumulated in the molten salt throughout the day and then transferring the energy onto the power block (Padowitz, 2012).
Cold Tank	Stores the molten salt at liquid temperature (290°C) (Padowitz, 2012)
Foundation	Supports the storage tanks and also to provide stability against loads such as wind (MNRE, 2012d).
Heat Exchanger	Transfer the heat from one medium to another.
Pump	Pumps the molten salt from the hot storage tank to cold storage tank and also to the heat exchangers (World Bank, 2011).
Heat tracing	Is a system used to maintain or raise the temperature of HTF in the pipes and vessels (Moore, Vernon, Ho, Siegel, & Kolb, 2010).

Power Block

Power block comprises steam turbine, generators, pumps, condensers, and fossil boilers (optional). An overview of power block components and their respective functions are highlighted in Table A1.8.

Table A1.8: Power Block Components and their Functions

Component	Function
Steam Turbine	Extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft.
Generator	It is a dynamo or similar machine, which is used to convert mechanical energy into electricity.
Condenser	Converts steam from gaseous state to liquid state below atmospheric pressure.
Cooling Tower	Removes heat from the condenser to the atmosphere.
Pump	Delivers liquid or a gas to a specific place at a required rate.
Fossil Boiler	In fossil boilers, steam is generated by firing coal, oil, or natural gas in a furnace. In PT plants, fossil boilers are optional. Fossil boilers are used only when the solar radiations are intermittent in nature.

Solar Tower

In a ST or central receiver system, solar radiation is concentrated on a receiver mounted on top of a tower. The mirrors along with the support structure and tracking system are termed as heliostats. Computer controlled heliostats track the sun and reflect the sunlight on the receiver. The complete group of heliostats is known as a collector field (Falcone, 1986).

The solar radiation incident on the receiver is absorbed by the heat transfer fluid such as water, liquid Sodium, or molten nitrate salt. The thermal energy of the HTF is transferred to the working fluid of a conventional power block to generate electrical power (Solar Paces, 2005).

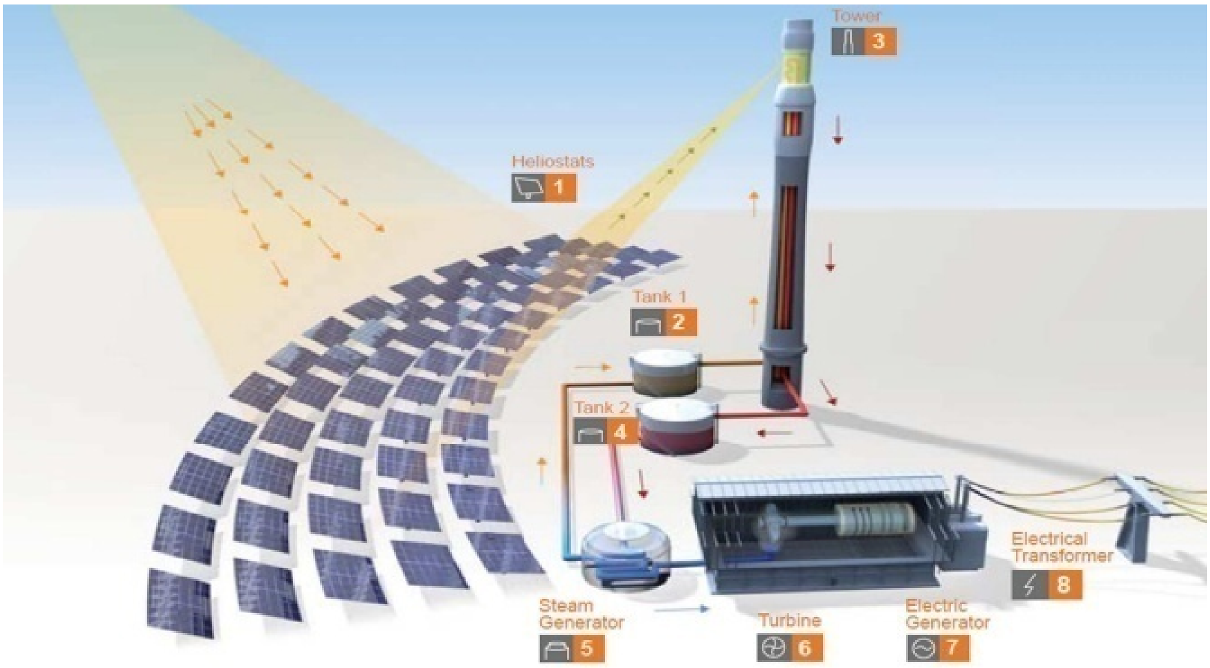


Figure A1.12: Schematic Illustration of a Solar Central Receiver System (Azcárraga, 2012)

Solar Tower – Components & Sub-Components

There are various process steps and components involved in a central receiver system. The support structure is made of steel or Aluminium on which heliostat is mounted. Mirrors in the heliostat are made from low Iron content clear glass sheets, which are thermally bent and coated with silver and Copper substrates. Reinforced concrete or steel is used for the construction of tower on which the receivers are mounted. Stainless steel tube of type AISI 304 or 316 is used in the manufacturing of receivers. The receivers are then coated with black paint to improve the absorption efficiency. The molten salt HTF flows in and flows out of the receiver through a header tube or surge tanks (Falcone, 1986). Thermal energy acquired by the HTF while flowing through the receiver is transferred to the feed water through heat exchangers to produce superheated steam, which drives the steam turbine coupled to a generator. (ESMAP, 2010) The sub-components of the system have been categorized into three major components as depicted in Figure A1.13. The components and their functions are described in the subsequent paragraphs.

Solar Field	**Thermal Storage**	**Power Block**
Receiver	Molten salt	Turbine
Heliostat	Hot Tank	Generator
Tower	Cold Tank	Condenser
Piping	Foundation	Cooling Tower
HTF	Heat Exchanger	Pump
HTF Pump	Pump	Heat Exchanger
Heat Exchanger	Heat tracing	Balance of Plant

Figure A1.13: Components of ST

Solar Field comprises of Receiver, Heliostat, Tower, HTF, Piping, and Heat Exchanger.

Table A1.9 highlights the solar field components and their respective functions.

Table A1.9: Solar Field Components and its Functions

Component	Function
Heliostat	Heliostats are nearly flat mirrors (some curvature is required to focus the sun's image) that collect and concentrate the solar energy on a tower-mounted receiver. Heliostat consists of a reflective surface, a support structure, drive mechanism (tracking), a pedestal, the foundation, and a control system.
Receiver	The central receiver intercepts and absorbs the concentrated energy flux and converts it to useful thermal energy for the subsequent thermodynamic cycle, which is in turn used for power generation. Tubular and volumetric are the two types of receivers.
Tower	The towers are constructed to provide support for the solar receiver at the required height above the collector field (heliostat). Steel or reinforced concrete is used to make tower.

Annexure 2: Turbine Specifications of Commonly Offered WTGs in India

Table A2. 1: Turbine Specifications of Commonly Offered WTGs in India

S.No	Manufacturers → Parameters ↓	Wind World/ Enercon	Gamesa			Garuda	GEWind		Inox Wind	Kenersys India	Leitner-Shriram	Nupower
1	Model	WW-53	AE59	G-58	G90-2.0	GARUDA 700.54	GE 1.6-82.5	GE 1.5-77	WT2000DF	K 82-2.0	LTW 77	W93-2.05
2	Rating in kW	800	800	850	2000	700	1600	1500	2000	2000	1500	2050
3	Rotor Dia. (m)	53	59	58	90	54	82.5	77	93	82	77	93
4	Hub height (m)	75	60.6	44/55/65	67/78/100	73	80/100	65/80	80	80/98	65/80	85 /100
5	Tower type	Steel/ Tubular concrete	Tubular Steel	Tubular	Tubular	Tubular Steel	Tubular Steel	Tubular Steel	Conical tubular steel	Tubular Steel	Tubular	Tubular steel
6	Power Regulation	Variable Pitch	Pitch	Pitch	Pitch	Pitch	Pitch	Pitch	Pitch	Pitch	Pitch	Pitch
7	Type of Generator	Synch	Synch	DFM	DFIG	PMSG	DFIG	DFIG	DFIG	EESG	PMSG	DFIG
8	Speed	Variable	Variable	Variable	Variable	Variable	Variable	Variable	Variable	Variable	Variable	Variable
9	Gear/ Gearless	Gearless	Geared	Geared	Geared	Geared	Geared	Geared	Geared	Geared	Gearless	Geared
10	Cut-in-wind Speed (ms/s)	3	NA	3	3	3.5	3.5	3.5	3	3.5	4.0	3
11	Cut-out-wind Speed (m/s)	25	NA	21	25	24	25	25	20	25	25	20
12	Rated wind Speed (m/s)	12	NA	17	15	11	11.5	14	11.5	14	16.0	12
13	Survival wind speed (m/s)	NA	NA	NA	NA	NA	-	-	52.5	-	NA	NA
14	Wind Class	II	IIIA	IIA/IIIB	IIA	IB	IIIB	IIA	IIIB	Class II	IIA/IIIA	IIA

S.No	Manufacturers → Parameters ↓	ReGen Powertech	RRB Energy	Suzlon					Vestas India		WinWinD
1	Model	V77	Pawan Shakthi-600	S 66	S 82	S 88	S 95	S97	V-82	V100	WWD-1
2	Rating (kW)	1500	600	1250	1500	2100	2100	2100	1650	1800	1000
3	Rotor Dia. (m)	77	47	66	82	88	95	97	82	100	60
4	Hub height (m)	75/85	50/65	74.5	78	80/100	80/90/100	80/90/100	70/78/80	80/95	66/70
5	Tower type	Tubular	Lattice/Tubular	Tubular	Tubular	Tubular	Tubular	Tubular	Tubular	Tubular	Tubular

S.No	**Manufacturers → Parameters ↓**	**ReGen Powertech**	**RRB Energy**	**Suzlon**					**Vestas India**		**WinWinD**
6	Power Regulation	Pitch	Pitch	Pitch	Pitch	Pitch	Pitch	Pitch	Active stall	Pitch	Pitch
7	Type of Generator	PMSG	Async (SIG)	Async	Async/ Induction	Async/ Induction	DFIG	DFIG	Induction-Optislip	Async	PMSG
8	Speed	Variable	Single	Dual	Variable	Variable	Variable	Variable	Single	Variable	Variable
9	Gear/ Gearless	Gearless	Geared	Geared	Geared	Geared	Geared	Geared	Geared	Geared	Geared
10	Cut-in-wind Speed (ms/s)	3	4	4	4	4	3.5	3.5	3.5	4	3.6
11	Cut-out-wind Speed (m/s)	22	25	20	20	25	25	20	20-24	20	20
12	Rated wind Speed (m/s)	13	15	12	14	14	11	11	13	12	12.5
13	Survival wind speed (m/s)	52.5	NA	52.5	52.5	NA	NA	NA	NA	NA	NA
14	Wind Class	IIIA	II	IIIA	IIIA	IIA	IIA	IIIA	IIA	IIA/IIIA	IIIB

(Source: WISE)

Annexure 3: Renewable Energy Projections for India

This section examines the electricity generation projections from renewables for India for four Five Year Plan (FYP) periods beginning 2012-13. The chapter also examines the composition of different RE technologies for the projections. This information is used to further determine the material requirement for the identified critical components for the 'Make vs. Buy'[81] strategy.

The projections are made for four different scenarios under four time frames coinciding with the 12th (2012-17), 13th (2017-22), 14th (2022-27) and 15th (2027-32) five year plans. The four scenarios are Base case, Five Year Plan (FYP), National Action Plan for Climate Change (NAPCC) and National Action Plan for Climate Change Plus (NAPCC Plus).

A3.1 Electricity Demand Projections for India

Demand projection plays a prominent role in the planning exercise. It is difficult, if not impossible, to allocate finance, manpower or develop a roadmap without a good hold over future projections. In India, electricity plan and projections are developed by the Central Electricity Authority (CEA) and the Planning Commission. CEA's National Electricity Plan (2012) and Electric Power Survey (18th EPS) are conducted and published once in five years. On a similar note, a Steering Committee on 'Power and Energy' under the aegis of the Planning Commission is designated to assess the energy demand for the country for the oncoming five year period (12th Five Year Plan).

Long-term electricity projections for India have also been made by ICF International (ICF International, 2013), EREC (GWEC/ EREC/ Greenpeace, 2012)and IEA (IEA, 2010a) (IEA, 2011), to name a few. The methodology used by the different institutions varies. Some of the methods to project electricity demand are as follows:

- Econometric model
- Time series method
- Time trend method (CAGR)
- End-use method
- Partial end-use method

Time trend method and Partial end use method are popular approaches. The time trend method uses the GDP growth rate and the elasticity of electricity growth rate with respect to the GDP growth rate to determine the CAGR of electricity sector. This multiplied by the electricity consumption or generation in the base year determines the electricity consumption/generation for that year. In the partial end use method, electricity growth rates of consumption by the end-use sector i.e. residential, commercial, industrial, agriculture etc. are determined, and any one of the approaches above is engaged to determine the electricity demand.

The **National Electricity Plan, 2012** engages the time trend method. It proposes five demand scenarios and considers 2009-10 as the base year. The scenarios range from Business-as-usual (following past CAGR trend) to using varying energy elasticity from 0.8-1 and GDP growth rate of 9% for two planned periods (12th and 13th FYP). The electricity consumption ranged from 1348 Billion Units (BU) to 1,518 BU for the different scenarios in 2016-17 and 1,895 BU to 2241 BU at the end of 13th planned period (CEA, 2012a).

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[81]Make vs. Buy chiefly determines the wind turbine and solar energy technology components that India should indigenously make or import in short and long-term perspectives. More of this is explained in Chapter 5.

The **18th EPS survey** uses partial end use method for forecasting electricity demand. According to it, all India electricity requirements is assessed at 1,354 BU by the end of 12th plan, 1,904 BU, 2,710 BU and 3,710 BU respectively at the end of 13th, 14th and 15th planned periods (CEA, 2012c).

The 18th EPS assumes that the energy demand will grow at a CAGR of ~7.3% by 2031-32. According to the study, growth is expected to be higher in the initial plan period, i.e. 12th FYP, at ~8.2% while slowing down to ~6% by the end of the 15th FYP. ICF study assesses the all India demand at 1,522 BU at the end of 12th FYP, 2,150 BU, 3,054 BU, and 4,170 BU respectively by the end of 13th, 14th, and 15th FYP (ICF International, 2013)[82].

The **working group on power for the 12th FYP** considers 2009-10 as the base year and assumes 9% GDP growth rate and 0.9 & 0.8 elasticity during the 12th& 13th FYPs respectively. The electricity demand takes into account BEE's Energy Efficiency measures and DSM programs. The energy demand is assessed to be 1,403 BU by the end of 12th plan and 1,993 BU at the end of 13th plan (Planning Commission, 2012c).

The **Integrated Energy Policy (2006)** has projected total primary commercial energy requirement on the basis of falling elasticity of demand (from 0.95 in 2004-05 to 0.78 in 2031-32) with GDP growth rates of 8% and 9%. The energy requirement projections is in the range of 1,524-16,87 BU for 2016-17, 2,118-2,438 BU, 2,866-3,423 BU and 3,880-4,806 BU at the end of 13th, 14th and 15th FYP (Planning Commission, 2006).

The **Energy Technology Perspective (ETP 2010)** published by IEA engages two projection scenarios - the Baseline and the BLUE Map scenarios, based on a bottom-up system engineering model. The Baseline scenario considers expected developments on the basis of the energy policies that have been implemented or approved for implementation. The BLUE Map scenariois target-driven and aims to halve global energy-related CO_2 emissions by 2050 compared to 2005 levels (IEA, 2010a).

The **Technology Development Prospects for power sector in India (2011)** goes beyond the analysis presented in the ETP 2010, and develops an alternative strong growth case for India. In the alternative scenario, the future growth of GDP is expected to be higher than that used in the scenarios in ETP 2010. This is termed as Baseline High Demand and Blue Map High Demand scenarios (IEA, 2011).

