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gef

Ministry of New and Renewable Energy
Government of India

Solar Energy Quality Infrastructure in India

United Nations Industrial Development Organization

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Executive Summary

This report is about the quality of infrastructure (QI) used in renewable energy installations, pertaining specifically to Solar PV and Solar Thermal. The study is first of its kind in India about the quality improvement of the processes and components involved in a project installation at different levels in the Indian renewable energy market along its entire value chain including manufacturing, logistics, testing, certification, execution of the projects and Operation & Maintenance.

This is a novel study and the report explains the essential concepts, along with the benefits of developing and implementing QI, and provides guidance on how to incrementally develop QI in support of national renewable energy technology markets. This report focusses primarily on Solar PV and Solar Thermal among all the renewable energy technologies, analyses the gaps and challenges and offers recommendations for developing Quality Infrastructure for both these technologies in order to improve the effectiveness and efficiency of the installed systems.

Quality assurance is a pre-requisite in order to ensure swift acceptance of renewable energy technologies. Renewable sector is still in its nascent stages considering its vast potential and hence requires quality assurance across the entire value chain to prevent installation of unsafe, underperforming and failure-prone products and in turn ensure effective maintenance of the projects. Quality assurance of standards is must in order to ensure that products are efficient and perform as expected. Quality assurance provides credibility to new and developing technologies and act as instrument of verification for optimal performance of such emerging technologies. The establishment of Quality Assurance framework requires an institutional infrastructure.

Quality Infrastructure refers to a system comprising of initiatives, organizations, activities and people who collectively contribute to governmental policy objectives, implement quality standards and ensure the compliance of these standards. This report encompasses the current status, established targets, existing standards, testing, certifications and quality management systems required for Solar Thermal and Solar PV technologies.

In this report, we have covered the Renewable Energy overview of the country along with its value chain including the investments made in sector as well as the potential of investments to be made by FY 2022. A linear decline has been observed in the investments owing to the lower dollar-denominated costs and timing of the projects. A lot of projects in wind and solar which were financed in late 2015, only got commissioned in 2016. The ambitious target of 175 GW installations in RE sector can only be achieved with the combination of funding from commercial banks, NBFCs as well as from multilaterals and bilateral funding agencies.

We have then narrowed down the sector to Solar Thermal and Solar PV, discussed the manufacturing landscape of Solar PV and Solar Thermal in the country and the challenges faced by them, the imports of solar modules and PV cells since the current manufacturing capacity in India is unable to accommodate the pace of installations along with their quarterly price trends. The plummeting PV tariffs in the country as new lows have been achieved driven by the aggressive in reverse auctions and the factors behind such low PV tariffs from developers' perspective majorly the government policies, high energy yield, leveraging debt equity and grid integration among other factors.

The overview of Solar Thermal and growth in the country is then discussed in contrast with the developed and developing economies of the world. Solar Thermal market is still in its nascent stages but flourishing at a rapid pace in orientation with the ambitious target of 20 million square meter of collector area by FY 2022. Currently, India just account for 1.4% of the total with 323.8 GW_{th} Solar Thermal technologies installed in the world. The major concern in Solar energy is harnessed at a much larger scale to generate electricity in the country but processing heat for industrial procedures through CST applications still accounts for less than 1% of global solar thermal capacity. Further, we have shifted our complete focus on Solar Thermal (heating and cooling), their working principles, comparative analysis of different solar thermal technologies such as Imaging, Non-Imaging, Line focus and Point focus, its cost components, the suitability of the type of

technology based on the temperatures, its industrial applications along with the current status and expected growth in this technology.

Moving on towards major area of focus i.e. Quality Infrastructure in Solar PV and Solar Thermal, it requires development of testing laboratories and certification bodies, along with supporting organizations for accreditation, inspection, installer training and standards development. With regard to certification of equipment, design qualification is based on type testing according to IEC, EN or other national standards. The importance of quality and its applications begin from the raw material procurement and extends up to the consumer applications. Quality assurance needs to be maintained in all the phases of the project execution including manufacturing, development and operations & maintenance. We have further stated the standards, currently specified by BIS and the methodology to identify the gaps in QI and REQI framework for its improvement.

A Standard is a technical specification designed to be used regularly as a rule, guideline, or a definition. We have discussed about the relevant minimum technical requirements, quality standards and specifications for Grid-connected Rooftop Solar PV Systems component wise and the infrastructure requirement for Renewable Energy quality testing. Certification and Testing are other major tools of Quality Assurance and are necessary to ensure efficiency and improve the power plant performance. Certification against standards is observed through a verification and auditing process based on benchmarking against criteria and scheme documents. Thus, it becomes imperative to benchmark the quality of installed components with our internally developed metrics and the audit experience. The auditing procedure provides an overview of the performance of the system and helps in minimizing the losses.

The report also focusses on the regulatory guidelines and the technical requirements for Grid connected ground mounted and rooftop PV plants (including all the components, sub-system, performance monitoring and even the disposal of exhausted plants). Theoretically, all the quality assured technical requirements are mentioned for all the equipment of a solar plant such that the efficiency can be maximized and the overall performance of the plant can be optimally improved.

The report also analyses the status of solar PV and thermal domestic manufacturing value chain and their component wise pros and cons pertaining to raw material availability, capacity to manufacture, incentives and investments, bottlenecks to scale and trade and an assessment of indigenous component costs and their global positioning in terms of competence and reliability.

The report encompasses the Solar Thermal value chain analysis covering raw material suppliers, component manufacturer, solar thermal developers and the end user. As solar thermal technologies become more acceptable, the need to implement and further develop product and performance standards for solar thermal has increased. Certification and quality assurance contribute to a successful usage of solar water heating and subsequently increase consumer confidence in the technology. Currently there are eight regional centers for testing of flat plate water heating systems, evacuated tube collectors, box and dish type solar cookers and apart from that there are two regional test centers for testing concentrated technology. These are further discussed in detail in the respective sections of the report. Then there is a need of off-site and on-site testing facility to evaluate the impact of different parameters on thermal output of the CSTs under quasi-stable state.

Regarding the testing and certification of CST, there are no particular standards but under UNDP-GEF project both mobile and immobile labs have been established and are helping manufacturers and new entrepreneurs in improving quality of their products and getting certification for participation in Ministry programme. This is expected to provide an immense push to the CST programme in the country.

The report concludes with the Gap Analysis and the key findings for improvement in the Quality Infrastructure for both the Solar PV and Solar Thermal. The requirement to improve the quality of the infrastructure installed and rectify it to improve the efficiency and performance ratio of the plants makes it absolutely imperative to identify the gaps and suggest the means to bridge these gaps. To be certain of the performance of the equipment installed, they must have suitable IS or IEC standards (as applicable) obtained from the designated bodies.

We have tried to narrow down the recommendations specifically to CST since it is literally in its embryonic stages of installations in the country and with an ambitious target (20 million square meter of collector area) to be achieved by 2022, it requires primary focus and customized solutions for the customers. Processing heat for industrial procedures through CST applications still accounts for less than 1% of global solar thermal capacity but have a huge potential in replacing fossil fuels consumption.

1. Renewable Energy in India

1.1. Introduction to Renewable Energy in India

India is on the cusp of transition from conventional energy to clean, sustainable and affordable form of energy. Renewable energy being the important component of India's energy infrastructure planning and the adoption of renewable energy in India at grid scale started in early 2000. New age technologies in renewable energy have seen rapid expansion in different segments of energy sector viz. power generation, heating and cooling, transport and rural and off-grid energy usage applications.

India's energy usage has been rapidly increasing as a result of economic growth in the last decade; however India still has one of the lowest per capita consumptions of energy and electricity in the world and majority doesn't receive round the clock uninterrupted power supply. As of July 2018, India's power sector stands at a total capacity of 345.5 GW[1] with Coal-fired plants accounting for the lion's share of 197 GW of this installed capacity, followed by renewables that come in at over 70.6 GW. Hydropower projects, gas-based, nuclear and diesel projects make up the remaining capacity in decreasing order of installed capacity.