The Energy Revolution (2012) develops reference and energy revolution scenarios. The Energy [R]evolution scenario describes development pathways to a sustainable energy supply, achieving the CO_2 reduction target and a nuclear phase-out, without unconventional oil resources. The Energy [R]evolution scenario projects the share of the renewable generation sources to reach 31% by 2030 and 40% by 2050 with the help of expansion of smart grids, demand side management (DSM) measures, and increased storage capacity. The assessed energy requirements are expected to be in the range of 1,718-1,872 BU by 2020, 2,565-3,000 BU by 2030, and 5,034-5,440 BU by 2050. The lower and upper bounds correspond to reference scenario and Energy [R]evolution scenarios respectively (GWEC/ EREC/ Greenpeace, 2012).

Table A3.1 provides a summary of the energy demand/projections by the different organizations.

[82]The study by ICF cites the 18th EPS to derive the electricity demand projections. The *draft* 18th EPS consulted by ICF engages different projections compared to the final version. As such, there is a difference in the yearly demand projected by ICF and 18th EPS.

Table A3. 1: Summary of Electricity Demand Projections for India (in Billion Units)

Year	NEP (2012)	12th Plan Working Group on Power (2012)	18th EPS (2012)	IEP (2006)	IEA (2011)	Energy Revolution, (2012)
Base year	**2009-10**	**2009-10**	**2009-10**	**2003-04**	**2006-07**	**2009**
2016-17	1348-1518	1403	1354-1522^	1524-1687	1020-1322 (2015)#	-
2021-22	1895-2241	1993	1904-2150	2118-2438	1185-1929 (2020)#	1718-1872 (2020)#
2026-27	-	-	2710-3054	2866-3423	1405-2700 (2025)#	-
2031-32	-	-	3710-4170	3880-4806	1791-3720 (2030)#	2565-3000 (2030)
2050	-	-	-	-	3700-6600 (2050)#	5034-5440 (2050)#
^ Lower bound corresponds to 18th EPS report and higher bound is taken from the ICF report						
# Corresponding year of projection						

A3.2 Scenarios

The study considers four scenarios – Basecase, FYP, NAPCC, and NAPCC Plus to calculate the technology specific contribution in the renewable electricity generation mix. Basecase scenario assumes that penetration of renewables in the electricity mix will remain the same for all the FYPs from 2012-32. FYP scenario adopts the approach under which the renewable additions will follow the targets established in the 12th Five Year Plan. NAPCC scenario is more optimistic than FYP and assumes that the target of 15% renewables in the overall electricity mix by 2020 and 3% solar by 2022 will be accomplished. NAPCC Plus scenario is very ambitious and assumes that deployment of renewable will exceed NAPCC targets and will achieve 39% grid penetration by 2032. The following explanation briefly describes the assumptions and rationale for each of the scenarios.

Basecase: According to this scenario, the RE penetration in grid will remain the same as was in 2011-12 for all the five-year plans. The net energy generation from RE sources in 2011-12 was 5.79% of total generation. Further, the study assumes that the percentage share of wind (61%), solar (3%) and others (36%) in renewable will also remain same as it was in 2011-12.

FYP: This scenario follows the 12th FYP targets in India. The 12th plan Energy chapter has established a target of 30 GW of RE capacity during the planned period (Planning Commission, 2013a). This has been considered in the scenario. According to this scenario, the country would achieve the target set in 12th FYP (9%) and will reach 9.6% RE in the total electricity mix by 2016-17. Post 2017, it assumes that the renewable energy dissemination grows linearly at 2.5% over the five-year period in each of the 13th, 14th and 15th FYPs. It also conforms to RE target of 16% in the overall electricity mix by 2030 as estimated in the 12th FYP (Planning Commission, 2013b). Renewable penetration in the grid in 2032 FYP scenario is expected to reach 17.1%.

NAPCC: The scenario is relatively more optimistic and aligns itself to renewable target set under NAPCC. NAPCC has set a target of 15% generation from renewables in the total electricity mix by 2020 (Kapoor, 2013) and 3% solar by 2022 (MNRE, 2013b). It assumes that the renewables penetration will increase at a higher rate than 12th FYP targets and will achieve 12% RE by 2017. Thereafter, it assumes a growth of 1% in RE generation per year till 2032. Generation from renewables in the overall electricity mix in 2032 is expected to reach 27%.

NAPCC Plus: This represents an aggressive scenario for renewable development in India. It envisages a great business opportunity in renewable sector in India and assumes a large inflow of investments in this sector, facilitated by favourable government policies and incentives. In 2011-12 the contribution of RE in the electricity mix was approx. 5.79%. The assumption for growth of RE till 2020 are same as NAPCC scenario i.e. 1% per year. However, post-2020 this scenario assumes that the growth in RE will be 2% per year till 2032. Thus, as per NAPCC Plus scenario the RE penetration in the grid will reach 39% by 2032.

A3.3 Assumptions and Methodology

In this study, energy demand was estimated using both time series analysis and partial end-use method. In time series analysis approach, actual electricity demand from 2002–12 was considered to draw the trend line and determine the demand projections for 2032 (2,706 BU).

In partial end-use method, energy demand projections for each consumer category from 2009-2022 from 18th EPS are obtained and the same is extended until 2032 using a trend line. Using this approach, the energy demand for 2032 is estimated at 2,933 BU. Figure A3.1 provides the range of estimations for the two approaches. This was compared with the projections by the different organizations as depicted in Table A3.2 and a range of electricity demand for the different FYP periods was determined. The range is highlighted in Table A3.2

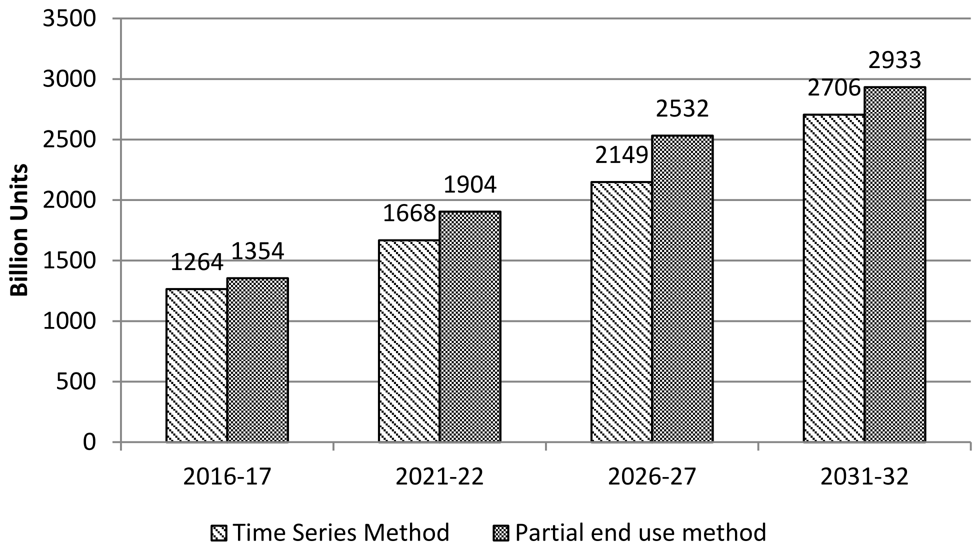


Figure A3. 1: Projected electricity demand from 2017-2032

Table A3. 2: Range of Electricity Demand for FYPs

Time period	Electricity demand (in BU)	Mean Value* (in BU)
2016-17	1264-1354	1300
2021-22	1668-1904	1850
2026-27	2149-2532	2350
2031-32	2706-2933	2800
*Mean of the projected electricity demand has been used for renewable projections and has been rounded		

In this analysis, mid- value of the afore-mentioned projection range rounded off to nearest 50s or 100s has been considered for all the FYPs. The rate of RE penetration for the different scenarios is employed to arrive at the RE generation for the respective planned periods. After which, adjusting for auxiliary power consumption, technology specific CUFs are used to derive the installed capacity of the different renewable energy technologies.

The contribution from renewable electricity is calculated by multiplying the RE penetration rate with the total electricity projected for the different scenarios. The penetration of the renewables increases linearly by 2.5% during all five-year plan periods in the FYP scenario and by 5% in the NAPCC scenario. Whereas in NAPCC Plus scenario, the contribution increases by 1% per year until 2020 and 2% thereafter till 2032. Figure A3.2 highlights the renewable penetration in the total electricity mix in the four FYPs for Base case, FYP, NAPCC, and NAPCC Plus scenarios.

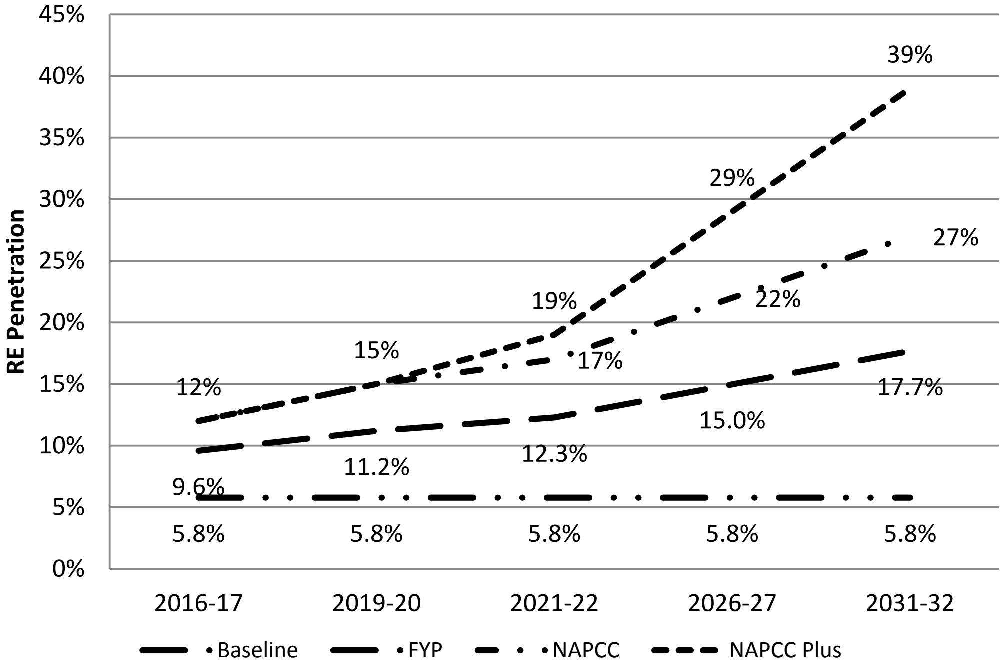


Figure A3. 2: Renewable in the Total Electricity Mix from 2017-32 for the Different Scenarios

Considering that the generation within the technologies could differ, the study developed wind and solar driven sub-scenarios. The major difference is the share (%) of generation coming from wind and solar technologies. The study assumes that the share of wind and solar will increase gradually vis-a-vis other renewables. In the FYP scenario, the estimated share of wind and solar in total RES will be approximate 70% by 2016-17. Further, the study assumes that gradually the share of solar and wind in total renewable generation will increase and reach 75% and 85% by 2017-22 and 2022-32 respectively. Table A3.3 highlight the assumed share of different technologies in the wind and solar driven sub-scenarios. The solar and wind driven sub-scenarios are considered only after 2017 as the trend is more clear till 2017 as per the 12th plan. For 2017-22 NAPCC scenarios, the share of various technologies takes into consideration solar RPO target of 3% by 2022.

Table A3. 4: Share of Different Renewable Power Technologies across Different FYP Periods

RES Technology share (%)in generation								
RES	**2012-2032 (Base case)^ (%)**	**2012-17**		**2017-22**	**2017-22**		**2022-32**	
		FYP* (%)	**NAPCC & NAPCC Plus** (%)**	**NAPCC & NAPCC Plus** (%)**	**Wind Driven (%)**	**Solar Driven (%)**	**Wind Driven (%)**	**Solar Driven (%)**
Wind	61	44	52	50	60	55	55	50

Solar	3	24	15	25	15	20	30	35
Others~	36	32	33	25	25	25	15	15
Total	100	100	100	100	100	100	100	100

~Others include biomass, bagasse cogeneration, small hydro and waste to energy
^In Basecase scenario, share is assumed constant across all time frames.
* Estimated as per 12th FYP targets
** The values align with the NAPCC target of 15% RE by 2020 and 3% solar RPO by 2022

The technology specific renewables i.e. wind and solar driven sub-scenarios are multiplied with the respective CUFs and the renewable contribution in the electricity mix after adjusting for auxiliary power consumption to determine the installed capacity. The study assumes different CUFs for the period of dissemination. CUFs for 2022-32 periods are higher than the ones for 2012-22. The improvement in technology (efficiency) and plant operations are the primary reasons for assumption of higher CUFs. The CUF is provided by CERC and KERC for 2011-12 were assumed to hold good for the 2012-22 period (CERC, 2011) (KERC, 2013). Table A3.4 highlights the CUFs assumed for the 2012-22 and 2023-32 periods.

The CUF of solar depends on the composition of PV and Thermal. The CUF of PV varies between 18-21% and solar thermal is around 24-26% without storage and 60% with storage. This study assumes that share of CSP will be around 20% by 2017 and 30% by 2032. Post-2022 CSP will come with storage having higher CUF of 60%.

Table A3. 5: Capacity Utilization Factor (in %) for Different Renewable Energy Technologies[83]

Technologies	Till 2011-12	2012-22	2022-32
Wind Power	21	25	27.4
Solar (PV & Thermal)	19	20.2	32.7

As such the sudden increase in solar CUF post-2022 is on account of higher CUF for CSP technology with storage (CUF = 60%). In wind, the marginal increase in CUF post 2022 is on account of offshore installations with higher CUF of 35% (as assumed) and marginal increments in technology and operational efficiency.

Although the projections have been conducted for all the four scenarios, only the results and analysis for FYP and NAPCC scenarios have been presented. Secondly, the projections are in line with the existing national policies. This yields in the installation of 115 GW of wind and 49 GW of solar in 2032 in the wind driven FYP scenario and 110 GW of wind and 53 GW of solar in the solar driven FYP scenario. NAPCC scenario yields 183 GW and 74 GW respectively of wind and solar capacity in the wind driven scenario whereas 173GW and 82 GW respectively of wind and solar capacity for solar driven scenario. Table A3.6 highlights the installed capacity for all the renewable technologies across FYP and NAPCC scenarios from 2012-32. As such, the overall installed capacity of all the renewable technologies for wind and solar driven sub-scenarios of the FYP and NAPCC scenario for 2032 are in the range of 189-296 GW. The CAGR of total renewables in the wind driven sub-scenarios of FYP and NAPCC scenarios are 10.95% and 13.3% from 2012-32, marginally higher compared to the growth rates for the solar driven case i.e. 10.92% in FYP and 13.25% in NAPCC.

Table A3. 7: Installed Capacity of Renewables for the Different Scenarios from 2012-32

Installed Capacity RE (GW)					
RES	2011-	2016-17	2021-22	2026-27	2031-32

[83]The study has assumed CUFs of solar and wind based on industry inputs. Whereas, for the rest of the technologies CERC guidelines have been considered (CERC, 2011). For waste to power technology, currently, no specific assumptions prevail and as such a conservative estimate of 65% has been assumed.

	12	FYP	NAPCC	FYP	NAPCC	FYP	NAPCC	FYP	NAPCC
Wind	17.4	32.4	42.2	55.6-57.7	79.8-83.2	81.7-84.3	123.7-128.1	109.8-115.2	173.2-182.6
Solar	1.0	11.0	9.9	18.8-21.5	22.6-26.9	34.6-36.8	49-52.7	48.9-53.4	74.1-82
Others~	6.2	11.2	14.5	16.6	23.3	20.9	30.6	25.6	38.9
Total	24.5	54.6	66.6	93.2-93.7	129-129.9	139.4-139.8	207-207.7	188.8-189.7	294-295.5

The corresponding generation for wind technology under the wind and solar driven scenarios are in the range of 246-264 BU under FYP scenario and in the range of 393-423 BU under the NAPCC scenario. For solar, the generation, under the wind and solar driven scenarios for FYP and NAPCC are in the range of 111-129 BUs and 175-205 BUs respectively. Thus, the overall generation projected from the different renewable technologies (including biomass, small hydro etc) for the two scenarios for 2032 are in the range of 478-756 BU.