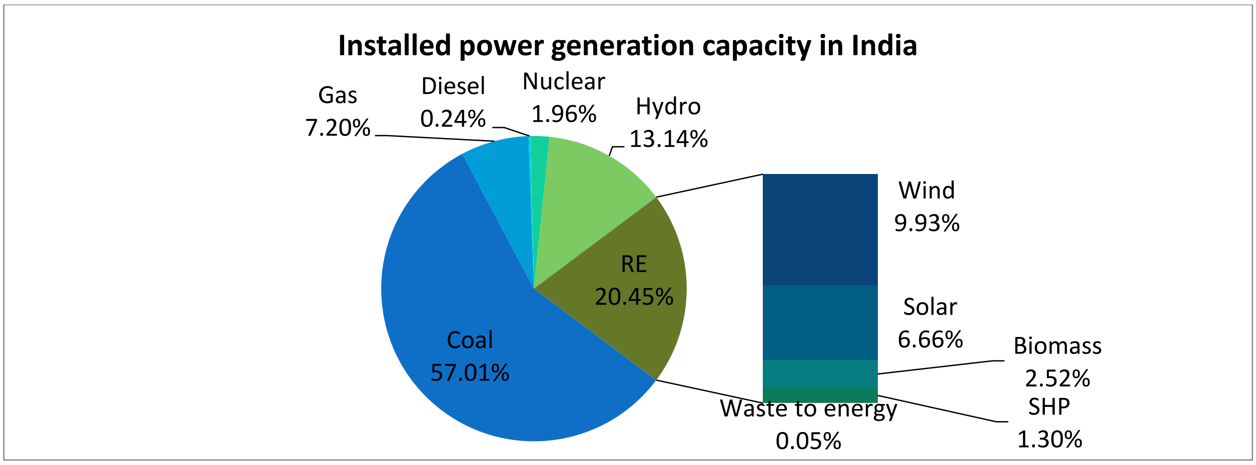


Figure 1: Installed power generation capacity in India, Source: CEA

India has made fast strides in Renewable Energy deployment with the installed capacity increasing from 3.5 GW in 2002 to approximately 70.6 GW[2] (excluding large hydro[3]) in July 2018. The government has formulated various policies at the state as well as national levels to foster investments in the sector. Private sector investments, primarily driven by government incentives such as fiscal incentives, direct and indirect tax benefits, depreciation allowances and 100% FDI allowance have been the major drivers of the renewable sector in India. The growth of renewable energy over the years has been depicted in the figure 2:

Though wind energy has predominantly been the largest contributor of installed RE capacity, with its contribution a little below 50%, the share of solar has increased considerably from almost 1% to 30% during the last 5 years. In an attempt to increase the percentage of renewables in the electricity mix of India, the nation has currently established a target for the implementation of 175 GW renewable energy by 2022. This target includes 100 GW solar energy, 60 GW wind, 10 GW

[1] http://www.cea.nic.in/reports/monthly/installedcapacity/2018/installed_capacity-07.pdf
[2] http://www.cea.nic.in/reports/monthly/installedcapacity/2018/installed_capacity-07.pdf
[3] Indian Government may include large hydro power projects under the scope of renewable energy. At present, only hydro power projects with a maximum capacity of 25 MW are considered renewable. As on 31st march 2017, large hydro installed capacity was 44.47 GW which was 13.91% of total installed capacity in India.

biomass and 5 GW small hydropower projects. Technology-wise installed capacity, potential available and deployment targets are shown below:

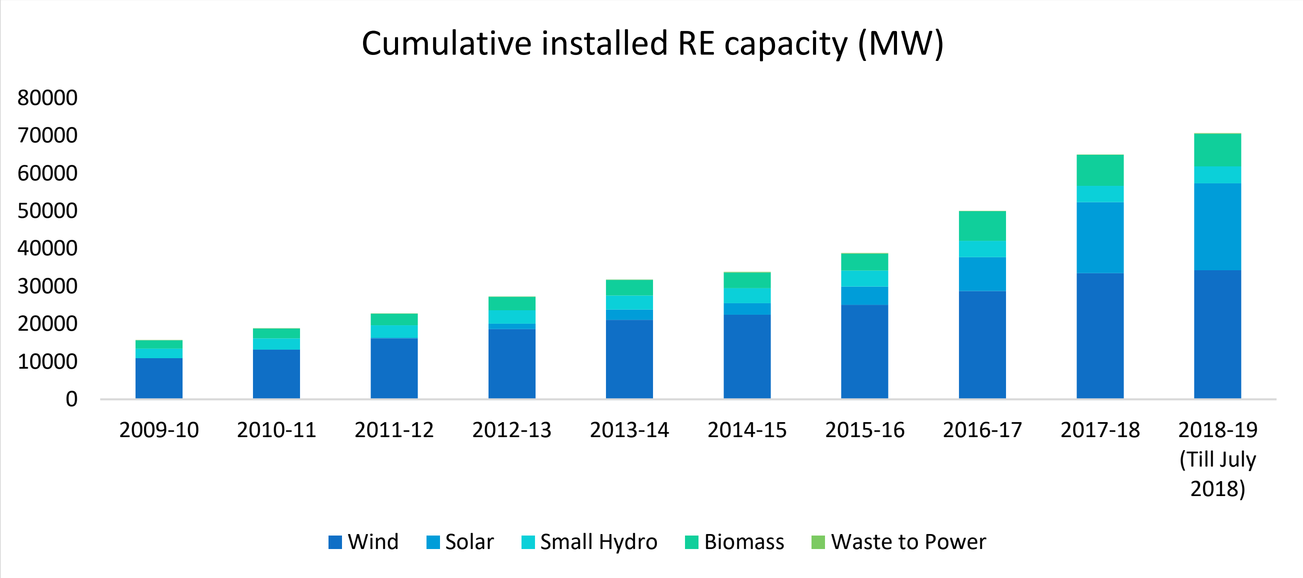


Figure 2: Source wise renewable capacity (FY 10-18), Source: CEA

Table 1: Renewable Energy Potential in India

Technology	Installed Capacity (July' 2018) (GW)	Potential available (GW)	Deployment target (GW)
Solar	23.0	748.99	100
Wind	34.3	102.77	60
Bio-Power	8.7	25.09	10
Small Hydro	4.5	19.75	5
Total	**70.6**	**896.60**	**175**

Electricity demand in the country is increasing at rapidly and expected to grow in the near future. UN Environment Program's (UNEP) 'Global Trends in Renewable Energy Investment 2016' report ranks India among the top 10 countries in the world investing in renewable energy. India has attracted FDI[4] of $ 5181 million in non-conventional energy segment from April 2000 to March 2017, 100 percent FDI is allowed for the renewable power generation projects and furthermore distributed subject to provisions of the Electricity Act, 2003.

As per the 3rd National electricity plan, the draft of which was released by CEA Electric Power Survey report released by CEA, India's installed capacity of generation in 2022 will be 523 GW and will increase to 640 GW by 2027. This assumes that India will achieve 175 GW of installed renewable capacity by March 2022 and subsequently 100 GW of renewable capacity will be added by March 2027. The entire growth curve for this is depicted in figure 3, which also signifies the split of fossil vs non-fossil based resources.

[4] http://www.dipp.nic.in/sites/default/files/FDI_FactSheet_January_March2017.pdf

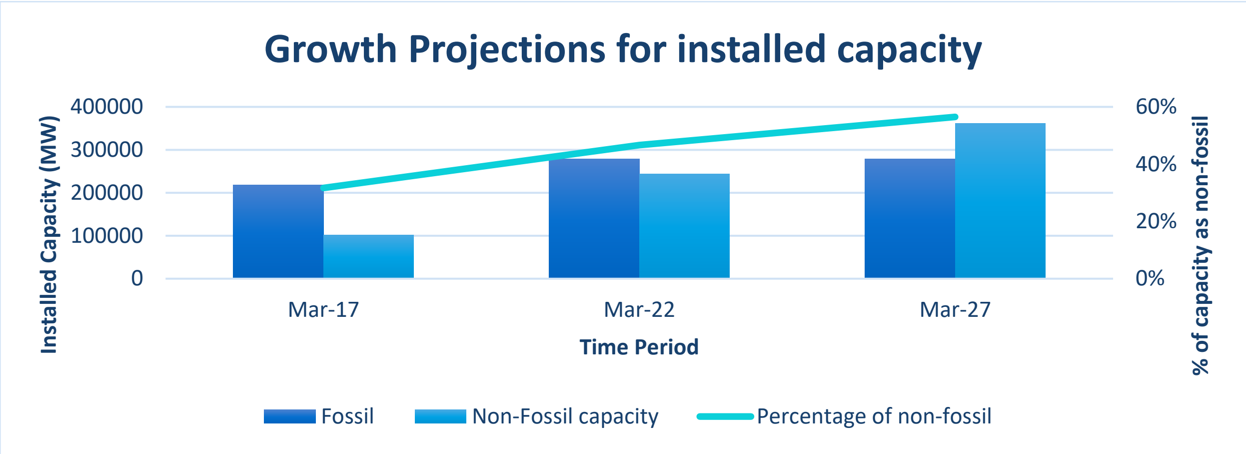


Figure 3: Growth Projections for installed capacity

With India looking to boost the share of clean energy mix to 40% by 2030, global business are strategizing to capture a slice of the market and to reap the benefits. The country's ambitious plan of 175 GW of renewable power installations by 2022 with a strong commitment to cut carbon emissions by 35% by 2030 over 2005 levels offers global players in renewable energy technologies and other equipment manufacturers a major business opportunity. The need of the hour for India to adopt large scale renewable energy adoption depends on overcoming not only technical and regulatory challenges but also implementing quality in renewable energy infrastructure.

1.2. Renewable Energy Value Chain in India

Renewable energy has grown explosively in India, which has opened up various opportunities for various business from manufacturing to servicing in various parts of the value chain from raw materials to products manufacturing and system integration. The major market segment in renewable energy in India is occupied by solar PV, Solar thermal, Wind, Hydro and Bio-power and the array of services and products pertaining to these energy resources. Many emerging and existing players wants to tap these opportunities and reap the benefits of growing renewable energy market.

The key elements of renewable energy value chain framework includes of generation resources and their products along with the raw material used to manufacture, research and development, Engineering, Equipment Manufacturing and processes, EPC contractors, Operation and Maintenance, Multi-stake holder engagements, Electrical Utilities and Testing and Quality assurance.

In India solar energy is generated from Solar PV modules and Solar Thermal products and have off grid and on- grid interactive systems. The country also explored the options of solar PV parks at GW scale and MW scale in solar PV rooftop segment. In solar thermal technologies, the primary application being used is for domestic and industrial heating using the solar flat plate collector and concentrated solar using parabolic trough technologies.