A3.3.1: Other assumptions in RE projections

1. Post 2016-17, the study assumes following RE additions in the electricity generation for the three scenarios.
    - FYP: 2.5% increase in each FYP from 2017-18 to 2031-2032.
    - NAPCC: 5% increase in each FYP from 2017-18 to 2031-2032.
    - NAPCC Plus: 1% per year till 2020 in sync with NAPCC scenario and thereafter 2% increase per year till 2031-2032.
2. The assessed potential of the renewables as of 15th April 2013 by MNRE is given in Table A3.6. The renewable potential stands at ~256 GW. However, the available potential could increase with advancement in technologies. As such, there is a greater likelihood of the renewable potential exceeding 100 GW for both wind and solar. This has already been showcased by LBNL and CSTEP in the case of wind technology (LBNL, 2012)(CSTEP, 2013b).

Table A3. 8: Technology Potential of Electricity Generation from Renewables in India

RES	Potential (in GW)
Wind	100
Solar	100
Biomass	32
SHP	20
Others^	3.88
Total	255.88
^ Others correspond to waste to energy, Industrial and Municipal Solid Waste.	

A3.4 Summary of RE projections

Scenario 1: Basecase

At the end of 11th FYP, i.e. 2011-12 renewables accounted for 5.79% of total net electricity generation with 24.5 GW of installed capacity. The renewables are lead by wind having 61% share followed by 3% solar and others[84] accounting for 36%. In Basecase scenario, the renewable penetration and share of solar and wind is assumed to remain same at 2011-12 level across all four time frames. **In Basecase scenario, the installed capacity for solar and wind will reach 2.5 GW and 47 GW respectively by 2032.**

Scenario 2: FYP

In this scenario, India is expected to achieve the 12th FYP RE target of 30 GW of new installed capacity in 2016-17. Thus the cumulative RE installed capacity is estimated to reach 54.5 GW by 2016-17. As a result, the RE penetration in 2016-17 is expected to reach 9.6% from 5.79% in 2011-12. From there on, it is assumed to increase at 2.5% for each FYP from 2017-18 to 2031-2032. RE penetration in the total electricity mix is expected to reach 17.1% by 2032.**In 2032, the installed capacity for solar and wind falls in the range of 49-53 GW and 110-115 GW respectively.**

Scenario 3: NAPCC

This scenario is relatively more optimistic compared to FYP scenario. It is assumed that the RE penetration will increase by 2016-17 to 12% in the total electricity mix as outlined in NAPCC. We have then assumed that the RE continues to be pursued vigorously i.e. 5% additions during each FYP from 2016-17 to 2031-2032, attaining 15% by 2020 and subsequently 27% by 2032. In addition, India is able to achieve the National Tariff Policy targets set for solar of 1.25% in 2016-17 and 3% by 2021-22. **In this scenario, the installed capacity for solar and wind is in the range of 74-82 GW and 173-183 GW respectively.** Figure A3.3 highlights the installed capacity of renewables in the FYP and NAPCC scenarios in 2031-32.

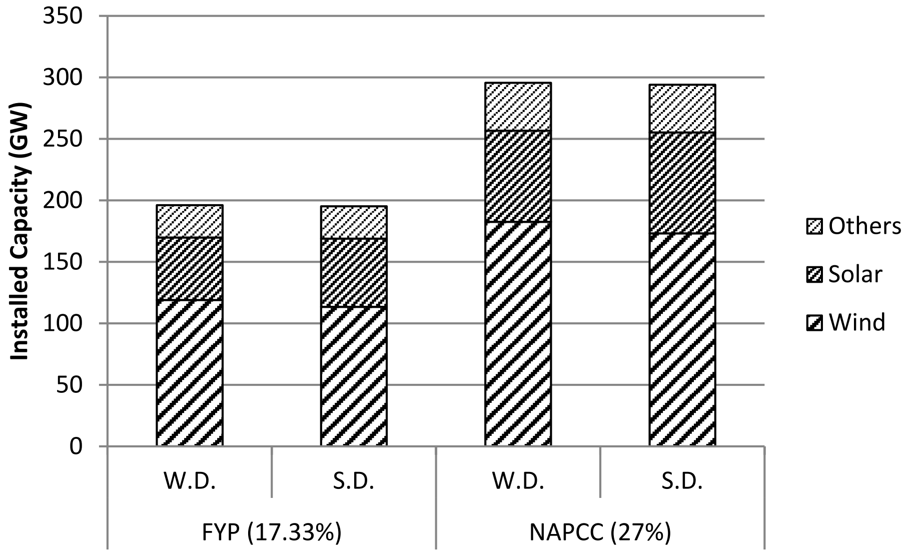


Figure A3. 3: Installed Capacity of Renewables in the FYP and NAPCC Scenarios in 2032

Scenario 4: NAPCC Plus

This is the most aggressive scenario for RE penetration. The RE growth rate assumptions are similar to NAPCC till 2020. However, post-2020, conducive policy environment (push and pull mechanisms) coupled with increased investment by the private sector is assumed to increase the RE penetration at a higher rate of 2% every year till 2032. RE penetration will reach 19% by 2021-22 and subsequently 39% by 2031-32. **In this scenario, the installed capacity for solar and wind is in the range of 110-123 GW and 245-260 GW respectively.**

[84]Others comprise of Biomass, Small Hydro, Cogeneration and Waste to Energy.

The study finds inconsistency in the projections made in the power report of 12th FYP working group and targets established in NAPCC. The report by the working group on power for the 12th FYP states that *"The share of renewables in electricity generated is expected to rise from around 6 per cent in 2012 to 9 per cent in 2017 and 16 per cent in 2030"*. Further, ahead, the report highlights that "*The National Action Plan for Climate Change (NAPCC) norms envisage that the share of renewable electricity in the electricity mix which was 7 per cent in 2011–12 should reach 12 per cent by 2016–17. For this the corresponding renewable power requirement would be 132 BU or 52,000 MW considering the conservative average capacity utilization factor of 30 per cent"* (Planning Commission, 2012c).

A3.5 Share of Different Renewable Technologies

This study considers two sub scenarios – Sub-Scenario 1 and Sub-Scenario 2 for the FYP and NAPCC scenarios. The analysis has been further pursued for 2017 and 2032 five-year plan period. In India, as of Sep 2013, approximately 57% of the total PV installations was attributed to c-Si cell whereas, 93% of the total CSP installations was based on PT technology. In all the scenarios, c-Si holds the highest share among all the technologies. Whereas, among CSP PT yields the higher share to solar tower technology in 2032's Sub-Scenario 2.

A3.5.1 Geared and Gearless Turbines

In chapter 2, the technology trends for wind turbines show an increased share of gearless turbines in the recent years. The annual installations of the gearless turbines exceeded 40% of annual wind turbine installations in 2012-13 in the Indian market. In the new wind power capacity, we have assumed a share of 40% of gearless turbines by 2017 in the Indian market. This share is expected to be 45% and 50% in 2022 and 2032 respectively.

These two technologies (geared and gearless wind turbines) will constitute the share of 15 GW additional wind installations by 2017 under the FYP scenario and 24.9 GW under the NAPCC scenario. By 2022, the FYP scenario estimates a total of 23-25 GW and the NAPCC estimates 38-41 GW of incremental wind power installations over 2017 level. Finally, by 2032, the FYP scenario estimates 28-31 GW of wind installations whereas the NAPCC scenario estimates 50-54 GW incremental capacity over 2022 level. The share of geared and gearless turbines in these projections is shown in Figure A3.4.

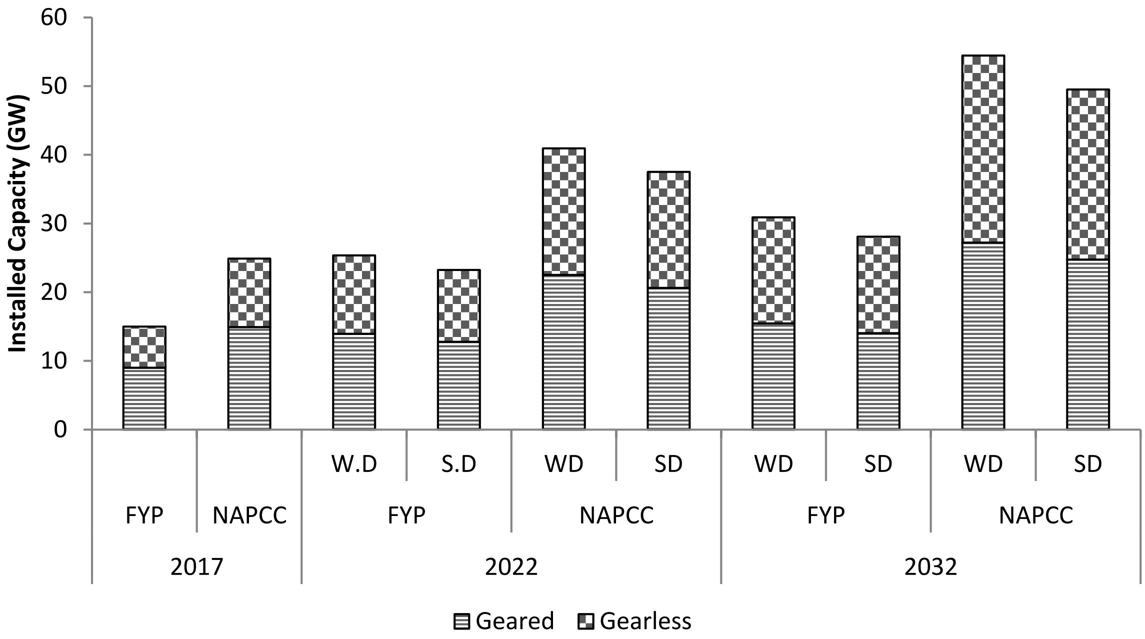


Figure A3. 4: Share (%) of Geared and Gearless Wind Turbines in New Capacity

Beside the onshore wind power market, the offshore wind power market is also likely to take off by 2022. Few pilot/demonstration offshore wind power projects may be expected by then. However, by 2032 the offshore wind power may contribute 10-15 GW of installed capacity in India. It is expected that, in offshore wind market also the gearless or direct drive turbines will have major share.

A3.5.2 Share of PV and CSP

In 2012-17, the analysis assumes that 80% of the solar installation would be PV based and the rest operate on CSP technology. In Sub-Scenario 1, bulk i.e. 48% of all the installations would be c-Si whereas in CSP, PT (14% of all installations) would be the dominant technology. The assumptions are based on the current trend of installations. Thus, around 4.8 and 4.3 GW of installations would be based on c-Si technology in FYP and NAPCC[85] scenarios. In Sub-Scenario 2, % of total installations using c-Si technology is 52% whereas the assumptions on CSP remain the same. **Annexure 7** comprises the assumptions and share of different PV and CSP technologies in Sub-Scenario 1 and Sub-Scenario 2 for 2012-17. Figure A3.5 highlights the projected share of different PV and CSP technologies for FYP and NAPCC scenarios in 2012-17.

[85]NAPCC scenario assumes the target of 1.25% of total electricity generation from solar in 2016-17 and hence these work out to be smaller than the FYP projected installed capacity.

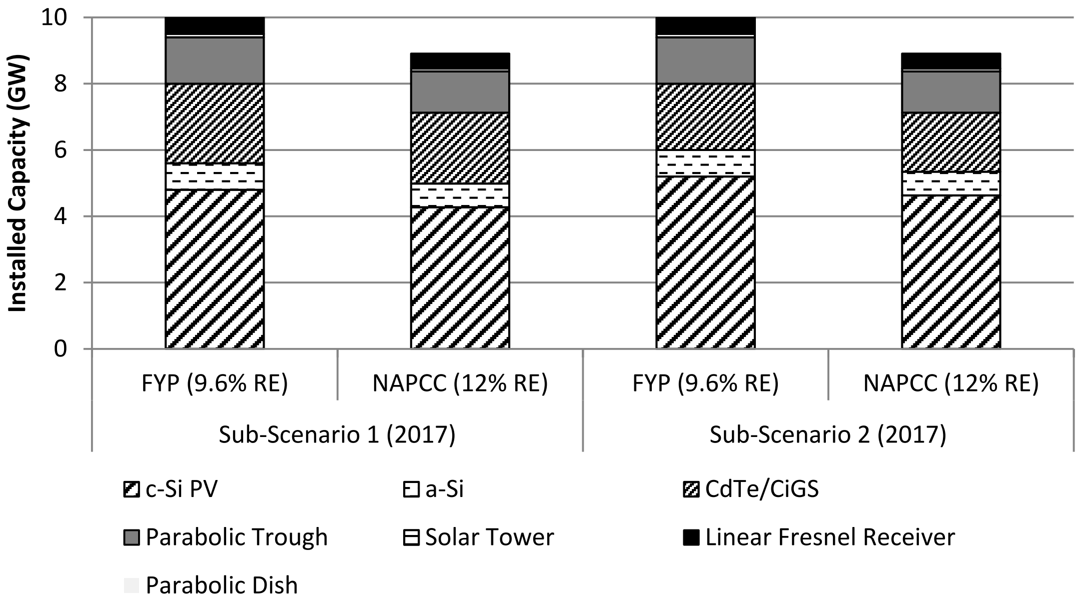


Figure A3. 5: Technology Wise Capacity Projections for the Different Scenarios in 2012-17

In 2017-32, the analysis assumes 70:30 shares of PV and CSP technologies. In PV, in Sub scenario 1 and Sub scenario 2, the study assumes c-Si contribution of 35% and 46% respectively of the total solar installations. Whereas for CSP, Sub-Scenario 1 assumes 18% share for PT technology, in Sub-Scenario 2, ST plays a prominent role occupying a share of 15% in the overall solar installation. In the solar driven scenario of Sub-Scenario 1, around 15 GW and 25 GW of c-Si based system are installed in FYP and NAPCC scenarios. In Sub-Scenario 2, approximately 29 GW and 33 GW of c-Si technology is projected. After c-Si technology, CdTe/CIGS and PT technologies play a prominent role in Sub-Scenario 1. Section A3.5.3 comprises the assumptions and share of different PV and CSP technologies in Sub Scenario 1 and Sub-Scenario 2 for 2017-32. Figure A3.6 depicts the projections for the different technologies across FYP and NAPCC scenarios in 2017-32.