The country has untapped wind sites and have installed wind turbines in wind rich states like Tamil Nadu, Gujrat and Maharashtra. India has off shore and on shore policy to set up wind power parks to utilize both the technologies. India has around 7,600 km of coastline with the potential for offshore wind power development. Wind turbines are available in different technologies like synchronous machines, double fed induction generators, and DC generators equipped with yaw and pitch control.

India has an estimated potential of 19.75 GW of small hydro projects. Most of the potential is in the Himalayan region as river based projects and other states as irrigation canals. Setting up of SHP projects comes under the purview of state governments. Potential sites are either developed by the state or allotted to private developers for setting up of projects. Typical run-off-river hydro plants are equipped with water storage, penstock and turbines to generate power.

This report focuses on solar PV and Solar thermal technologies and their products and components, the image below depicts the value chain steps in renewable energy infrastructure.

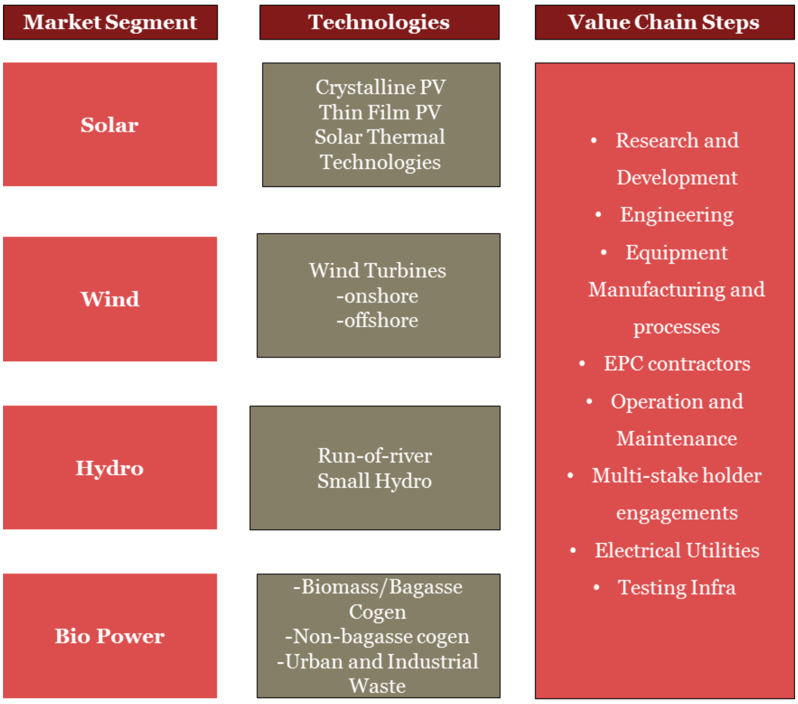


Figure 4: Value chain in Renewable Energy Technologies

1.3. RE investments

Solar tariffs are constantly falling (with the lowest-ever solar tariff of INR 2.44/unit being achieved recently) in the country however the investments in the sector cease to decline and it is expected that around $7.4 trillion will be infused towards the installation of new renewable energy plants by 2040 in India alone – which accounts for 72% of the total $10.2 trillion that is projected to be spent on new power generation worldwide. Investment in India's renewable industry increased by

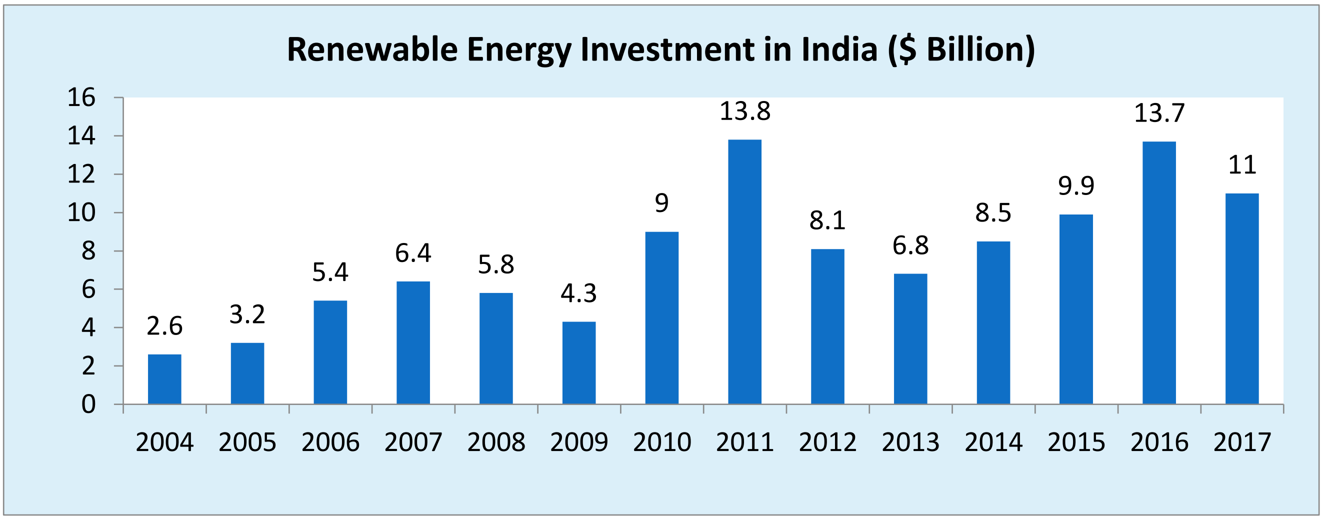


Figure 5: Renewable Energy Investment in India ($ Billion), Source: BNEF

a whopping 38% in 2016 compared to the previous year but it declined by almost 20% in 2017 to reach $11 bn[5] when compared to 2016.

Investments in almost all the geographies including US, Middle East Asia & South America saw a decline but stood constant in Europe and India. The renewable energy investment continued to be dominated by just two sectors – solar and wind. However, both these sectors suffered a marginal increment in net investment in 2016 as compared to 2015.

Solar installations constitute $2.8 trillion of the total investments in the renewable energy sector and is expected to see a jump of almost fourteen times in the installed capacity by 2040. The levelized cost of electricity from solar PV, which is now almost a quarter of what it was just in 2009, is set to drop by another 66% by 2040. The levelized cost of electricity from solar PV will become cheaper than coal in India along with the international economies such as China, Mexico, United Kingdom and Brazil by 2021. But if we count the price of solar power and storage together, it is far higher than thermal (coal) power, so it still requires investments and time when the actual cost of solar generation will fall below or will be at par with thermal (coal) power.

Globally, the investments in Renewable Energy sector exhibited a sharp decline of almost 13% and went down to $272 billion[6] in 2016 from $312 billion, a record set in the previous year. This can be attributed to several reasons one of the most important of which was lower dollar-denominated costs and timing of the projects. A lot of projects in wind and solar which were financed in late 2015, only got commissioned in 2016, in which case the investment associated with them were recorded in the earlier year and the capacity addition in the latter year.

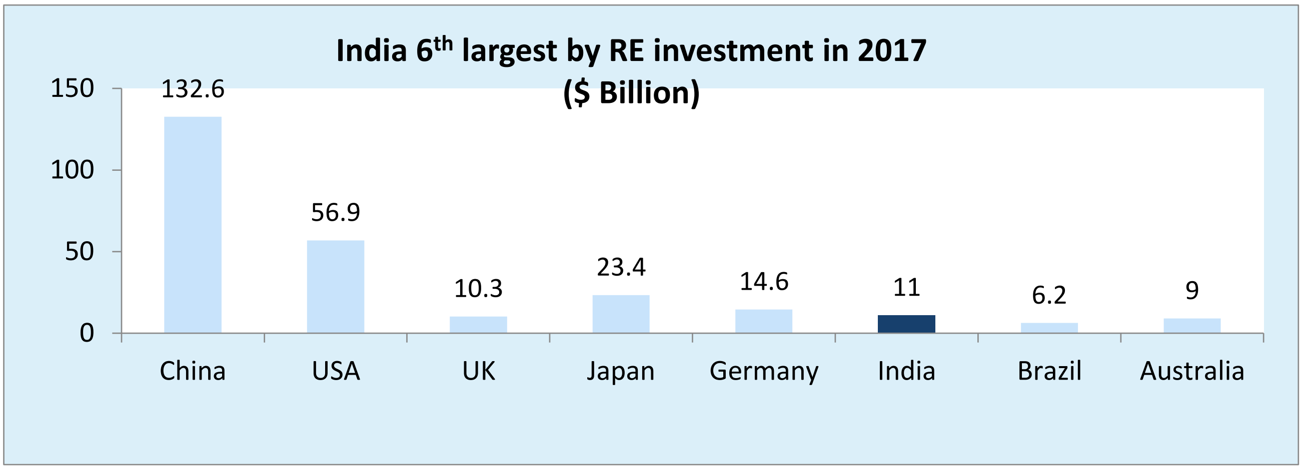


Figure 6: Global RE Investments, Source: BNEF

The investments marginally rose to $274 billion[7] in 2017, which were almost at par with the 2016 figures.

There were lower dollar-denominated costs in 2016 as compared to 2015.

The average capital cost for PV projects starting construction in 2016 was 13% lower than in 2015.