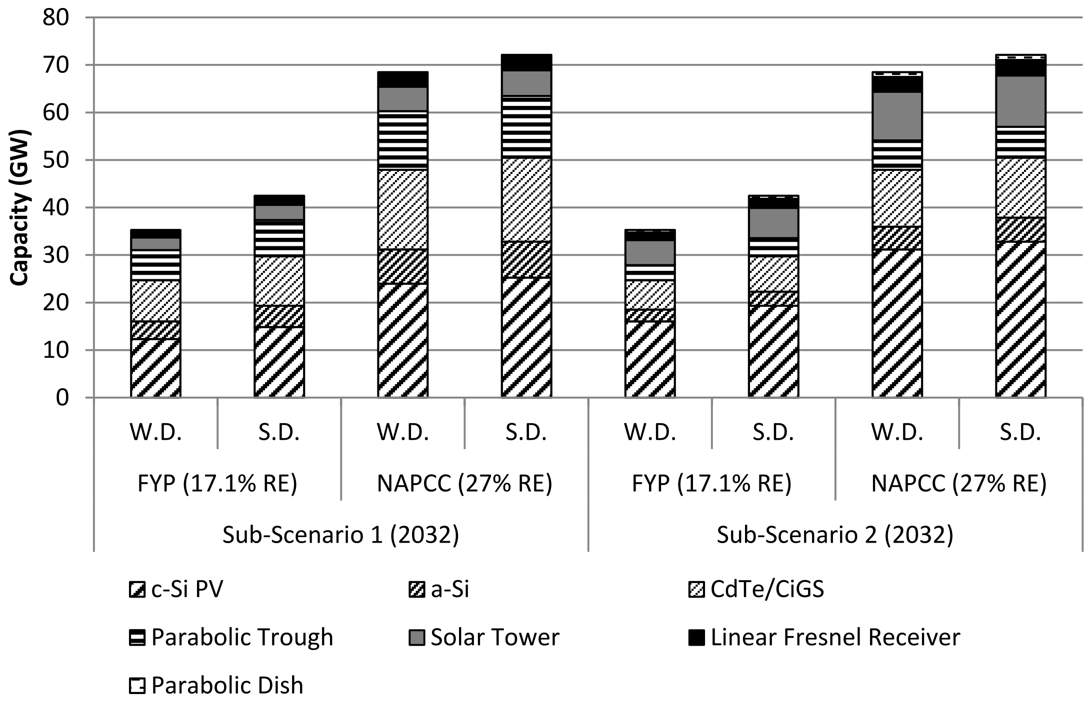


Figure A3. 6: Technology Wise Capacity Projections for the Different Scenarios in 2017-32

A3.5.3 Assumptions and share of different PV and CSP technologies in Sub Scenario 1 and Sub-Scenario 2 for 2017

Sub-Scenario 1 (2017)								
Solar Technologies	**c-Si PV**	**Thin film PV (GW)**		**CSP(GW)**				**Total (GW)**
		a-Si	**CdTe/CIGS**	**PT**	**ST**	**Linear Fresnel Receiver**	**Parabolic Dish**	
% share of PV and CSP	**80%**			**20%**				100%
Share of respective technologies	60%	10%	30%	70%	5%	25%	0%	100%
% share in solar (PV & CSP) technology	48%	8%	24%	14%	1%	5%	0%	100%
FYP (9.6% RE)	4.8	0.8	2.4	1.4	0.1	0.5	0	10.00
NAPCC (12% RE)	4.3	0.71	2.1	1.2	0.09	0.45	0	8.91

Sub-Scenario 2 (2017)								
Solar Technologies	**c-Si PV**	**Thin film PV (GW)**		**CSP(GW)**				**Total (GW)**
		a-Si	**CdTe/CIGS**	**PT**	**ST**	**Linear Fresnel Receiver**	**Parabolic Dish**	
% share of PV and CSP	**80%**			**20%**				100%
Share of respective technologies	65%	10%	25%	70%	5%	25%	0%	100%
% share in solar (PV & CSP) technology	52%	8%	20%	14%	1%	5%	0%	100%
FYP (9.6% RE)	5.20	0.80	2.00	1.40	0.10	0.50	0.00	10.00
NAPCC (12% RE)	4.63	0.71	1.78	1.25	0.09	0.45	0.00	8.91

A3.5.4 Assumptions and share of different PV and CSP technologies in Sub Scenario 1 and Sub-Scenario 2 for 2032

<table>
<tr><th colspan="10">Sub-Scenario 1 (2032)</th></tr>
<tr><th colspan="2" rowspan="2">Solar Technologies</th><th rowspan="2">c-Si PV</th><th colspan="2">Thin film PV (GW)</th><th colspan="4">CSP(GW)</th><th rowspan="2">Total (GW)</th></tr>
<tr><th>a-Si</th><th>CdTe/CIGS</th><th>PT</th><th>ST</th><th>Linear Fresnel Receiver</th><th>Parabolic Dish</th></tr>
<tr><td colspan="2">% share of PV and CSP</td><td colspan="3">70%</td><td colspan="4">30%</td><td>100%</td></tr>
<tr><td colspan="2">Share of respective technologies</td><td>50%</td><td>15%</td><td>35%</td><td>60%</td><td>25%</td><td>15%</td><td>0%</td><td>100%</td></tr>
<tr><td colspan="2">% share in solar (PV & CSP) technology</td><td>35%</td><td>10.5%</td><td>24.5%</td><td>18.0%</td><td>7.5%</td><td>4.5%</td><td>0.0%</td><td>100%</td></tr>
<tr><td rowspan="2">FYP (17.1% RE)</td><td>W.D.</td><td>12.35</td><td>3.70</td><td>8.64</td><td>6.35</td><td>2.65</td><td>1.59</td><td>0.00</td><td>35.28</td></tr>
<tr><td>S.D.</td><td>14.87</td><td>4.46</td><td>10.41</td><td>7.65</td><td>3.19</td><td>1.91</td><td>0.00</td><td>42.47</td></tr>
<tr><td rowspan="2">NAPCC (27% RE)</td><td>W.D.</td><td>23.97</td><td>7.19</td><td>16.78</td><td>12.33</td><td>5.14</td><td>3.08</td><td>0.00</td><td>68.49</td></tr>
<tr><td>S.D.</td><td>25.24</td><td>7.57</td><td>17.67</td><td>12.98</td><td>5.41</td><td>3.25</td><td>0.00</td><td>72.12</td></tr>
</table>

<table>
<tr><th colspan="10">Sub-Scenario 2 (2032)</th></tr>
<tr><th colspan="2" rowspan="2">Solar Technologies</th><th rowspan="2">c-Si PV</th><th colspan="2">Thin film PV (GW)</th><th colspan="4">CSP(GW)</th><th rowspan="2">Total (GW)</th></tr>
<tr><th>a-Si</th><th>CdTe/CIGS</th><th>PT</th><th>ST</th><th>Linear Fresnel Receiver</th><th>Parabolic Dish</th></tr>
<tr><td colspan="2">% share of PV and CSP</td><td colspan="3">70%</td><td colspan="4">30%</td><td>100%</td></tr>
<tr><td colspan="2">Share of respective technologies</td><td>65%</td><td>10%</td><td>25%</td><td>30%</td><td>50%</td><td>15%</td><td>5%</td><td>100%</td></tr>
<tr><td colspan="2">% share in solar (PV & CSP) technology</td><td>45.5%</td><td>7.0%</td><td>17.5%</td><td>9.0%</td><td>15.0%</td><td>4.5%</td><td>1.5%</td><td>100%</td></tr>
<tr><td rowspan="2">FYP (17.1% RE)</td><td>W.D.</td><td>16.05</td><td>2.47</td><td>6.17</td><td>3.18</td><td>5.29</td><td>1.59</td><td>0.53</td><td>35.28</td></tr>
<tr><td>S.D.</td><td>19.33</td><td>2.97</td><td>7.43</td><td>3.82</td><td>6.37</td><td>1.91</td><td>0.64</td><td>42.47</td></tr>
<tr><td rowspan="2">NAPCC (27% RE)</td><td>W.D.</td><td>31.16</td><td>4.79</td><td>11.99</td><td>6.16</td><td>10.27</td><td>3.08</td><td>1.03</td><td>68.49</td></tr>
<tr><td>S.D.</td><td>32.81</td><td>5.05</td><td>12.62</td><td>6.49</td><td>10.82</td><td>3.25</td><td>1.08</td><td>72.12</td></tr>
</table>

A3.5.5 Other RE Technologies- Biomass, Small Hydro

Although the study primarily focused only on two major technologies, viz. wind and solar, the projection analysis also revealed insights into the estimations of other renewables such as biomass, Small Hydro Power (SHP) and others such as waste to energy, cogeneration etc.

The analysis assumes the share of these technologies as 25% until 2022 and 15% till 2032. The capacity addition projections for these technologies are shown in Figure A3. 7.

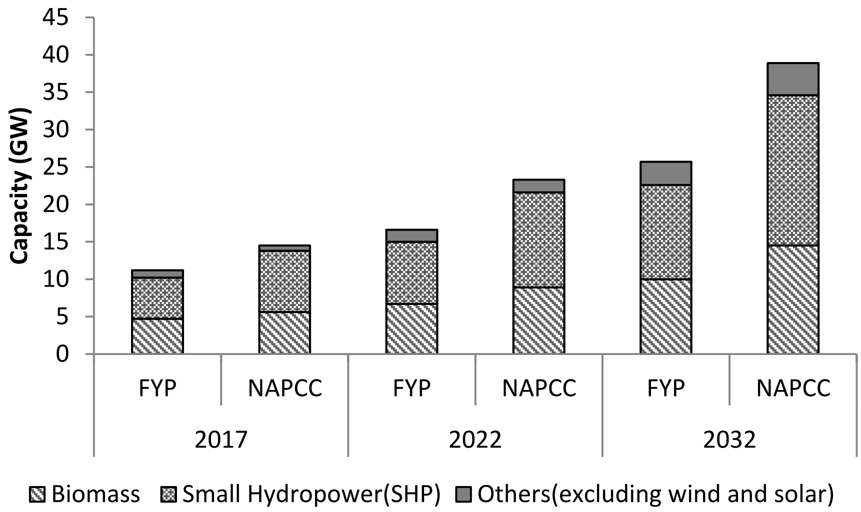


Figure A3. 8: Projections of Other RE Technologies in 2017-32

Annexure 4: List of Major Forged Components in a Wind Turbine

There are several components in the wind turbine, which require a forging process while manufacturing. Table A4.1 shows the forged components of a wind turbine and its weight in tonnes. The main shaft is the heaviest and the largest component and this limits the number of suppliers available. For wind turbines exceeding 2.5 MW, the shafts required will be even heavier and may pose a supply constraint.

Table A4.1: Major Forged Components of Wind Turbine (<2.5 MW) (E4tech and Avalon Consulting, 2012a)

Components	% share of forging as manufacturing process used	No of components per unit	Weight of forged components (Ton)
Bearing rings	100%	1	1
Rotor shaft	80%	1	7
Low speed shaft	100%	1	2.5
Slewing rings	100%	12	1.5
Gear rim	100%	1	1.5
Sun gear	100%	1	1.8
Planet gear	100%	3	0.6
Lock plate	100%	1	1.5
Rotor brake disk	100%	1	1.5
Blade adaptor	100%	3	1.5
Clamping unit (main shaft to gearbox)	100%	1	1
Coupling (gearbox to genset)	100%	1	1
Tower flange	30%	20	3

Annexure 5: Sample Survey Forms for Wind and Solar Industry

Wind Industry Questionnaire

Q1. Please provide the following details

Note: First row (shaded) has been filled as an example.

Component Name	In-house manufacturing (MW/annum)	Components outsourced (MW/annum)	Major component supplier (Country, location, MW/annum)	Other preferred suppliers (Country, location, MW/annum)
Blades	**50**	**50**	**LM wind (India, Bangalore, 40)**	**XYZ Ltd(India, Chennai,7)**
Blades				
Tower				
Generator				
Gearbox				
Control System				
Bearings				
Hub				
Shaft				
Any other				

Q2. Shown below are some of the challenges that could be faced in indigenous manufacturing, please rate them according to the following scale: High -1, Medium -2, Low -3. First row (shaded) has been filled as an example.

Component/Challenge	Raw Material	Process	R&D	IPR	Logistics	Infrastructure	Costs and financing	Man-power
Blades	3		2		1	1		
Towers								
Blades								
Gearboxes								
Generators								
Large bearings								
Control Panel								
Shaft								
Convertors								
Any other								

Q3. Which components do you import from other countries? Please provide reasons for importing a given component from a particular country.

Component	Country of import	Reasons for preference over indigenous suppliers
Towers		
Blades		
Gearboxes		
Generators		
Large bearings		
Control Panel		
Shaft		
Convertors		

Any other		

Q4. In your opinion, which are the most preferred states for setting up a manufacturing /OEM assembly facility? Are these states offering specific benefits for setting up manufacturing/green energy manufacturing? Kindly explain.

Q5.What are the constraints faced by you as a WTG/component manufacturer? What steps can possibly be taken by the government to address them?

Solar Industry Questionnaire

Q1: Please offer your thought on the criticality of the following components from the perspective of indigenous manufacturing

Component	Low	Medium	High

Q2: Kindly furnish the information on the current sourcing mix for the following components

Component	Domestic	Imported

Q3: Kindly offer your perspective on probable future (2017-22) sourcing mix for the following components

Component	Domestic	Imported

Q4: Please offer your thought on the relative significance of following measures for the promotion of solar industry

Measures	Low	Medium	High
Financial Incentives			
Tax related Incentives			
Regulatory			
Infrastructure support			
Trade and Investment restrictions			

The aforementioned questions were asked with the manufacturers of the following components

c-Si PV	a-Si Thin film PV	Parabolic Trough	Solar Tower
Ingot	Silane	Mirror	Heliostat
Wafer	Hydrogen	Receiver	Receiver
Cell	Diborane	Heat Transfer Fluid	Heat Transfer Fluid
Silver Paste	Phosphine	Support Structure	Heat Exchanger

Glass	Glass Substrate	Turbine	Turbine
Encapsulant	TCO	Tracking	Generator
Backsheet	Silver Paste	Heat Exchanger	Pump
Frame	EVA	Generators	Thermal Storage
Tabbing Ribbon	Backsheet		
Junction box	Tracking System		
Cable and Connector	Solar Cable		
Tracking system	Silane		
Mounting structure	Hydrogen		

Annexure 6: Material Requirements and Availability for Wind Turbine Components

The major raw materials used in manufacturing wind turbine components are steel, fiberglass, Copper, adhesive, Aluminium and core material (balsa and foam). Weight wise, steel comprises about 90% of the entire WTG. Fiberglas and other lightweight composites are also important, particularly for blade manufacturing. Other core materials include Aluminium, pre-stressed concrete, Copper, and silica. Major raw materials and their percentage in weight are shown for a 1.5 MW turbine in Table A6.1.

Table A6. 1: Major Raw Material Requirement for Wind Turbine (Congressional Research Service, 2012)[86]

Material requirement	Steel	Fiber Glass	Copper	Concrete	Adhesive	Aluminium	Core material
Weight %	89.10%	5.80%	1.60%	1.30%	1.10%	0.80%	0.40%

Note: Foundation and small parts of wind turbine have not been considered here

Table A6.2 shows the material requirement in tonnes for turbines with different capacities and hub heights. Tower height and type of tower is a big determinant of turbine weight and material requirement.

Table A6. 2: Raw Material Requirement for Wind Turbine Including Tower Base (European Commission , 2012)

Material requirement	V-80 2 MW, DFIG, 78 m steel tower	90 m-rotor, 2MW DFIG 105-m hub, Steel tower	E82 E2, 2.3MW DD-EMG, 107-m pre-cast concrete tower	70-m rotor,1.8 MW DD-EMG, 65-m hub steel tower
Steel	236	296	246	178
Concrete	805	1164	1880	360
Iron and cast iron	20	40	73	44
Resin	3	10		4.8
Fiber glass	21.5	24.3	29	10.2
Copper	3	2.4	11	9.9
Aluminium	1.7		1.3	
Source	Elsam [2004]	Guezuraga et al	Zimmermann	Guezuraga et al

Various grades of steel and alloys are used in the different components of the wind turbine and are shown in Table A6.3. The commonly used materials viz. aluminium, concrete and steel face no availability issues, however certain grades of steel such as Cold Rolled Non Grain Oriented (CRNGO) Steel used in electrical equipment such as generator and transformer has availability constraints (DHI, 2011).

Raw material requirement is calculated based on 1.5 MW wind turbine by % of weight, including blade and tower.

Table A6. 3: Type of Steel or Alloy Design for Turbine Manufacturing (International Molybdenum Association, 2011)

Component	Material	Alloy design
Tower	Steel Plate	S355 or grade 50[87]
Gearbox	Steel forging, Cast Iron	Carburizing steel, typically 18 CrNiMo7-6; Nb, Ti additions for high temperature carburization; spheroidal cast Iron (GJS) or austempered ductile Iron, ADI(MO alloy)
Bearing	Steel forging	Through-hardening Cr-Steel (100 Cr6), or CrMo steel (100 CrMo7-3).
Generator	Steel forging	Heat traceable CrNiMo (V) steel
Hub	Cast Iron	GJS or ADI (Mo alloyed)
Main shaft	Steel forging and cast Iron	Heat traceable CrMo, GJS or ADI

India is dependent on imports for the raw materials used in blade, fiberglass, and epoxy resin. The manufacture of epoxy resin is dependent on biphenol-A (Phenol) which is chiefly imported (FICCI and TATA strategic management group, 2010)(Working Group for 12th FYP, 2013). India currently has 82,000 t/annum installed capacity of fiberglass but import constitutes a major portion of domestic demand (Ministry of Textiles, 2011).

Copper supply may also become a bottleneck in the future, Hindustan Copper Ltd. is the only player in mining, and its current production capacity is only 32,000 tons per annum. (Ministry of Mines, 2012)

Along with these major materials, critical materials whose availability is limited are also used as raw material. These are depicted in Table A6.4. Dy and Nd are rare earth materials and are used in Permanent Magnet Synchronous Generators (PMSG) while all other critical metals are used in various steel alloys.

Table A6. 4: Critical Material Requirement per MW of WTG (JRC-IET, 2011)

Critical elements	Dysprosium	Neodymium	Molybdenum	Nickel	Chromium	Manganese
	Dy	Nd	Mo	Ni	Cr	Mn
kg/MW	2.8	40.6	136.6	663.4	902.4	80.5

Critical rare earth material could create a bottleneck in PMSGs due to China's monopoly in rare earth materials. (E4tech and Avalon Consulting, 2012a). In India, approximately 15% of all installations employ PMSG generator, two major manufacturers Wind World India and ReGen Powertech are using direct drive wind turbines with PMSG being used by ReGen Powertech. Besides major manufacturers, Leitwind Shriram uses PMSG with direct drive; Garuda Vayu and WinWinD uses PMSG with geared drive train.

India is also dependent on import of molybdenum and nickel, which is expected to continue until commercially extractable mines are found (FICCI, 2013a) (Indian Bureau of Mines, 2012b). Chromium is extracted from chromite ore, whose supply is not a constraint (Indian Bureau of Mines, 2012b).

[87] http://www.charles-hatchett.com/system/resources/interfaces/ContentItem.ashx?id=87

Annexure 7: Methodology for Projection of Materials for Solar PV and CSP

A7.1 Solar PV

For a-Si PV and multi Crystalline PV, the reference module specifications are shown in Table A7.1. Panel area per watt peak is calculated and the area ratio is found to be approimately 1.62. This means that for same wattage rating, a-Si module requires 1.62 times more area than multi crystalline PV.

Table A7. 1: Specifications of c-Si and a-Si Module

Technology	Module Size (lxbxt) (mm^3)	Efficien cy	Area (m^2)	Panel Area (m^2)/W_p	Watt Rating	Company
c-Si	1660 x 990 x 50	14.6 %	1.64	0.01111	240	EMMVEE Solar
a-Si (Tandem Structure)	1409 x 1009 x 46	9.5%	1.42	0.00685	128	Sharp Solar

To estimate the material requirement, polysilicon, silane and PV glass is measured in kilo tonnes. While encapsulant and backsheet is estimated in, million meter square. The details are given in Table A7.2.

Table A7. 2: Material Requirement for a-Si and c-Si on Wp Basis

Raw Material Specification	Requirement	c-Si	a-Si
Monosilane (8.11g for 128Wp)	3.8 g/m^2	-	0.04 g/Wp
Glass sheet, low Iron, tempered (1% loss, density 2500 kg/m^3; thickness = 3.5mm)	8,080 g/m^2	55.9 g/Wp	90.6 g/Wp
EVA consumption (0.96kg/m2, +6% more than glass area)	960 g/m^2	.0137 m^2/Wp	.0111 m^2/Wp
Backsheet (TPT, 350 micron thickness: 2x37 micron polyvinylfluoride, 250 micron polyethylene terephthalate; 488 g/m2, 7% cutting loss)	488	0068 m^2/Wp	.0111 m^2/Wp
Polysilicon	-	7g/Wp (2012-17)	-
		5.3g/Wp (2017-32)	

A7.2 Solar CSP

A7.2.1 Short-Term

The main assumptions engaged for the short-term material projection is

- All the CSP plants are without storage
- CUF of the plant is 25%

Parabolic Trough

The critical components used in production of PT are Mirror, Receiver, HTF, Turbine, and Generator. The methodology involved in calculating the material requirement for the critical components are discussed in the following sections:

Parabolic Mirror

Low Iron content glass is one of the critical raw materials used in the production of parabolic mirror (The World Bank, 2011). Andasol -1, a 50 MW PT plant located in Spain is taken as a reference plant to calculate the material projections for glass (NREL, 2013b). 6,000 tonnes of glass is used in the production of parabolic mirror for the Andasol-1 Plant (The World Bank, 2011). 93.75 MW is the equivalent capacity of the Andasol-1 plant considering 8 hrs of operation. Therefore, a tonne of glass required per MW is calculated by dividing the tonnes of glass used in the Andasol plant to the equivalent capacity. Thus, 64 tonne/MW of glass is required for a parabolic mirror of a 50 MW capacity. Table A7.3 shows the specification of Andasol-1 plan and its glass requirement.

Table A7. 3: Specification of Andasol 1 Plant (NREL, 2013b)

Plant Specification	
Operating Hrs of the day	8
Capacity in MW	50
Storage in Hrs	7
Equivalent Capacity in MW	93.75
Glass Utilised in Tonne	6000
Glass requirement in tonne per MW	64

Receiver

Borosilicate glass tube and Stainless Steel 304 (SS-304) are critical raw materials used in the production of receivers (The World Bank, 2011). The quantity of borosilicate glass and SS-304 is calculated for a 50MW PT plant located in Jodhpur (CSTEP, 2013a). Schott PTR 70 receiver is taken as a reference to calculate the material requirement (Schott Solar, 2013b). Table A7.4 shows the plant details and specifications of receiver. The mass of SS-304 and Borosilicate glass is calculated using the following formula:

Mass= Density × Volume

Where, Volume is calculated by multiplying area and length of the tube.

From the above calculations, 8.0028 tonnes of SS-304 and 2.3678 tonnes borosilicate glass are required in a 1MW PT plant.

Table A7. 4: Specifications and Short-Term Material Requirement for Receiver in a PT Plant

Location	Jodhpur
Capacity in MW	50
Storage in Hrs	0
Solar Field Mirror Area in m2	2,89,190
Solar field Area in m2 for 1 MW	5783.8
Aperture Width in m	5.75
Length of the tube in m	1005.878
Outer Diameter of Stainless Steel in m	0.070
Inner Diameter of Stainless Steel in m	0.066
Stainless Steel Area in m2	0.00102
Outer Diameter of borosilicate glass in m	0.125
Inner Diameter of borosilicate glass in m	0.119
Borosilicate Area in m2	0.00106
Density of SS-304 in kg/m^3	7,800
Density of Borosilicate glass in kg/m^3	2,230
SS-304 requirement in tonne per MW	**8.0028**
Borosilicate glass requirement in tonne per MW	**2.3678**

Heat Transfer Fluid

Synthetic oil is used as the HTF for a PT plant. Synthetic oil is a eutectic mixture of 73.5% diphenyl oxide ($C_{12}H_{10}O$) and 26.5% biphenyl ($C_{12}H_{10}$). The amount of HTF required for a 50MW project is 1,100 tonne (Concentrated Solar Power, 2012). Therefore, 22 tonnes of HTF is required for a 1MW PT plant.

Table A7.5 provide the details of raw material requirement for all the critical components in a 1 MW PT plant.

Table A7. 5: Raw Material Requirements for the Critical Components in PT

Critical Components	Raw Materials	Requirements in tonne/MW
Parabolic Mirror	Low Iron content glass	64
Receiver	Stainless Steel – 304	8.0028
	Borosilicate Glass	2.3678
Heat Transfer Fluid	Diphenly Oxide, Biphenyl oxide	22

Solar Tower

Heliostat and Receiver are the critical components of ST systems. The methodology involved in calculating the material requirement for the critical components are discussed in following sections:

Heliostat

Low Iron content glass and Carbon steel are the major raw materials used in the production of Heliostat (ESMAP, 2010). The amount of low Iron content glass and Carbon steel are calculated for a 2.5 MW ST plant located in Bikaner, Rajasthan (NREL, 2013a). The mass of Carbon steel and glass are calculated using

Mass= Density × Volume

From the above calculation, 77.09 tonnes of glass and 167.02 tonnes Carbon are required in a 1MW ST plant. Table A7.6 gives the plant specification and the quantity of glass and steel required.

Table A7. 6: Specifications and Material Requirements in a ST Plant (NREL, 2013a)

Location	Rajasthan, Bikaner
Area in m^2	17,844
Number of Heliostats	14,280
Heliostat Aperture Area in m^2	1.25
Tower Height in m	46
Capacity in MW	2.5
Storage in Hrs	0
Density of glass in kg/m^3	2,700
Thickness in mm	4
Number of Heliostats for 1 MW	5,712
Mass of glass per heliostat in Kg	13.49
Glass required for 1 MW in tonne	**77.09**
Carbon Steel	
Density of carbon steel in kg/m3	7,800
Thickness in mm	3
Mass of carbon steel per heliostat in Kg	29.25
Carbon Steel required for 1 MW in tone	**167.02**

Receiver

Stainless Steel-304 is one of the most critical raw materials used in the production of a receiver. External cylindrical receiver used in 'solar two' plant located in US is used for the calculation.

From the analysis, 2.8645 tonne of steel was used in the external cylindrical tubular receiver plant (Reilly & Kolb, 2001) . Table A7.7 gives the plant specification and the quantity of stainless steel requirements.

Table A7. 7: Specifications of US 'Solar Two' ST Plant

Location	US
Plant	Solar Two
Number of panels	24
Number of tubes per panel	32
Outer dia of each tube in m	0.0209
Thickness of each tube in m	0.00125
Inner dia of each tube in m	0.0184
Height of each tube in m	6.2
Volume of each tube in m^3	0.00048
Total volume of tubes in m^3	0.367
Density of steel in kg/ m^3	7,800
Mass of steel required in kg	2,864.51
Mass of steel required in tonne	2.865

Table A7.8 gives the details of raw materials required for the critical components in a 1MW ST plant.

Table A7. 8: Raw Material Requirements for the Critical Components in ST

Critical Components	Raw Materials	Requirements in tonne/MW
Heliostat	Low Iron Content Glass	77.09
	Carbon Steel	167.02
Receiver	Stainless Steel	2.865

Long-Term

The main assumption for the long-term material projections are:

- All the CSP plants have 8 hours of storage
- The CUF of the plant is 60%

Parabolic Trough

The methodology involved in calculating the material requirement for the critical components in long-term is explained in the subsequent sections.

Parabolic Mirror

Low Iron content glass is the raw material used in parabolic mirror. The quantity of glass required is calculated for a 50 MW PT plant with 8 hours of storage located in Jodhpur (CSTEP, 2013a). The mass of glass is calculated using

Mass= Density × Volume

From the above calculation, 125 tonnes of glass is required for a 1MW PT plant with 8 hours of storage. Table A7.9 gives the details of the plant specification and the quantity of glass required.

Table A7. 9: Specifications of a 50 MW PT sample Plant in Jodhpur

Plant Location	Jodhpur
Solar multiple	2
Capacity in MW	50
Storage in Hrs	8
Solar Field Mirror Area in m^2	578381
Solar field mirror Area in m^2 for 1 MW	11,567.62
Density of glass in kg/m^3	2,700
Thickness in mm	4
Volume of glass in m^3	46.27
Mass of glass in tonne per MW	**124.93**

Receiver

Borosilicate glass and SS-304 are the raw materials used in receivers. Again, the material projections have been conducted for a 50 MW sample PT plant with 8 hours of storage located in Jodhpur. Long-term material requirement calculations are similar to the short-term receiver calculation. Therefore, 16 tonnes of SS-304 and 4.74 tonnes of borosilicate glass are required for a 1MW PT with 8 hours of storage. Table A7.10 highlights the specification and material requirements for the plant.

Table A7. 10: Long-term Receiver and Borosilicate Requirement for a 50 MW PT Plant

Plant Location	Jodhpur
Capacity in MW	50
Storage in Hrs	8
Solar Multiple	2
Solar Field Mirror Area in m^2	578,381
Solar field Area in m^2 for 1 MW	11,567.62
Aperture Width in m	5.75
Length of the tube in m	2,011.76
Outer Diameter of Receiver in m	0.070
Inner Diameter of Receiver in m	0.066
Receiver Area in m^2	0.001
Outer Diameter of borosilicate in m	0.125
Inner Diameter of borosilicate in m	0.119
Borosilicate Area in m^2	0.0011
Density of SS-304 in kg/m^3	7,800
Density of Borosilicate glass in kg/m^3	2,230
SS-304 requirement in tonne/MW	**16.0056**
Borosilicate glass requirement tonne/MW	**4.74**

Heat Transfer Fluid

The amount of HTF required for a 1MW without storage is 22 tonne. For the long-term considering solar multiple of 2.3, 44 tonnes of HTF is required for a 1MW PT plant with 8 hours of storage.

Table A7.11 summarizes the raw material requirement for all the critical components in a 1 MW PT plant with 8 hours of storage.

Table A7. 11: Long-Term Raw material requirements for the critical components in PT plant with storage

Critical Components	Raw Materials	Requirements in tonne/MW
Parabolic Mirror	Low Iron content glass	124.93
Receiver	Stainless Steel – 304	16.006
	Borosilicate Glass	4.74
Heat Transfer Fluid	Diphenly Oxide, Biphenyl oxide	44

Solar Tower

Area Calculation

The sample ST system is located in Jodhpur. It is a 50 MW plant with 8 hours of storage. The solar field aperture area is calculated using the relation between DNI radiation, power block efficiency, heat exchanger efficiency, receiver efficiency, and solar field efficiency. The calculation yields in a solar field aperture area equal to 669,954 m^2. Table A7.12 provides the details leading to the calculation of the solar field aperture area

Table A7. 12: Calculation of the solar field aperture area

Location	Jodhpur
Capacity in MW	50
Storage in hours	8
Operating Hours	8
Equivalent capacity in MW	100
Power block efficiency	40%
Receiver efficiency	80%
Heat Exchanger efficiency	95%
thermal power to be delivered to HE in MW	329
Solar field efficiency	50%
thermal power to be collected by the solar field in MW	658
DNI in jodhpur in W/ m^2	982
Total aperture area in m^2	**669,954**

Heliostat

Low Iron content glass and Carbon steel are the raw material used in heliostat. The quantity of glass and Carbon steel required is calculated for a 50MW PT plant with 8 hours of storage located in Jodhpur (CSTEP, 2013a). Using the formula mentioned below, a requirement of 159.18 tonnes of glass and 344.89 tonnes Carbon steel is obtained.

Mass= Density × Volume

Table A76.13 provides the plant specification and the quantity of glass and Carbon steel required in the long-term (2017-32).

Table A7. 13: Long-Term Glass and Steel Requirement for a 50 MW PT Plant

Location	Jodhpur
Area in m^2	736,949
Capacity in MW	50
Storage in Hrs	8
Equivalent capacity in MW	100
Density of glass in kg/m3	2,700
Thickness in mm	4

Glass required for 50 MW with 8 hrs of storage in tonne	7,959
Glass required for 1 MW with 8 hrs of storage in tonne	**159.18**
Carbon Steel	
Thickness of carbon steel in mm	3
Density of steel in kg/m^3	7,800
Steel required for 50 MW with 8 hrs of storage in tonne	17,245
Steel required for 1 MW with 8hrs of storage in tonne	**344.89**

Receiver

Stainless Steel-304 is the raw material used in receiver. Due to the unavailability of information on receiver we have considered the data of external cylindrical receiver of 'solar two' plant. Therefore, the mass of stainless steel is taken as 2.86 tonne per MW. Table A7.14 provides the details of raw materials required for all the critical components in a 1 MW ST plant with 8 hours of storage.