A lot of projects in wind and solar that were financed in late 2015, only got commissioned in 2016

Chinese and Japanese solar markets decelerated sharply in 2016

There is another issue due to which an underlying slowdown did set in, in some key markets, during the course of 2016. In particular, the Chinese solar market decelerated sharply, after a hectic first half that saw 22 GW solar installations compared to a second half in which only 8 GW of solar was installed. Japanese solar market also slowed down from 11.5 GW installations in 2015 to 9.2 GW in 2016.

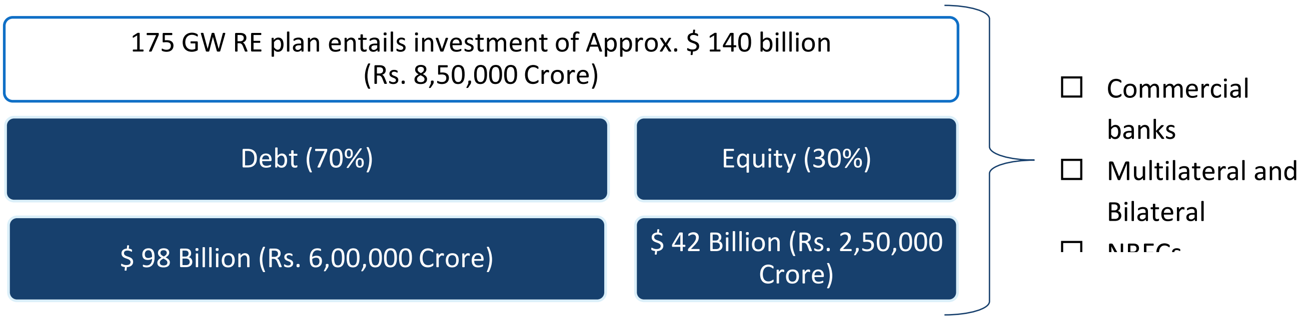
[5] https://data.bloomberglp.com/bnef/sites/14/2018/07/BNEF-Clean-Energy-Investment-Trends-1H-2018.pdf
[6] https://data.bloomberglp.com/bnef/sites/14/2018/04/Clean-Energy-Investment-Trends-1Q-2018.pdf
[7] https://data.bloomberglp.com/bnef/sites/14/2018/04/Clean-Energy-Investment-Trends-1Q-2018.pdf

However, the Renewable energy market in India defied this global trend of slowdown and continued to rise. India witnessed a marginal growth of approximately 1.5% in investments in 2016 compared to the previous year. India stood sixth in terms of amount invested in the RE sector globally in 2016 and the total investments amounted to about $9.7 billion.

Almost all the funding in the Renewable sector in India came through Asset financing. This trend of steady growth in India can be attributed to the government's commitment towards installations of 175 GW in renewable energy generation by 2022 and have renewable energy account for 40% of installed capacity by 2040.

India was ranked third on last year's renewable energy country attractiveness index (RECAI) only behind the US and China. This year, India has moved up to second position owing to the combination of strong government support and increasingly attractive economics in the sector.

To achieve the 175 GW target, an investment of approximately $140 billion is required in the sector that can only be achieved with the combination of financing from commercial banks, NBFCs as well as from multilaterals and bilateral funding agencies.



Projected Investments in RE sector in India

India needs an investment in the range of approximately $ 0.14 trillion in Renewable Energy sector in order to realize the ambitious target of 175 GW by 2022. The graph below depicts the projected annual investments required in the sector till 2022 covering all the technologies of Renewable sector including Small Hydro, Biomass, Wind and Solar.

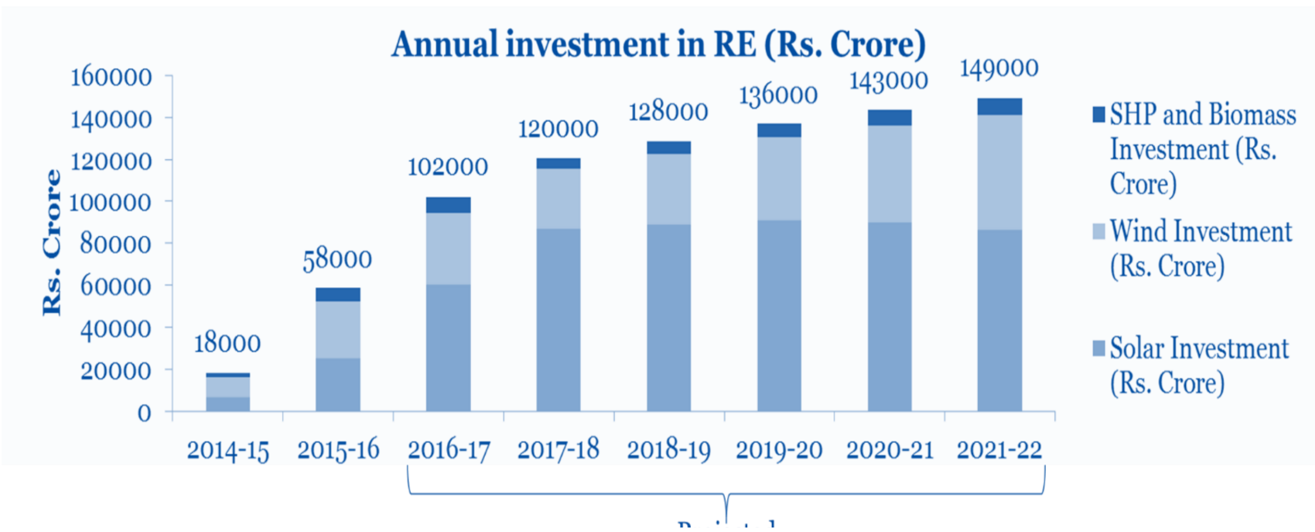


Figure 7: Projected investments

Instead of all these developments, the image of the sector is not all that impressive and there are still challenges in the sector that needs to be addressed in order to maintain the growth, instill investments and achieve the established targets. The availability of capital still remains a concern which can be tackled easily with the help of the government. It can ease rules around tapping of foreign debt which will definitely help in boosting the investments along with addressing other major challenge, including land acquisition. These ratifications will certainly go a long way in meeting the 175 GW target.

2. Solar Energy in India

India is endowed with good solar insolation receiving almost 300 sunny days in a year, the calculated solar energy incidence on India's land area is about 5000 trillion kilo-watt hours per year and there is lot of untapped potential of solar energy in India. The government of India took the initiatives to adopt large scale solar PV capacities as part of their national solar mission. In January 2015 the Indian government expanded its solar plans, targeting US$100 billion in investment and 100 GW of solar capacity (including 40 GW from rooftop solar) by 2022.

The Jawaharlal Nehru National Solar Mission (JNNSM) was launched in 2010 after which the Indian Solar PV segment has seen significant growth. Grid connected solar PV plants consists of ground mounted, rooftop and solar PV powered micro grids. With the provision of conducive policy environment and appropriate subsidies and financing arrangements, the total installed capacity rose from 10 MW in 2010 to 23GW[8] as on July 2018. As a part of the ambitious targets, the government has invited private companies to invest under 100 percent FDI routes in solar energy which led to one of the fast growing industry in India. The year wise capacity additions are depicted in the figure below:

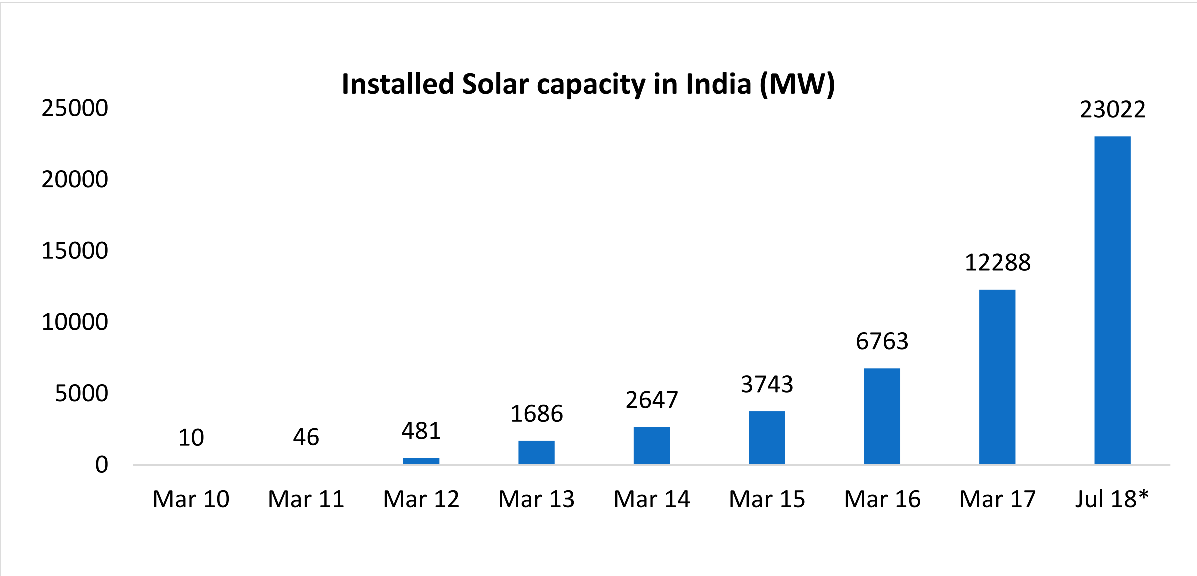


Figure 8: Installed solar capacity in India (MW)

To meet the ambitious target of 100 GW by 2022, the year wise cumulative targets are depicted in the figure below.