Table A7. 14: Long-Term Raw Material Requirements for the Critical Components in ST

Critical Components	Raw Materials	Requirements in tonne/MW
Heliostat	Low Iron content glass	159.18
	Carbon Steel	344.89
Receiver	Stainless Steel	2.8645

Annexure 8: A Summary of Supply and Demand Side Policies Related to Renewable Energy Manufacturing

Table A8. 1: Supply Side Policies

Policies	Description
Local content requirement	Policies could require a minimum share of local content in final RE products. The purpose of LCRs is to gradually promote the domestic manufacturing sector.
Preference or incentive for local component	Local content and manufacturing can be encouraged without being mandated through the use of incentives that award developers selecting wind turbines/ solar panels made locally with low-interest loans for project financing, or provide RE component companies that relocate their manufacturing facilities locally with preferential tax incentives.
Export subsidies	Subsidies provided (in the form of direct grants or concessional loans) to encourage local manufacturers and other firms offering renewable energy products and services to other countries.
Excise duty rebates	Rebates on sales, royalties and other levies are targeted at increasing RE production or manufacturing capacity.
Export tax rebates	Tax concessions could be used to encourage exports of RE products and services.
Production subsidies for equipment manufacturing	Capital grants or low-interest loans could be extended to RE producers/manufacturers to lower the cost of equipment production or help to expand manufacturing capacity.
Tax incentives	Tax incentives can be used to encourage local companies to get involved in the RE industry, or a reduction in sales or income tax can be used to increase the international competitiveness of a domestic technology.
Anti dumping duty	Anti-dumping is a measure to rectify the situation arising out of the dumping of goods and its distortive effect on trade. It provides relief to the domestic industry against the injury caused by dumping via imports.
Market access restrictions	Tariff barriers could favour domestic manufacturers. Such measures by restricting the number of players in the market offer indirect support to domestic manufacturers.
Certification and testing programs	A national certification and testing program that meets international standards can promote the quality and credibility of an emerging manufacturer by building consumer confidence in an otherwise unfamiliar product.
Technical standards	Countries can also restrict imports by the way of promoting technical standards adopted by domestic manufacturing companies.
Research, development and demonstration programs	Sustained public research support for RE technologies, particularly demonstration and commercialization programs, can be crucial to the success of a domestic industry, particularly when R&D between private RE technologies firms and public institutions is coordinated
Compulsory licensing of intellectual property (IP)	Compulsory licensing of IP could be one means to support domestic renewable energy manufacturing industry as it ensures that firms have access to the best technologies.
Land acquisition	Infrastructure support can also be offered to build RE local manufacturing base.

Table A8. 2: Demand Side Policies

Policies	Description
Feed in Tariff	FiTs offer investors in RE a preferential tariff rate price and often guaranteed by long-term PPAs and grid access.
Consumer subsidies	These subsidies are provided directly to the end consumers in order to encourage them to substitute RE for fossil fuel.
Preferential credit	Many commercial/ development banks that perceive investments in RE projects

Policies	Description
	risky could be offered low-cost credit lines and partial risk guarantees by the government to encourage them to offer preferential lending to RE project developers.
Accelerated depreciation	Accelerated depreciation promotes investments in manufacturing and production capacity by domestic firms as it allows project developers to use higher depreciation rates on their RE assets and thus receive related tax breaks.
Production tax credits	These are generation-based incentives, paid per kWh of electricity produced over and above the guaranteed power tariff.
Demand guarantees (RPOs)	Renewable purchase obligations require power utilities to purchase a certain share of their electricity from RE producers. Over time, the share could increase, thereby creating and expanding the RE market.
Government procurement	Regulatory provisions that require governments to purchase more energy-efficient products or consume greater shares of RE could significantly influence market signals.
Grid connections	Regulatory measures could be introduced that force utilities to extend transmission lines to RE project sites or to build electricity substations when projects are announced.
Financial incentives	An energy cess on electricity generated from non-renewable sources, or directly on an electricity consumer's utility bill (often called a system benefits charge), can be used to collect funds that can then be used to encourage renewable energy development.
Tax incentives	Tax-related incentives, either in the form of a corporate income tax deduction for investment in RE technology, or a property tax deduction, may promote investment in renewable power generation.
Green power markets	Several countries have programs that permit electricity consumers to voluntarily purchase green electricity at a premium cost to support the higher cost of renewable power and encourage investment in new renewable generation projects.
Government auctions or resource concessions (PPA)	The government can directly solicit long-term power purchase agreements with RE developers, reducing many of the uncertainties in investing in RE projects in an unstable policy environment.

Annexure 9: NIMZs & SEZ

National Investment and Manufacturing Zone

The National Investment and Manufacturing Zones (NIMZs) have been envisaged in the NMP and will be developed as integrated industrial townships with state-of-the art infrastructure and land use on the basis of zoning; clean and energy efficient technology; necessary social infrastructure; skill development facilities, etc., to provide a productive environment to persons transitioning from the primary sector to the secondary and tertiary sectors. These NIMZs would be managed by Special Purpose Vehicles (SPVs)[88] which would ensure master planning of the zone; and pre-clearances will be provided for setting up the industrial units located within the zone.

- Minimum land requirement will be 5,000 hectares for NIMZ.
- State government will be responsible for land allotment and cost of resettlement and rehabilitation.
- Irrespective of the model adopted, the state government will ensure that land can be mortgaged by the prospective allottees for securing financial assistance from banks/ Financial Institutions.
- Ownership could be by the state government/joint venture/public private partnership /BOOT/ or any other appropriate model.
- After identification of the land, it will be the responsibility of the state government to get the environmental impact study conducted for a prospective NIMZ.
- At least 30% of total land area proposed for NIMZ will be utilized for locating manufacturing units.
- The Department of Industrial Policy and Promotion will act as a nodal agency to resolve any issues pertinent to NIMZ.
- An SPV will be responsible for planning, strategy, preparation of rule and regulation, operations and obtaining clearances for each NIMZ.

Special Economic Zone

The Special Economic Zone (SEZ) policy was announced in April 2000. The focus of the SEZ policy was to work as an engine for economic growth supported by quality infrastructure complemented by an attractive fiscal package both at central and state level. The Special Economic Zones Act, 2005, was passed by the Parliament in May 2005, which received the Presidential assent on 23rd of June 2005. After extensive consultations, the SEZ Act, 2005, supported by SEZ Rules, came into effect on 10th February 2006. The act provides simplified procedures and single window clearance on matters relating to central as well as state governments.

After the announcement of the policy, seven Export Processing Zones set up by the central government and an EPZ set up by the private sector were converted to SEZs. In addition, 11 SEZs were set up by the state governments/private sector during 2000-2005 in West Bengal (2), Gujarat (1), Madhya Pradesh (1), Uttar Pradesh (1), Rajasthan, (2) and Tamil Nadu (4). After the establishment of the SEZ Act, 2005, 588 formal approvals have been granted for setting up Special Economic Zones out of which 386 SEZs have been notified and are under various stages of

[88] SPV is a business entity created to finance large projects and is used by companies to ensure bankruptcy remoteness. SPV issues securities to public or private investors, which are supported by cash flows from the securitized assets or in some cases the underlying assets themselves. The assets are associated with the SPV and shielded from the originator (company). SPV has independent trustees/directors (Basu, 2005).

operation. A total of 173 SEZs are export oriented. Table A9.1 provides the value of exports from the functioning of SEZs during the last six financial years. (Department of Commerce, 2013b)

Table A9. 1: Exports from SEZs during 2006-13 (Department of Commerce, 2013b)

Year	Value (Crore of INR)	Increase (%) over previous year)
2006-07	34,615	52
2007-08	66,638	93
2008-09	99,689	50
2009-10	220,771	121.4
2010-11	315,868	43.11
2011-12	364,478	15.39
2012-13 (Dec 2012)	353,195	

Table A9.2 provides a comparison between Special Economic Zone and National Manufacturing Zone.

Table A9. 2: Comparison of SEZ and NIMZ (PwC, 2012)

	SEZ	NIMZ
Minimum land area	10 to 1000 Hectares depending upon sector	5000 Hectares, processing area may include one or more SEZ
Maximum area	5000 Hectares for multi-product	Not specified
SPV mandatory	No	Yes
Can land be mortgaged by SPV?	Not specified	The state government needs to ensure that land can be mortgaged by the prospective allottees
Responsibility for EIA	Developer	State Government
Minimum processing area	50%	30%
Cost of master planning	Not specified	Central government
Renewable energy or depending on green technology	No mandate or incentive for renewable energy or green technology.	Mandatory to get a certain % of its electricity mix from renewable sources. Low interest loans and investment subsidies.
Special preference by government	Not specified	In government purchases, preference will be given to units located in NIMZs.
Interest subsidy for working capital requirement	Not specified	In government purchases, preference for subvention of interest on working capital by 4%.
Applicability of Viability Gap Funds (VGF)	Not specified	Yes
Incentives to promote innovation	Not specified	Nearly 50% of the expenditure incurred in filing international patents will be shared by the government. Tax exemption on expenditure incurred in taking national, international process or product certification
Single window clearance	Yes	Yes
Tax incentives / concession to SEZ vis-a-vis NIMZ	Presently, supplies to SEZ is exempt from indirect taxes subject to fulfilment of export obligations and other conditions	NMP proposes to provide various tax exemptions/concessions to units established in NIMZ.

Annexure 10: State Renewable Energy Policies

Gujarat

Wind Power Policy 2013

- **WTGs** installed during the operative period will be eligible for the incentive declared under this policy for a period of 25 years
- Wheeling of power for captive consumption at 66 kV voltage level and above shall be allowed on payment of transmission charges and transmission losses applicable to normal open access consumer. Wheeling of power to consumption site below 66 kV voltage level shall be allowed on payment of transmission charges and transmission and wheeling losses@10% of the energy fed to the grid. Wheeling for third party sale will be allowed at the rate applicable for normal open access consumer
- Electricity generated from the WTGs shall be exempted from the payment of electricity duty and wheeling of wind energy for third party and captive consumption shall be exempted from cross subsidy surcharge
- Electricity generated from WTGs may be sold to distribution licensee within the state at rate of INR 4.15/unit of electricity and also distribution licensee may purchase surplus power from captive consumer after adjustment of energy against consumption at recipient unit at a rate of 85% of tariff applicable to WTGs
- Third party sale of electricity from WTG is allowed
- Metering point shall be at the 66 kV pooling substation located at the wind farm site
- All wind power project should submit day ahead schedule to SLDC but are kept out of the preview of state Availability Based Tariff mechanism
- The drawal of reactive power shall be charged as per GERC order
- Banking of electricity generated by captive plant is allowed for a period of one month
- Evacuation facility within the range of 100 km shall be erected by developer at their own cost and beyond this limit GETCO shall erect the evacuation facilities
- Preferential tariff as determined by regulator : INR 4.15/kWh

Maharashtra

New policy for power generation from non-conventional sources 2008

- Private developer will undertake the erection of HV and EHV substation as well as transmission and distribution lines required for the project
- Evacuation arrangement after commissioning will be transferred to MSECL/MSEDCL company
- MEDA will reimburse 50% of the approved expenses on the evacuation arrangement to developer/promoter from green energy fund
- 100% expenditure needed for approach road shall be payable as subsidy from green energy fund
- Electricity generated from WTG are exempted from electricity duty
- A subsidy of 11% of the total share capital of the project shall be paid from green energy fund for wind power project installed and commissioned by co-operative institutions
- 100% refund of octroi tax/entry tax for equipment of wind power project will be through green energy fund
- Preferential tariff as determined by regulator:-

Wind Power Density (WPD) 200-250 W/m^2: INR 5.81/kWh
WPD 250-300 W/m^2: INR 5.05/kWh
WPD 300-400 W/m^2: INR 4.31/kWh
WPD > 400 W/m^2: INR 3.88/kWh

Karnataka

Renewable Energy Policy 2009/14

- Renewable energy development is to be classified as an industry. Land is therefore to be made available to the developers by the commerce and industries department based on single window system
- A green energy cess at INR 0.05/unit on commercial and industrial consumer to generate INR 55 crore annually of which INR 50 crore will be set aside for renewable energy project financing and strengthening the evacuation system
- Year-wise proposed capacity addition for wind
    - 2009-10: 630 MW
    - 2010-11: 680 MW
    - 2011-12: 530 MW
    - 2012-13: 530 MW
    - 2013-14: 599 MW
- Provision of single window service for technical consultation, source of finance and project clearances
- This policy has an obligation to sell the electricity generated from the renewable energy projects to the respective geographical ESCOMs in which the project is located at the tariff determined by KERC under a long-term power purchase agreement
- Target for wind power capacity addition by 2014 will be 4,337 MW
- Barren government lands, reserved as per industrial planning for industrial use can be declared as renewable energy sites. 10% of such lands will be kept at the disposal of KREDL for developing the land to set up the renewable energy power projects
- Identified revenue, private and forest lands will be developed by KREDL to facilitate setting up various renewable energy projects in an efficient manner
- Various statutory clearances that are essential for the development and commissioning of the renewable energy project will be dealt by KREDL with the concerned department and agencies
- 10% of lands will be set apart for renewable energy project in all approved and future SEZ to be identified under industrial policy 2009
- Establish renewable energy SEZ under the provision of the industrial policy 2009
- A state level empowered committee with the Chief Secretary, Government of Karnataka as chairman will provide single window clearance for developing the renewable energy power plant
- Respective renewable energy project developer will bear the cost of transmission lines from the project site to the substation as per grid norms
- Wheeling charges @ 5% will be applicable subject to the KERC norms
- Exemption of demand cut to the extent of 50% of the installed capacity assigned for the captive use purpose will be allowed
- Revised value added tax on various renewable energy equipment and instruments
- Letter of credit to the developer for realizing payment in scheduled period for the renewable energy power sold to the ESCOM
- To avoid locking of huge capacities the wind power project allotment will be restricted to 59 MW at a given area each time. The government waste land in windy location identified for industrial use development will be offered to set up wind projects
- The capacity of the earlier commissioned wind turbine which are more than 10 year old will be considered for augmentation by replacing with efficient higher capacity WTG
- Preferential wind tariff as determined by regulator: INR 4.20/KWh

Rajasthan

Policy for promoting generation of electricity from wind, 2012

- The state will promote setting up wind power plants for direct sale to DISCOMs of Rajasthan in the tariff determined through competitive bidding process from the year 2013-14 onwards:
  - 2013-14: 300 MW
  - 2014-15: 400 MW
  - 2015-16: 500 MW
- To promote wind power plant of unlimited capacity for captive use or sale to third party
- Pooling substation shall be developed and maintained by developers
- For creating a proper facility for receiving power at the receiving substation, the developer shall pay grid connectivity charges
- Power injection beyond the nominal voltage range of 97%-103% may attract reactive power charges as per the relevant grid code
- Electricity generated from WTG for captive use are exempted from electricity duty
- Government land required for wind power developers will be provided at concessional rate of 10% of the rate determined by District Level Committee
- For setting up wind power project maximum allotment of land to the developer shall be 5 Hectare/MW
- Open access for third party sale is allowed
- Preferential tariff as determined by regulator: INR 5.46/kWh (for projects in Jaisalmer, Jodhpur and Barmer district); INR 5.73/kWh (for other districts)

Tamil Nadu

Power Procurement from New and Renewable Sources of Energy Regulations, 2008

- Wheeling charge is 5% of total wheeled energy
- Banking charge is 5% of energy
- Unutilized banked energy as on 31st March permitted for sale @ 75% of purchase rate to the distribution company
- The cost of grid integration up to interconnection point shall be borne by the generator but the work shall be executed by STU/ Distribution licensee. But in case of sale of entire power to the distribution licensee by any new and renewable resource based generators, the cost of interfacing line up to interconnection point shall be have to borne only by STU/distribution licensee
- The tariff determined by the commission in the tariff order shall be applicable for the power purchase agreement period of 20 years
- Preferential tariff as determined by regulator = INR 3.51/kWh

Annexure 11: State-Wise Feed in Tariff for Wind and Solar

State wise feed in tariff for wind power projects

State	Tariff (INR/KWh) (Without Accelerated depreciation)
Andhra Pradesh	4.70
Gujarat	4.15
Haryana	WPD 200-250 W/m^2 : 6.14 WPD 250-300 W/m^2 : 4.91 WPD 300-400 W/m^2 : 4.09 WPD >400 W/m^2 : 3.84
Karnataka	4.15
Kerala	4.77
Madhya Pradesh	5.92
Maharashtra	WPD 200-250 W/m^2 : 5.81 WPD 250-300 W/m^2 : 5.05 WPD 300-400 W/m^2 : 4.31 WPD >400 W/m^2 : 3.88
Orissa	5.31
Punjab	6.29
Rajasthan	5.46 (for projects in Jaisalmer, Jodhpur and Barmer districts) 5.73 (for other)
Tamil Nadu	3.51
Uttar Pradesh	3.21
West Bengal	5.71

(IREEED, 2013)

State Wise Feed in Tariff for Solar Power Projects

State	Tariff (INR/KWh) (Without Accelerated depreciation)		
	Small Solar	Solar PV	Solar Thermal
Andhra Pradesh		17.91	15.31
Bihar		8.75	11.69
Gujarat	11.57	9.64	12.91
Haryana		9.18	12.17
Jharkhand		17.96	13.12
Karnataka	14.50	14.50	11.35
Kerala		15.18	
Madhya Pradesh	10.70	10.14	12.65
Maharashtra	9.48	8.98	12.31
Orissa		17.80	14.73
Punjab		8.75	11.90
Rajasthan		9.63	11.95
Uttar Pradesh		15.00	15.00
West Bengal		8.90	

(IREEED, 2013)

Annexure 12: Grid based Energy Storage for Accelerated RE Deployment

A12.1: Need of Energy Storage for RE

Energy storage plays a vital role to match supply and demand. Renewable sources, being intermittent would require grid scale storage to ensure effective use of extra power generated by renewables and maintain grid discipline in the power system.