[8] http://www.cea.nic.in/reports/monthly/installedcapacity/2018/installed_capacity-07.pdf

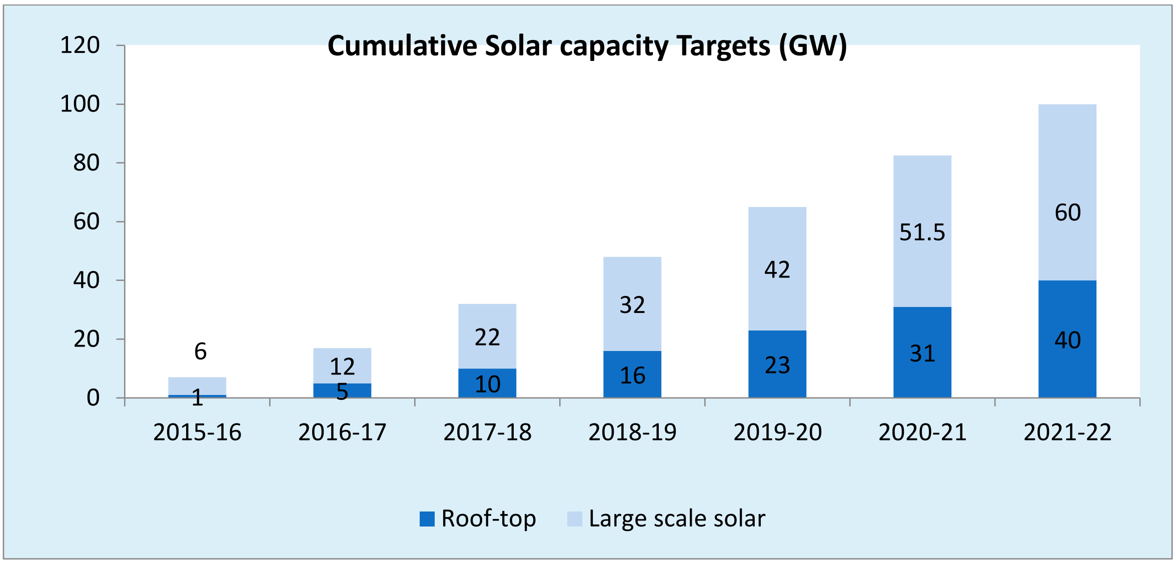


Figure 9: Cumulative Solar capacity Targets (GW)

2.1. Overview of Solar Thermal

The Solar Thermal market in India has been flourishing at a rapid pace, with its installations in the country rising every year, in alignment with country's ambitious goal of '20 million square meter of collector area' by FY 2022. Solar water heaters, currently form a major chunk of this collector utilization, which can be largely attributed to mature technology, more awareness, ease of deployment and even mandatory obligations in some cases for certain categories of buildings. The commercialization of CSTs in India have been predominantly achieved on the backdrop of host of support programmes in the form of capital subsidies, launched by the MNRE.

Specifically in terms of solar thermal technologies, the global installed capacity at the end of 2017 stood at 472 GW_{th}[9], translating to a total collector area of approximately 674 million m^2. China accounts for the maximum installations out of this, comprising 71% of the total with 336 GW_{th} installed capacity. China is followed by USA, which accounts for another 4%. Predominantly of glazed collectors are used in installations, whereas unglazed collectors account for less than 10%.

The year 2016 witnessed almost 35 GW_{th}[10] equaling 50 million square meters of collector area being installed globally. This represents roughly 7% of the total installed capacity. Denmark emerged as the leader in such installations with 84% of 2016 for newly installed solar water heating capacity taking place in the country but dropped from the ranks in 2017 with Tunisia gaining new ground in the sector.

[9] http://www.ren21.net/wp-content/uploads/2018/06/17-8652_GSR2018_FullReport_web_final_.pdf
[10] http://www.ren21.net/wp-content/uploads/2018/06/17-8652_GSR2018_FullReport_web_final_.pdf

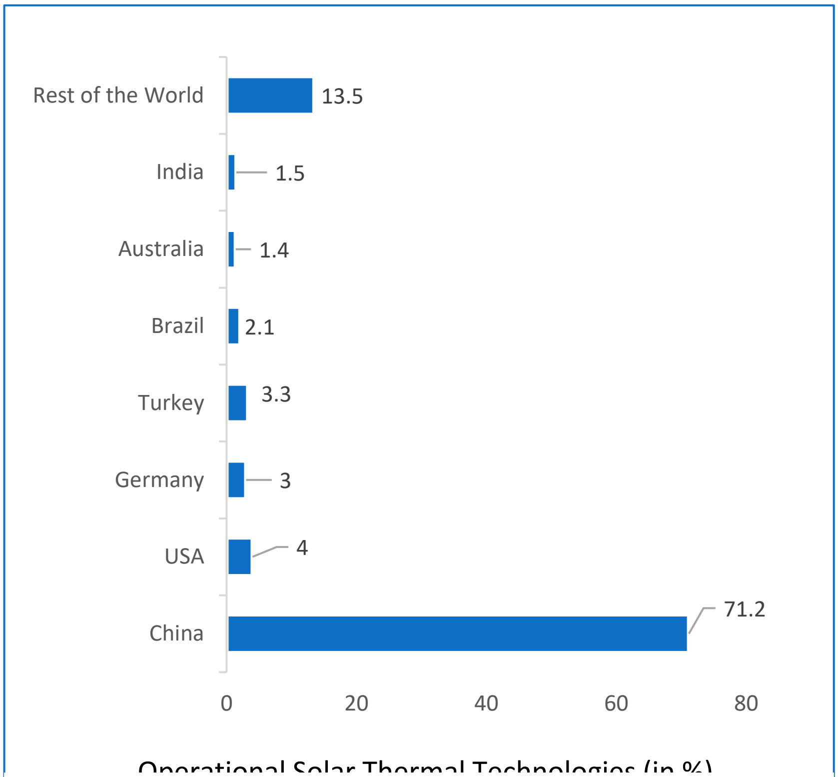


Figure 10: Global Solar Thermal Technologies

China was undoubtedly the world leader in solar thermal market adding another 26.1 GWth in 2017. Solar district heating capacity doubled in Denmark in 2016. Among Denmark's new installations was the world´s largest solar thermal plant, with 110 MWth (156,694 m^2) of installed capacity, in the town of Silkeborg. The solar district heating plant was commissioned in December, after only seven months of construction. The world's second largest solar thermal plant – the 49 MWth (70,000 m^2) district heating field in Vojens – is also located in Denmark. At the end of 2016, Denmark's solar district heating capacity summed up to 911 MWth (1.3 million m^2), with 104 systems in operation.

Out of the total capacity additions in the previous year, vacuum tube collectors make up around three-fourths of the total installed capacity. In installation terms, China was followed by Turkey, Brazil, India and the United States of America. In absolute terms, the additions in China were 26.1 GW_{th}, which was almost 19 times more than Turkey in the second place, which added 1.375 GWth in 2017. Also, success in Denmark in 2016 had inspired intensive discussions and project development activities in other central European countries, especially in Germany and Poland.

Consequently, Germany's first record-size solar district heating plant in 11 years became operational in August 2016, when 5.8 MWth (8,300 m^2) of vacuum tube collectors began feeding into the municipal district heating network in Senftenberg. In total, Germany installed a combined 9 MWth (12,921 m^2) in four new systems, increasing the country's district heating capacity to 39 MWth by the end of the year.

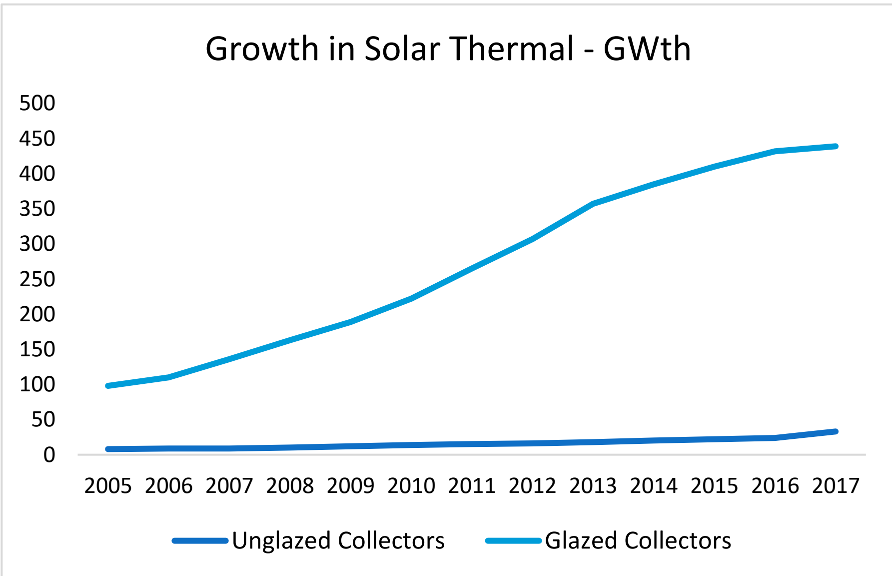


Figure 11: Growth in Solar Thermal technologies

This trend was primarily attributed to the emergence of new business models such as ESCO contracts and the easier availability of finance at better conditions. A model that has been much appreciated in this regard is the Danish cooperative model of consumer owned renewable district heating that involves projects being owned by non-profit consumer cooperatives. These cooperatives are responsible for running and maintaining the projects and all decisions of authority related to its operation.