According to the European Commission's working paper on the Future Role and Challenges of Energy Storage(European Commission, Directorate General for Energy, 2013), if the intermittent renewable share is lower than 15% of the overall electricity consumption the grid operators are able to handle intermittency but with increased renewables penetration of 25% and above, variable generation needs to be curtailed even during the low demand periods to avoid grid perturbation (frequency, voltage, reactive power) and grid congestion, unless the excess renewable generation can be stored.

In India, renewable energy capacity is concentrated in five states i.e. Rajasthan, Gujarat, Maharashtra, Karnataka, and Tamil Nadu. The share of RES of these states is given in Table A12.1.

Table A12. 1: Share of RES as on 28/02/2014 (CEA, 2014a)

	Total Installed capacity (MW)	**RES Installed Capacity (MW)**	**% of State installed capacity**	**% of Total RES Capacity (India)**
Rajasthan	14,094	3,483	24.7%	11.8%
Gujarat	27,020	4,203	15.6%	14.3%
Maharashtra	33,046	4,769	14.4%	16.2%
Karnataka	13,978	3,639	26%	12.4%
Tamil Nadu	21,063	7,946	37.7%	27%

The extent of variable type of generation as compared to the total generation capacity available in the state plays an important part in determining the action required to be taken to handle the variability (CEA, 2013a). As in future the share of renewable is expected to increase, it is essential to have energy storage facility to back the renewable energy generation.

Different states have their own ways of grid balancing; Tamil Nadu backs the generation by engaging coal-based power plants, which are older plants of 210 MW, Gujarat uses both thermal and hydro power stations and also maintains a margin to accommodate variability, Gujarat also has a dedicated renewable engineer and desk for operations and forecasting and Rajasthan uses thermal plants which backs down during excess RE generation. In accommodating more renewables, there will be more instances of unavailability during peak hours and greater availability during off peak hours; this gives an opportunity to deploy grid storage solutions, which can store energy during off peak hours, which could be used during peak hours (PGCIL, 2013).

The major uses of grid level energy storage in India are:

- Absorb the excess renewable energy during off peak low demand periods and provide energy during peak hours when required.
- Enhance the stability and reliability of electric power systems by providing ample regulating capacity and contingency reserve

Table A12.2 describes the various applications of grid connected energy storage systems.

Table A12. 2: Applications of Grid Level Energy Storage Systems (NREL, 2010)

Application	Description	System benefits when provided by energy storage	Timescale of operation
Load leveling arbitrage	Purchasing low-cost off-peak energy and selling it during periods of high prices.	Increases utilization of base load power plants and decreases use of peaking plants. Can lower system fuel costs, and potentially reduce emissions if peaking units have low efficiency	Response in minutes to hours. Discharge time of hours.
Firm capacity	Provide reliable capacity to meet peak system demand.	Replace (or function as) peaking generators.	Must be able to discharge continuously for several hours or more.
Operating Reserves			
Regulation	Fast responding increase or decrease in generation (or load) to respond to random, unpredictable variations in demand.	Reduces use of partially loaded thermal generators, potentially reducing both fuel use and emissions.	Unit must be able to respond in seconds to minutes. Discharge time is typically minutes. Service is theoretically "net zero" energy over extended time periods.
Contingency Spinning Reserve	Fast response increase in generation (or decrease load) to respond to a contingency such as a generator failure.	Same as regulation	Unit must begin responding immediately and be fully responsive within 10 minutes. Must be able to hold output for 30 minutes to 2 hours depending on the market. Service is infrequently called
Replacement/supplemental	Units brought on-line to replace spinning units.	Limited. Replacement reserve is typically a low-value service.	Typical response time requirement of 30-60 minutes. Discharge time may be several hours.
Ramping/Load Following	Follow longer-term (hourly) changes in electricity demand.	Reduces use of partially loaded thermal generators, potentially reducing both fuel use and emissions. Price is "embedded" in existing energy markets, but not explicitly valued, so somewhat difficult to capture.	Response time in minutes to hours. Discharge time may be minutes to hours.
T&D Replacement and	Reduce loading on	Provides an alternative	Response in minutes to

Application	Description	System benefits when provided by energy storage	Timescale of operation
Deferral	T&D system during peak times.	to expensive and potentially difficult to site transmission and distribution lines and substations. Distribution deferral is not captured in existing markets	hours. Discharge time of hours.
Black-Start	Units brought online to start system after a system-wide failure (blackout).	Limited. May replace conventional generators such as combustion turbines or diesel generators.	Response time requirement is several minutes to over an hour. Discharge time requirement may be several to many hours.
End-Use Applications			
TOU Rates	Functionally same as arbitrage; at customer's end.	Same as arbitrage	Same as arbitrage
Demand charge reduction	Functionally same as firm capacity; at customer's end.	Same as firm capacity	Same as firm capacity
Backup Power/ UPS/Power Quality	Functionally same as contingency reserve, at customer's end.	Benefits are primarily to the customer.	Instantaneous response. Discharge time depends on level of reliability needed by customer.

PGCIL in its study, Desert Power in India (PGCIL, 2013) has developed various load generation scenarios after incorporating renewables and have estimated the grid balancing/energy storage requirements up to 2022, 2032 and 2050 as shown in Table A12.3. The scale of investments required for energy storage is given in Table A12.4.

Table A12. 3: Balancing Reserve Requirements (PGCIL, 2013)

Type of storage	Capacity by 2022 (GW)	Capacity by 2032 (GW)	Capacity by 2050 (GW)
Concentrated solar power with storage		12	30
Pumped storage (up to @30% of 94 GW potential)	5	14	28
Other energy storage (like battery, flywheel)	2	4	10

Table A12. 4: Investment Requirement for Balancing Reserve in India by 2050 (PGCIL, 2013)

Plan period	Pumped Storage (INR Cr.)	Battery Storage (INR Cr.)
12th	2,000	
13th	40,000 (5 GW)	40,000 (2 hrs) (2 GW)
14th& 15th	72,000 (9 GW)	40,000 (2 hrs) (2 GW)
2032 to 2050	1,12,000 (14 GW)	1,20,000 (2 hrs) (6 GW)

A12.2: Energy Storage Technologies

There are three ways in which electricity can be stored:

1. **Electrochemical Storage**
    a. Lead acid batteries, Nickel based batteries, Lithium ion batteries, Flow batteries, Sodium Beta Alumina batteries, Metal air batteries, Electrical double layer capacitors, Pseudo capacitors, Hybrid capacitors, Fuel cells
2. **Mechanical Storage**
    a. Pumped hydro, Compressed air energy storage, Flywheel
3. **Thermal Storage**
    - Solar thermal, end use applications in heating and cooling

An overview of the various energy storage technologies is shown in Table A12.5

Table A12. 5: Characteristics of Various Energy Storage Technologies

Electricity Storage				
Technology	**Sub-category**	**Main characteristics**	**Stage**	**Potential**
High power density battery	Ni-Cd, Ni-MH and Pb-acid	Can supply excellent pulsed power; large and heavy compared to Li-ion.	Commercial	Relatively small
	NaS and Zebra (Na-NiCl2)	Much smaller and lighter than NiCd and Ni-Mh batteries. Energy-storage efficiency ~85%. Operate at 300°C and require constant heat input.	Commercial	Relatively small
	Lithium-ion	Small in size and light in weight (suited to portable applications). Energy-storage efficiency close to 100%. Drawbacks are high cost and detrimental effect when deep discharged	Commercial	Relatively large. R&D aimed at optimization of ancillary components such as packaging and overcharge protection circuitry for reduced cost
Flow battery	Polysulphide bromide (PSB), Vanadium redox (VRB) and zinc Bromine (ZnBr)	Energy storage efficiency 75-85%. Series and parallel combination of cells allows design of high current and high voltage solution. Isolated storage of electrolytes in charged state mitigates self-discharge	More or less commercial	Limited. ZnBr has increased capital and running costs (pump system to circulate bromine complexes)
	Cerium Zinc (CeZn)	Are relatively new to the market and offer larger cell potential and increased power	More or less commercial	Medium. Aim for higher power and energy density for

Electricity Storage				
Technology	**Sub-category**	**Main characteristics**	**Stage**	**Potential**
		density.		increased versatile technology
Super Capacitor	Carbon-based super capacitor	High-power-density energy-storage technology. Very high energy-storage efficiencies (>95%), can be cycled hundreds of thousands of times. Susceptible to self-discharge depending on nature of the Carbon electrodes. Applied in portable electronics and automotive industries.	More or less commercial	Relatively large. Focus on electrode, electrolyte, and package development. Besides, used in automotive, portable electronics industries, medicine, defence and consumer goods
Kinetic Energy Storage	Flywheels	Flywheels with a long working lifetime (>20 years) available, but no commercial applications in power management. High cost of stored energy, largely at demonstration stage.	Demonstration	Medium - cheap devices where space is not restricted (e.g land-based wind), High-performance - where space is a premium (marine-based wind).
Superconducting Magnetic Energy Storage (SMES)		To maintain superconducting state, device cooled to temperature at which superconductivity is attained. For low temperature superconductors liquid helium, for high temperature superconductors liquid nitrogen	Micro SMES devices (1-10 MW) are commercially available	Medium. Devices capable of 100 MW with efficiencies of 99% and a lifetime of 40 years based on high-temperature superconductors are being aimed at. Could be a realistic goal by 2050.
Pumped Storage	Compressed air energy storage (CAES)	Peaking gas turbine power plant consuming less than 40% of the gas used in conventional gas turbine to produce the same amount of power	Commercial	Limited

Electricity Storage				
Technology	**Sub-category**	**Main characteristics**	**Stage**	**Potential**
Regenerative Hydrogen Fuel Cell	Lithium oxide (LiO2)/Lithium nitride (Li3N)	Focus is on fuel cells for vehicles although there is potential for other applications. Also Hydrogen/Bromine is patented	RD&D	Possibly large. US provisional patent applications filed in February 2004, for Lithium Oxide (Li2O)/ Lithium Nitride (Li3N)

The choice of an energy storage technology typically depends on the type of application, which is largely determined by discharge time. Technologies with low discharge times of few seconds to minutes can be used to improve **power quality** by maintaining stability and real time frequency regulation. Technologies with discharge times up to an hour may be used as contingency reserves and for ramping, these come under **bridging power**. Technologies with higher discharge times of several hours can be used for **energy management** and can even replace firm power for some time. The energy technologies with their rated capacity and discharge times are depicted in Figure A12.1.

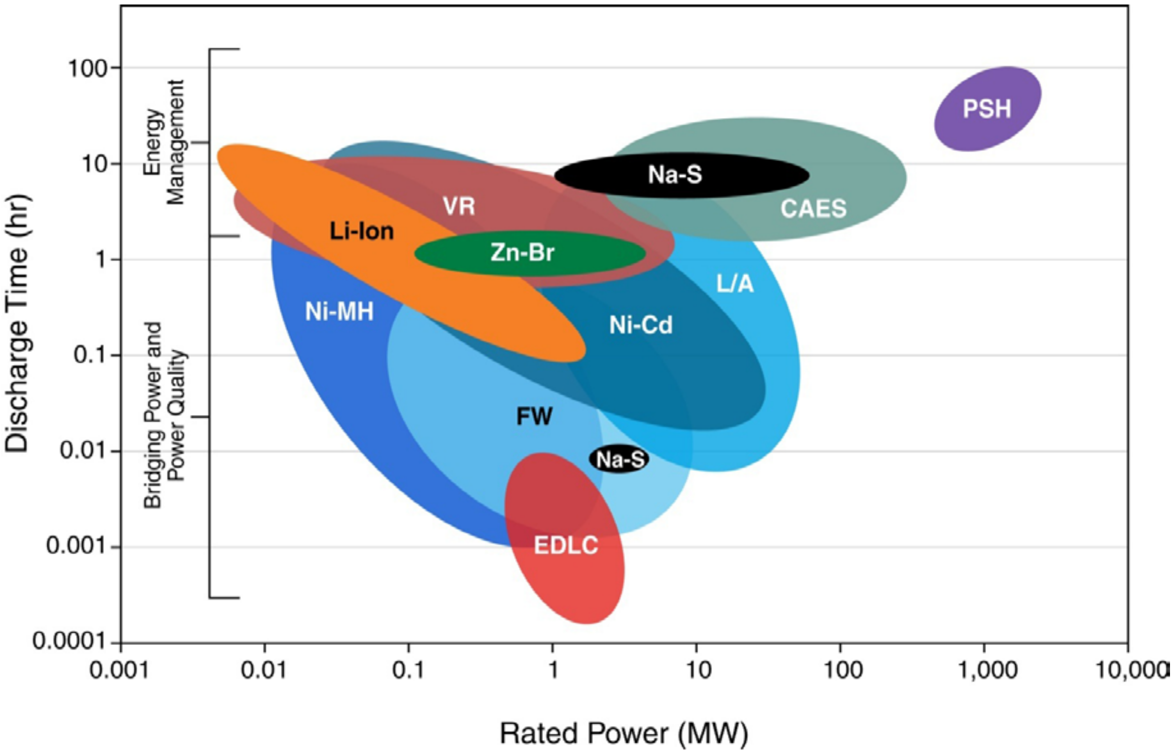


Figure A12. 1: Rated Power vs. Discharge Time of Various Storage Technologies (NREL, 2012)

A12.3 International Experience in Energy Storage

A12.3.1. Technology

Some of the technological developments in energy storage in various countries are:

- Hunfort Power plant is the first utility scale compressed air energy storage power plant, commissioned at the end of 1978 in Hunfort, Germany. The capacity of the plant is 321 MW (upgraded from 290 MW) and utilizes high pressure compressed air stored in salt caverns for the combustion process of a two stage gas turbine (Clean Energy Action Project, 2012)

- MacIntosh Compressed Air Energy Storage Facility is the second utility scale storage facility with a rated capacity of 110 MW and storage capacity of around 26 hours. The MacIntosh unit captures off-peak energy at night, when utility system demand and costs are low (Clean Energy Action Project, 2012)
- Zhangbei National Wind PV Energy Storage Project is commissioned by State Grid Corporation of China and BYD (a large Chinese manufacturer of automobiles and rechargeable batteries) in Hebei Province, China. This project is a wind-solar hybrid project with rated capacity of 140 MW (Wind: 100 MW, Solar: 40 MW) and 36 MW over 4 to 6 hour of Lithium-ion battery energy storage system (Clean Energy Action Project, 2012)
- AES Laurel Mountain Plant is lithium ion battery based energy storage system for a 98 MW wind farm based in West Virginia, USA (Clean Energy Action Project, 2012)
- The Rokkasho-Futamata Wind Farm is the largest and first combined wind generation (51 MW) plus battery energy storage (34 MW) facility in Japan and one of the world's largest Sodium Sulphur (NaS) battery assemblies. (Clean Energy Action Project, 2012)
- The Beacon Power Stephentown Advanced Energy Storage complex is the world's first live connection of a grid-scale flywheel energy storage system for a frequency regulation plant and the largest such advanced energy storage facility currently operating in the U.S. (Clean Energy Action Project, 2012)
- Solana Generating Station Arizona (280 MW) and Crescent Dunes Solar Energy Project Nevada (110 MW) are CSP project commissioned with molten salt based storage system (Clean Energy Action Project, 2012)
- Bath County Pumped Hydro Storage (3,004 MW) Virginia USA, Kannagawa Hydropower Plant (2,820 MW) Japan, Guangdong Pumped Storage Power Station (2400 MW) China are few examples of pumped storage hydro plant.

Some country specific highlights of energy storage are given in Table A12.6

Table A12. 6: International Landscape (US Department of Energy, 2013)

Country	Target	Projects	Technology & Application
Italy	75 MW	51 MW of storage commissioned by 2015. Additional 24 MW funded.	35 MW to be Sodium-Sulphur Batteries for long-duration discharge. Additional capacity is focused on reliability issues and frequency regulation
Japan	30 MW	Approved 30 MW of Lithium-ion battery installations	Primarily Lithium ion batteries. Recently increased regulatory approved storage devices from 31 to 55.
South Korea	154 MW		Reliability & UPS
Germany	USD 260m for grid storage		Hydrogen; CAES & Geological; Frequency Regulation
Canada		Announced first frequency regulation plant	
United Kingdom		6 MW multi-use battery	Battery will perform both load shifting and frequency regulation applications

A12.3.2. Energy Storage Policies in Germany and USA

Table A12. 7: Energy Storage Policies in Germany and USA

Country	Policy
Germany	▪ Implemented mechanisms to encourage energy storage. A €200 (USD261) million budget for storage R&D up to 2014, and new storage facilities are exempt from grid charges and the EEG levy (Cochran, Bird, Heeter, & Arent, 2012) ▪ Demonstration plants in operation that examine the benefits of using excess electricity production to produce hydrogen, and hence synthetic methane gas, which could be fed into (and so stored) in the gas grid (Cochran, Bird, Heeter, & Arent, 2012) ▪ Germany is also considering mechanisms to encourage CHP. One option under consideration would provide an incentive to CHP plant owners for including additional thermal storage. A second proposal would provide grants covering 30% of the costs for additional heat storage, with the goal of increasing CHP power production from around 15% in 2010 to 25% in 2020 (Cochran, Bird, Heeter, & Arent, 2012) ▪ The new energy storage system incentive program promotes the use of energy storage system for PV industry through low interest loan from KfW. From May 1 2013, the purchase of new battery storage for photovoltaic systems will be subsidized up to €660/kW of solar power. Plant operators can apply for financial support for photovoltaic projects that are installed in 2013 having a maximum capacity of 30 kW. (PV Magazine, 2013d)
USA (California)	▪ Under the self-generation incentive program an additional incentive of 20 percent will be provided for the installation of eligible distributed generation or Advanced Energy Storage technologies from a California Supplier. For projects with capacities greater than 1 MW, the first 1 MW receives 100% of the incentive rate; 1MW to 2 MW receives 50% of the incentive rate, 2 MW to 3 MW receives 25% of the incentive rate (DSIRE USA, 2013a) ▪ The California Public Utilities Commission (CPUC) set a target for California investor owned utilities to procure 1.325 GW of cost effective energy storage by 2020. (Energy Storage, 2013)
USA (New York)	▪ Under existing facilities program, an incentive of USD 300/kW (upstate) and USD 600/kW (downstate) is available for energy storage system in the building (DSIRE USA, 2013b) ▪ Creation of the New York Battery and Energy Storage Technology (NY-BEST™) Consortium. (NY BEST, 2010)

A12.4 Energy Storage in India

India is pursuing development in the field of energy storage to support its increasing energy needs. Recently, the telecom arm of Reliance Industries in India (Reliance Jio Infocomm) placed an order worth INR 273 crore to purchase Li-ion batteries for telecom towers (Times of India , 2013). This is one of the examples that demonstrate India’s potential as a market for energy storage technologies. Some of the other developments in the field of storage technologies in India are:

- Under the scheme of Alternative fuels for surface transportation program, MNRE provided a total of INR 95 crore of demand incentive to OEM during 2010 to 2012 (Department of Heavy Industry , 2012)
- Delhi Government provides a 15% subsidy on the base price, exemption of VAT and reduction of road tax and registration charges for electric vehicle (Department of Heavy Industry , 2012)

- Government of India has launched the National Electric Mobility Mission that has projection of 6-7 million of new set of electric vehicle sales and 2.2 to 2.5 million tons of liquid fuel saving can be achieved in 2020 (PIB, 2013c)
- Department of Telecom had also mandated the telecom service providers to adopt renewable energy technology in place of diesel energy generator (TRAI, 2013)
- **India Energy Storage Alliance:** The India Energy Storage Alliance (IESA) was launched in 2012 to promote Electric Energy Storage (EES) technologies and applications by creating awareness among various stakeholders to make the Indian industry and power sector more competitive and efficient (India Energy Storage Alliance, 2014). The major activity of IESA is to conduct market study for identification of opportunities and barriers for EES technology, provide insight on regulatory and polices to the stakeholder, organize conferences and seminars, interact with industrial trade organization and evaluate current financial mechanisms for EES technology.

Annexure 13: Offshore Technology: Balance of Plant for the Offshore Wind Turbine

Balance of plant is a more crucial aspect for an offshore wind turbine in comparison to an onshore wind turbine. Balance of plant for offshore wind turbine consists of the following main components: foundations, electrical infrastructure, vessels, and ports.

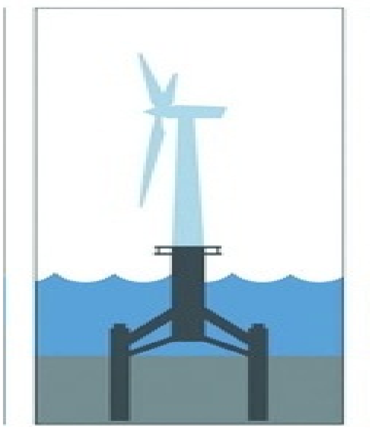
Foundation

Various types of foundations/substructures are deployed depending on water depth and commercial viability. A brief description of various types of substructures used in offshore wind is given in Table A13.1.

Table A13. 1: Types of Substructure used in Offshore Wind (LORC Knowledge, 2013 and EWEA, 2009)

Substructure		**Distance from shore**	**Dimensions and weight**[89]	**Examples**
Monopile • Made from steel tube, typically 4–6 m in diameter • Installed using driving/drilling method • Transition piece grouted on top of pile • Most commonly used substructure		1–30 kms	Diameter: 4–6m Depth: 10–30 m Weight: 250 – 700 tonnes	Utgrunden (SE), Blyth (UK), Horns Rev (DK) North Hoyle (UK), Scroby Sands (UK), Arklow (IE) Ireland, Barrow (UK), Kentish Flats (UK), OWEZ (NL), Princess Amalia (NL)
Jacket • Made from steel tubes welded together, typically 0.5–1.5m in diameter • Anchored by driven or drilled piles, typically 0.8–2.5m in diameter		25–45 kms	Diameter: 0.5–1.5 m per leg Depth :30–60 m Weight : 500–828 tonnes	Beatrice (UK), Alpha Ventus (DE)

[89] For a representative of 2.3 – 3.6 MW turbine size; 80 % of installed offshore turbines are in this range (WISE Analysis). The range of values in the table represents an average range; actual values may differ.

Substructure		**Distance from shore**	**Dimensions and weight[89]**	**Examples**
Tripod • Made from steel tubes welded together, typically 1–5m in diameter • Transition piece incorporated onto centre column • Anchored by driven or drilled piles, typically 0.8–2.5 m in diameter		45–80 kms	Diameter: 1–5 m per leg Depth: 20–50 m Weight: 700–750 tonnes	Alpha Ventus (DE)
Gravity base • Made from steel or concrete • Relies on weight of the structure to resist overturning, extra weight can be added in the form of ballast in the base • Seabed may need some careful preparation • Susceptible to scour and undermining due to size		1–25 kms	Diameter: 11–23 m Depth :10–20 m Weight: 1300–3000 tonnes	Vindeby (DK), Tuno Knob (DK), Lilgrund (SE), Thornton Bank (BE)

Vessels

Offshore wind sector has adopted some vessels from the oil and gas sector and uses vessels from civil marine sectors. The installation of offshore wind turbines has fostered the creation of specialized jack-up vessels to ensure the turbines can be quickly and efficiently installed. Three factors currently drive the current development of turbine installation vessels (TIV) (EWEA, 2009):

- wind turbine size; larger turbines imply larger ships
- water depth; the deeper the water, the more expensive and larger a turbine installation ship needs to be
- distance from shore; the farther a site from the supply harbour (and the larger the capacity of the turbines), the higher the transport costs to site
- optimization of installation in a given weather window

The types of vessels typically required for offshore wind installation are listed in Table A13.2.

Table A13. 2: Vessel Types used in Offshore Wind Installations

Vessel type	Use
Survey vessel	▪ To survey the sea floor in preparation for setting up an offshore wind farm ▪ Smaller survey vessels are used to perform environment impact assessment studies and post-evaluation.
Turbine installation vessel (TIV)	▪ Custom-built self-propelled installation vessels that can carry multiple turbines at a time.
Construction support vessel	▪ To assist in the construction of offshore wind parks. Includes motorized and non-motorized jack-up barges, barges, pontoons, and platforms.
Work boats	▪ Support the work of other vessels by providing supplies of tools and consumables to other boats.
Service vessel	▪ Used for scheduled maintenance work
Crew transfer vessel	▪ Carrying crew for small tasks , quick to build

The current technology trend will favour large-scale vessels able to carry multiple pre-assembled wind turbines. Turbine installation vessels have the advantage of being custom built, fast-moving, self-propelled, multi-turbine vessels that can fully exploit the available weather windows. A good example of TIV is the Wartsila HPTIV (Figure A13.1) which can be used in waters 4.5–50 m deep and has a mobile crane onboard (Wartsila, HPTIV Brochure).

Figure A13.1: Wartsila high performance turbine installation vessel

The European market has moved from adapting vessels for oil and gas to these dedicated vessels for offshore wind. Other parts of the world are likely to gradually follow suit in the future. As the industry grows and matures, the development of assembly-line style vessel coordination – where one vessel installs the foundation and is followed by a series of vessels installing the tower, nacelle, and blades – is also a possibility. Floating foundations in the future will likely require simpler vessel designs; turbines could be fully assembled on land and then simply towed with traditional or modestly modified tugs (Navigant Consulting , 2013).

Electrical Infrastructure

There are two types of transmission systems, namely High Voltage Alternating Current (HVAC) and Hgh Voltage Direct Current (HVDC). HVAC systems are the most commonly used systems for onshore transmission whereas HVDC systems are preferred for transmission under sea: HVAC systems have higher reactive losses, which renders them ineffective for long-distance transmission. The major advantage of HVDC systems are very low losses and higher power carrying capacity. The basic differences between these two systems are shown in Table A13.3. (Sven Tseke, 2005).

Table A13. 3: Comparison of HVAC and HVDC Systems

System	HVAC	HVDC
Voltage form of transport system	Three phase alternating voltage	Direct voltage, two pole
Voltage range	Up to extra high voltage (<420kV)	Up to extra high voltage (<800kV)
Required cable	Either three single cables or one three conductor cable	Two single cables or one two conductor cable

Required station at sea	Transformer from medium to extra high voltage (eg: 30kV to 400kV)	Convertor from medium AC voltage to extra high DC voltage (eg: 30kV AC to 400kV DC)
Required station on Land	Transformer from extra high voltage to main land grid voltage(eg: 400kV to 380kV)	Convertor from extra high DC voltage to main land AC grid voltage (eg: 400kV DC to 380kV AC)

HVDC systems are preferred to HVAC because of the following reasons.

- Transmission losses are low even over long distances. In addition, it is not feasible to use HVAC systems for longer distances (~120kms).
- Power is fully controlled and faults are not transferred.
- It is possible to connect non-synchronized systems. It can also provide more stabilized power to the grid.
- Magnetic fields from HVDC lines are negligible.

The only downside of HVDC systems is the cost of convertors required at the site and at the onshore substations. The breakeven distance in terms of cost for HVDC systems is 60–70 km (R Krishnappa, 2013).

With increasing distances from shore; cabling, substations and convertor stations are expected to undergo technological advances that can reduce costs. Increasing volumes should lead to industry standardization, which will lead to lower costs and higher efficiency. Innovations in HVDC technology and conversion are also expected to allow for modular deployment of HVDC technology. Modular substations could lower down the labour intensity of building and installing offshore substations. High-voltage cabling and larger turbines will allow for project layouts that minimize array cabling needs (Navigant Consulting , 2013).

Ports

Having a number of specially adapted ports is critical for supplying the offshore market. These facilities should possess deep-water and reinforced quaysides to take the large weights of turbines, and large storage areas with low premium and suitable space to move foundations and cranes. Most of the offshore assembly is done on land, so ports must have adequate facilities to address this requirement. Ports and harbours should be able to fulfil the following requirements (EWEA, 2009):

- an area of storage of 6 to 25 hectares (60,000 to 250,000 m^2)
- a private dedicated road between storage and quayside
- quay length, 150–250 m
- a seabed with sufficient bearing capacity near the pier
- draft of minimum 6 m
- warehouse facilities of 1,000 –1,500 m^2
- access for smaller vessels (pontoon bridge, barge etc.)
- access for heavy or oversize trucks
- potential license or approvals for helicopter transfer
- availability for the project installation.

Concerning operation and maintenance, the specific requirements include

- full-time access for service vessels and service helicopters
- water, electricity and fuelling facilities
- safe access for technicians,
- loading and unloading facilities.

Annexure 14: List of Organizations Contacted During the Study

Organizations Interviewed Collectively By WISE and CSTEP

Organization	Duration
Ministry of New and Renewable Energy, GoI	Q4 of project
Department of Electronics and Information Technology, GoI	
National Manufacturing Competitiveness Council, Dept of Industrial Policy and Promotion	
Directorate General of Anti Dumping, Dept of Commerce	
Directorate General of Foreign Trade, Dept of Commerce	
Indian Electronics and Semiconductor Association, New Delhi	

Field Visits & Interactions by WISE

Organization	Duration
Suzlon Energy Ltd	Q4 of project
Hero Future Energies	
Customized Energy Solutions	
Gamesa Wind Turbines Pvt. Ltd.	Q3 of project
ReGen Powertech Pvt. Ltd.	
Windar Renewable	
Kenersys	
Suzlon Energy Ltd	
SE blades ltd.	
Bharat Light Power	
Aruna Group	
Inox Wind	
Leitwind Shriram	
C-WET	
Global Wind Energy Council (GWEC)	
DEIF India Pvt. Ltd.	Q2 of project
Windward Technology Pvt. Ltd.	
Suzlon Energy Ltd	
Panama Wind Energy Pvt. Ltd.	
WinWinD	

Field Visits & Interactions by CSTEP

Organization	Duration
IACS	Q4 of project
NPL, CSIR, Delhi	
Lanxess	
Sun Power Solar	
Welspun Solar	
Bonfiglioli India	
Jupiter Solar	
Allied Glass	
Gujarat Borosil	
Lucent Technologies	
Brij Footcare	
Polycom Associates	
RenewSys	Q3 of project
NAL	
Exide	
GE	
Tata Power Solar System	
TUV	
BHEL	
Photonix Solar	Q2 of project
Delta	
Fairdeal Corporate Sales and Services	
Process Pumps Pvt Ltd	
Renen Power Technologies Pvt. Ltd	
EMMVEE Solar	
Areva	
Juwi India Renewable Energies Pvt. Ltd	
Glasstech	
Moser Baer Solar Limited	
Cargo Power & Infrastructure Ltd.	
Acira Solar	
Luminous Power Technologies	
MNRE	
Maharishi Solar	
Lanco Solar	

Asahi India Glass Limited	
Flowserve	
SCHOTT Glass India Private Limited	
3M	Q1 of project
HHV Solar	
Consun Energy	
Maxwatt	
MROTEK	

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