They thus have direct authority over their community's district heating program and are direct beneficiaries of the energy generated.

This growth is also augmented by the increased deployment of large scale solar thermal systems for district heating and industrial uses. In the year 2015, construction of the 1 GW_{th} solar thermal plant - Miraah in Oman was initiated.

The year 2016 saw the first assessment for the world market of Solar Heat for Industrial Processes (SHIP). At the end of 2016 at least 525 SHIP plants were operational, totaling a minimum of 416,414 m^2 of collector and mirror area (291 MWth) – enough capacity to provide approximately 18 GWh (1 PJ) of industrial process heat by the end of 2016. Prior to the assessment, it was estimated that 195 SHIP systems were in operation worldwide, with a total collector and mirror area of 177,892 m^2 (125 MWth).

German flat plate collector manufacturers Bosch, Viessmann, Vaillant, Thermosolar and Wolf figure amongst the leading manufacturers, placing Germany as the leading nation for manufacturing of flat plate collectors. Chinese manufacturers Sunrise East Group, Himin and Linuo-Paradigma place China as the leading Nation for vacuum tube collectors. Specifically in terms of concentrating solar thermal technologies, India has emerged as the Global leader in terms of area under implementation and currently has 15 channel partners of the Ministry of New and Renewable Energy that manufacture a range of customised solutions for customers. There are in total 27 manufacturers that actively operate in the market and have led to its growth over the years.

Until now the global deployment of renewable energy is primarily for power generation segment and limited investments and emphasis has been laid for utilizing renewable energy for heating applications, specifically in the industrial segment. These resources have huge potential in replacing fossil fuels consumption in the industrial segment. Biomass as a primary energy source in industrial segment has a share of around 15% however solar is still in its infancy stage. Although solar energy is harnessed worldwide to generate electricity, processing heat for industrial procedures through CST applications still accounts for less than 1% of global solar thermal capacity. Solar technologies have the potential to grow faster than any other renewable technology since their costs have reduced significantly in recent years and have less operation and maintenance requirements than any other renewable source.

International Energy Agency (IEA) technology Roadmap for Solar Heating and Cooling estimates the long-term potential for solar thermal applications in industrial applications at 7.2 EJ/year and 1.5 EJ /year for solar cooling. In order to show the magnitude of these figures, the solar collectors for low-temperature process heat (<120°Celsius) could reach an installed capacity of 3,200 GW (producing 7.2 EJ solar heat per year) by 2050, which would be the equivalent of 20% of energy use for low temperature industrial heat by that time. Reaching the above mentioned deployment levels for solar heating and cooling can avoid some 800 million tonnes of CO_2 emissions per year by 2050.

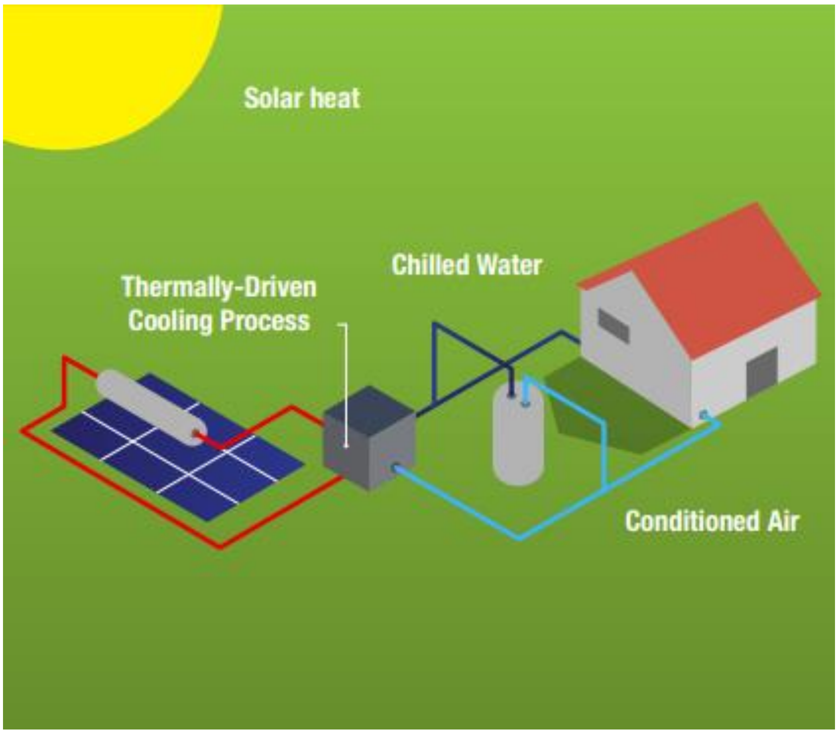
2.2. Working Principle of Solar Thermal

2.2.1. Solar thermal heating

Solar thermal technology utilizes the sun's energy (solar radiations) and convert it into heat which is then transferred to a heating system for use in industry, and in the residential and commercial sectors. The main source of heat generation is through solar panels which are used in conjunction with a boiler, collector or immersion heater. These systems utilize solar radiation to generate heat – as hot water, air or steam that can be readily deployed for meeting numerous applications in different sectors such as heating applications for industries, process heating, space cooling, community cooking and power generation on a large scale. These applications make use of solar energy collectors as heat exchangers that transform solar radiation energy to internal energy of the transport medium (or heat transfer fluid, usually air, water, or oil). The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space conditioning equipment or to a thermal energy storage tank from which can it be drawn for use at night and/or cloudy days.

2.2.2. Solar thermal cooling

Cooling is basically achieved by retrieving heat from a fluid or gas and transferring it to the environment, which is usually called heat rejection. This transfer can be done mechanically or chemically. One of the technologies used for cooling purposes are thermally driven chillers. These use thermal energy to cool down gases or fluids. This thermal energy can be provided by different technologies, including solar thermal energy.



Source: www.estif.org

The main feature of a solar cooling system, beyond the solar collector field, is the thermally driven chiller. On the thermal supply side, the solar thermal system is rather conventional, consisting of high quality solar collectors, a storage tank, a control unit and pipes. For the cooling process, the main element is the thermally driven cooling machine but the process of heat rejection is also important. This means that cooling towers or other heat rejection solutions are required.

The most common technological solution is an absorption cycle: the heat is used to chemically "compress" the refrigerant by desorbing (separating) it from a sorbent, cooling is produced as the "compressed" liquid is expanded in the evaporator to turn into gas.

6 to 20 degree Celsius cooling temperature

The temperature required from solar thermal plant changes according to needs and desired performance. It can start at 80 degrees Celsius but some systems operate well above 150 degrees Celsius.

-Source www.estif.org

More generally, there are two main commercially available solar cooling processes:

- Closed cycles, where thermally driven absorption or adsorption chillers produce chilled water for use in space conditioning equipment.
- Open cycles, which typically use water as the refrigerant and a desiccant as the sorbent for direct treatment of air in a ventilation system.

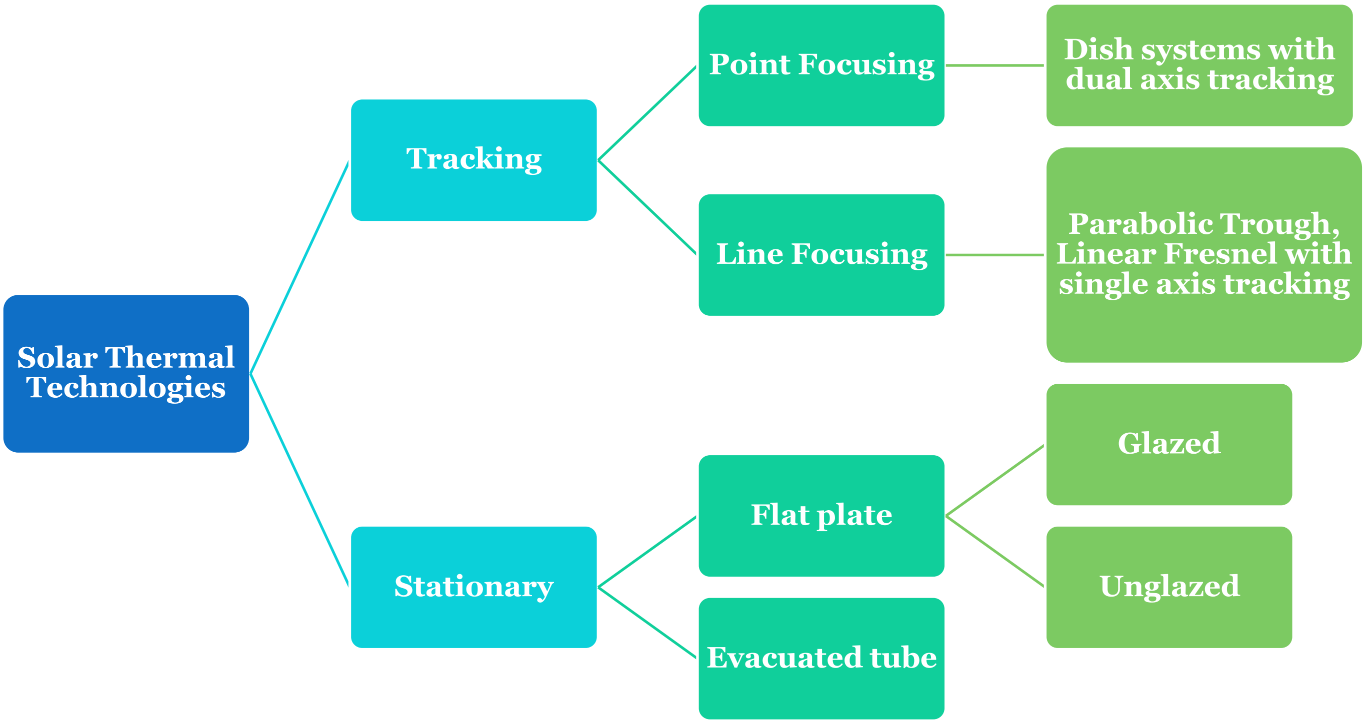
Generally, solar cooling systems are not installed without backup for cooling and heating. Therefore the majority of the financial savings are on the avoided energy use, rather than on the avoided traditional cooling device cost.

Solar thermal systems can be either non-concentrating or concentrating types. They may also be either stationary or with sun-tracking mechanisms, depending on the application, temperatures required and economic viability.

2.3. Different Solar Thermal Technologies

Solar thermal technologies can be roughly distinguished by the type of solar thermal collector used (unglazed water collectors, evacuated tube collectors, flat plate collectors, glazed and unglazed air collectors etc.) and the main type of applications include swimming pool heating, space heating, heating of industrial processes, solar district heating or solar thermal cooling.

Solar thermal technologies consist of collectors that convert solar irradiation hitting a surface into heat by heating a suitable heat transport media. Herein concentrating systems may also be used to increase the radiative flux at the absorber. Based on the type of concentrating systems, collectors are classified as either **Stationary or Tracking**. Stationary collectors are those that have no or very moderate concentration, whereas tracking collectors use tracking systems to have concentration ratios (Area of Aperture/Area of Absorber) that are typically greater than 10. The types of technologies as per this classification are depicted below:



Solar thermal collectors are classified as low, medium, or high temperature collectors. Low-temperature collectors are used mainly for heating water or air for residential and commercial use, whereas medium and high– temperature collectors can be used can be used in industries where higher input of heat (above 100 degrees Celsius) is required for processes such as distillation, boiler feed water, sterilization, pasteurization etc. High-temperature collectors concentrate sunlight using mirrors or lenses and are used for fulfilling heating requirements for some sectors up to 400 ◦C / 20 bar pressure and for electric power production.

High temperature solar thermal energy comprises of two categories, which includes Concentrated Solar Technologies (CST) for fulfilling heat requirements in some industries, and Concentrated Solar Power (CSP) when the heat collected is used for power generation.

Type	Temperature range[11]
Low temperature heat	< 150 ° C
Medium temperature heat	150 – 400 ° C
High temperature heat	>400° C

[11] IEA SHC Task 49, Technical Report A.1.3

2.3.1. Non-Imaging technologies

2.3.1.1. Non Imaging Concentrators

Also known as Compound Parabolic Collectors (CPC), NICs consist of specially coated absorber tubes that are enclosed in concentric vacuum glass covers to reduce convection losses. The fluid to be heated passes through these tubes and is transferred via a header to the central receiver tube on top.

Working Temperature: Up to 150ºC

Concentration Ratio: 5-25 suns

Pros
- Low O&M and adjustments
- Low Investment per unit area

Cons
- Relatively new
- Low Temperature

Tracking: Not Necessary

Compound Parabolic Collectors

2.3.2. Imaging technologies

Imaging technologies are further categorized into Line focus technologies and Point focus technologies which are explained in the following sections.

2.3.2.1. Line Focus technologies

2.3.2.1.1. Parabolic Trough Concentrator

Parabolic Trough Concentrators comprise of troughs that are made from parabolic shaped metal. This metal is coated with a reflecting material such as highly polished metal or metallized plastic which can withstand the

Pros
- Proven Technology
- Storage Available
- Commercial
- R&D Experience

Cons
- Complex Structure
- Flat area required
- Maintenance

Paraboloid Trough Concentrators

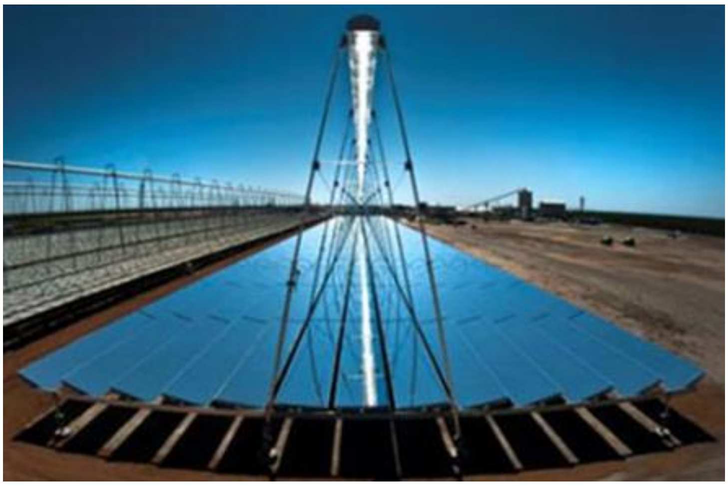
effect of external agents such as rain and also sunlight as well. These trough shaped surfaces reflect the incident sunlight on to a metallic collector pipe (the receiver) that runs axially along the trough.
Working Temperature: 150ºC - 250 ºC
Concentration Ratio: 10-100 suns
Tracking: Single Axis

2.3.2.1.2. Linear Fresnel

Linear Fresnel Reflecting Concentrators (LFRC) are similar in line focus to parabolic troughs, except that instead of the parabolic shaped reflecting surfaces, these are made from strips of straight reflecting material These surfaces also reflect the incident sunlight onto a metallic collector pipe (the receiver) that runs axially above the array of reflectors.
Working Temperature: 150ºC - 250 ºC
Concentration Ratio: 10-100 suns
Tracking: Single Axis

Pros
- Simplified Design
- Low Investment per unit area
- Storage Available
- Pre-Commercial

Cons
- Area requirement
- Flat area required
- Large size mirrors tougher to replace



Schematic of a Linear Fresnel

2.3.2.2. Point Focus Technologies

2.3.2.2.1. Fixed Focus Elliptical Dish

Also known as Scheffler concentrators, this setup comprises of a single dish system that is made up of large number of mirrors. All of these mirrors reflect the sun’s rays onto a fixed receiver that contains the heating fluid. The dish which automatically tracks the sun in the E-W direction from morning to evening is single axis tracked system.

Working Temperature: Upto 250°C
Concentration Ratio: 20-100 suns
Tracking: Single Axis

Pros
- Relatively Cheap
- Commercial, Simple Fabrication

Cons
- Limited Temperature
- No Storage

Scheffler Concentrators

2.3.2.2.2. Fresnel Reflector Based Dish

Also known as Fresnel Reflector Based Dishes, these comprise of a dish composed of panels of flat mirrors mounted on a frame with a cavity receiver connected to the dish. The receiver is at the focal point of the dish and such that it is held in a fixed position in relation to the reflectors by means of a suitable structure. The entire array of panels and receiver moves to track the Sun. The reflector and the receiver move in synchronization to track the Sun, such that the dish faces incoming sunlight at all times and concentrates that on the central receiver.

Working Temperature: Upto 400°C
Concentration Ratio: 10-100 suns
Tracking: Double Axis

Pros
- High efficiency
- Commercial
- Simple Fabrication

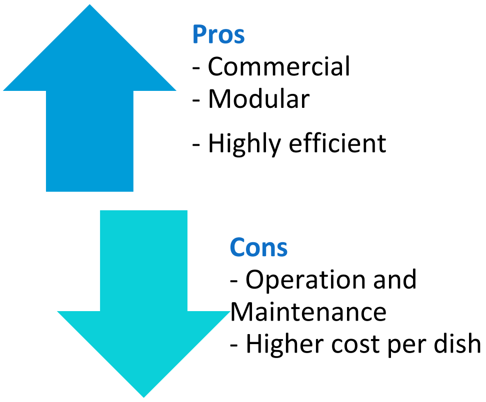
Cons
- Operation and Maintenance
- High tracking accuracy required
- Mirror cleaning a hassle

Fresnel Reflector based dish

2.3.2.2.3. Paraboloid Dish

Paraboloid Dish comprises of a dish with mirrors mounted on a truss structure such that the incident sunlight is reflected on to a central cavity receiver which is specially designed to reduce convective and radiation heat losses. In comparison to the Fresnel dish, these systems have lighter structures and can integrated wherever space permits and are hence suitable for retrofitting in congested layouts. These dishes are pole-mounted and thus have small footprint.

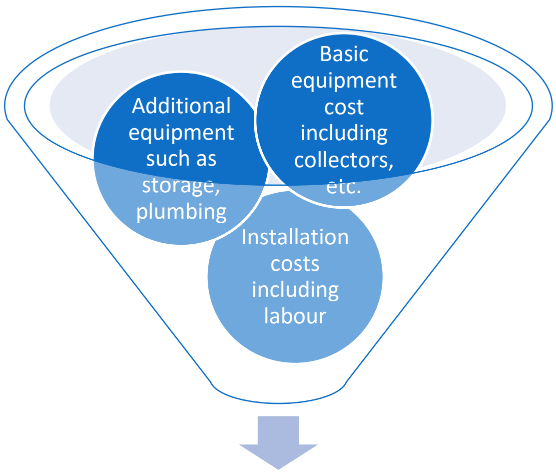
Working Temperature: Upto 400ºC
Concentration Ratio: 20-100 suns
Tracking: Double Axis



Paraboloid Dishes

2.4. Cost components of Solar Thermal

Like most of the renewable energy technologies, solar thermal technology is characterized by higher upfront costs and significantly lower variable costs like operational and maintenance costs because of absence of paid fuel requirements. The O&M costs are generally a part of the system manufacturer, involving fixed periodic charges that may or may not include component replacement charges. The essential upfront cost components of integrating a solar thermal system have been depicted in the chart alongside. The set-up costs vary significantly with the technology being implemented. Installation costs typically amount for a very low percentage of the overall system cost in developing nations, however in developed Nations these may account for up to 50% of the total system cost.[12]

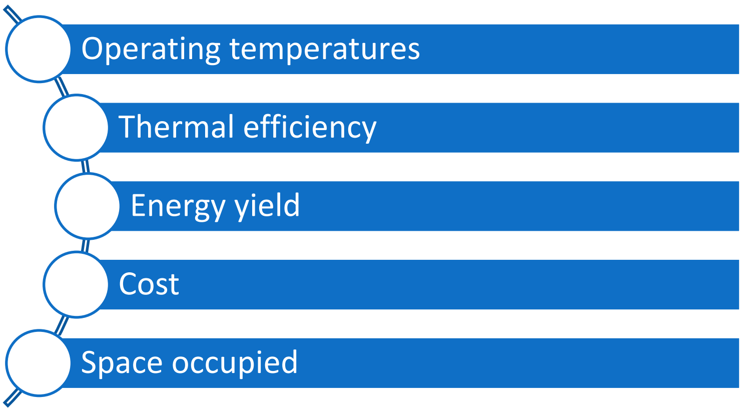


Cost of integrating a solar thermal system

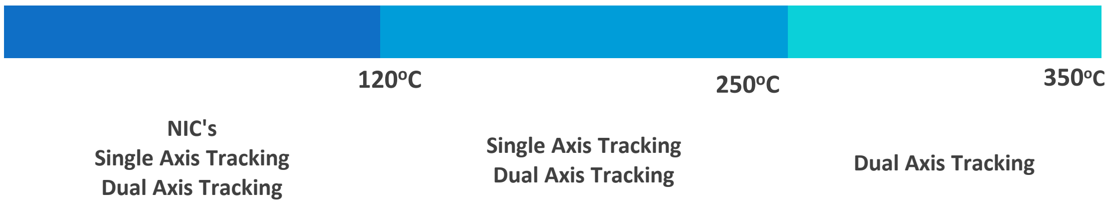
[12] Technology Roadmap 2050 : Solar Heating and Cooling, IEA

2.5. Selection of Appropriate Technology

The selection of an appropriate solar collector basically depends on five factors as have been described alongside.[13] For low temperatures, below 100ºC, generally evacuated tube and flat plate technologies are used. For medium temperatures, in the range of around 250ºC, generally parabolic troughs and linear Fresnel technologies were used, but lately solar dish technologies have started gaining prominence. In the case of higher temperatures, only point focus technologies can be used.



A brief representation of the suitability of the type of technology based on the temperatures to be achieved has been provided below for representation purposes.



Amongst the other criteria, another limiting criteria can be the availability of space and the suitability of a particular technology within the available space. For instance, certain rooftops might be built in such a manner that they might not be able to bear the load of a parabolic dish, etc.

2.6. Industrial applications of Solar Thermal

Industrial heat is characterized by a wide diversity with respect to temperature levels, pressures and production processes to meet the many different industrial process demands. CSTs track the sun's incoming radiation with mirror fields, which concentrate the energy towards absorbers, and then transfer it thermally to the working medium. The heated fluid or steam may reach high temperatures and may be used for various processes requiring heat.

Advantages of CST's to industries	De-risks existing business by reducing dependance on conventional fuels
	Reduces fuel and operational costs
	Incentives as may be offered on usage by the Government from time to time

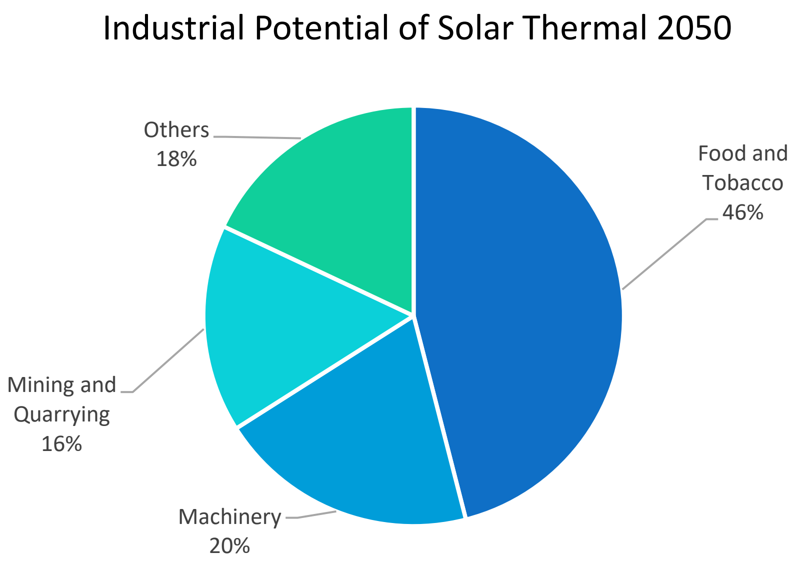
Energy requirements of industries can broadly be classified into two main categories, namely:

[13] Kulkarni, et al., 2009; Fernandez-Garcia et al., 2010

CSTs can produce a range of temperatures, between 50°C and up to over 400°C, which can be used in a variety of industrial process heat and space cooling applications. The industries showing good potential for implementation of solar concentrators are food processing, dairy, paper and pulp, chemicals, textiles, fertilizer, breweries, electroplating, pharmaceutical, rubber, desalination and tobacco sectors. Heating and space cooling and heating requirements in industrial processes can be fulfilled using solar thermal. Any industrial/commercial establishments currently using steam/hot water for process applications can also employ CSTs with a minimum tinkering to the existing setup. For industrial processes where lower temperature range (less than 120 °C) is required, technologies such as the non-imaging concentrators are common and for higher temperature range applications, technologies based on tracking mechanisms with a higher sun concentration ratio such as parabolic trough, Linear Fresnel and paraboloid dish are preferred.

According to a study (Ecoheatcool 2006), around 57% of the total industrial heat demand is required at temperatures below 400°C, thus falling within the purview of solar thermal applications. Currently about 85 solar thermal plants for process heat are reported worldwide, with a total installed capacity of about 27 GWth (38,500 m^2).

A potential assessment of the usage of renewables in process heat applications in industries carried out by UNIDO estimates that solar thermal technologies have the potential to provide 5.62 Exa Joules of energy to the industrial sector in the year 2050. Almost 50% of this energy will be provided to the food and tobacco industry.[14]

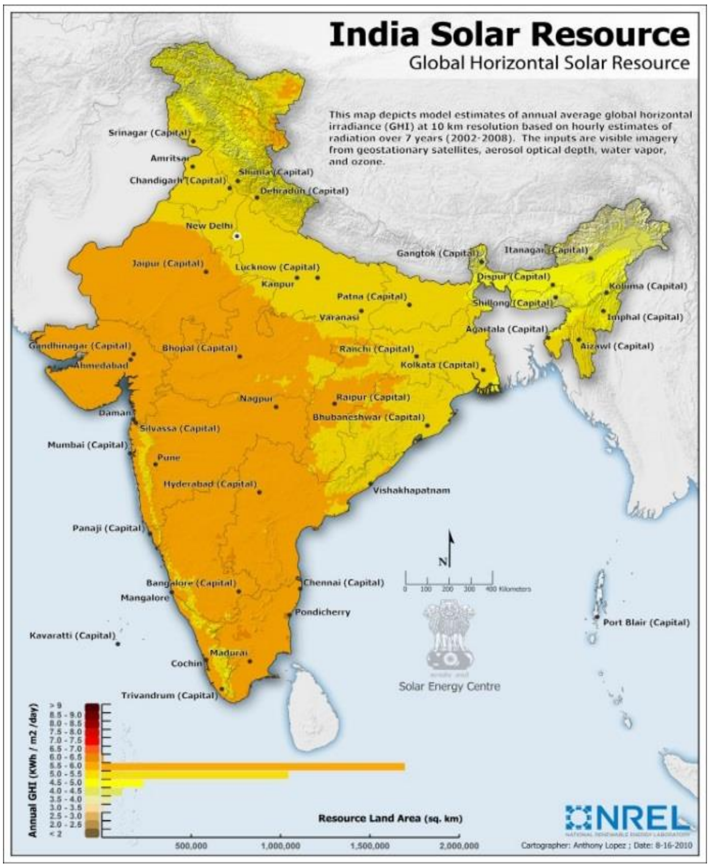


Source: Renewable Energy in Industrial Applications – An Assessment of the 2050 Potential, UNIDO

[14] Renewable Energy in Industrial Applications – An Assessment of the 2050 Potential, UNIDO

2.7. Solar Thermal technologies in India

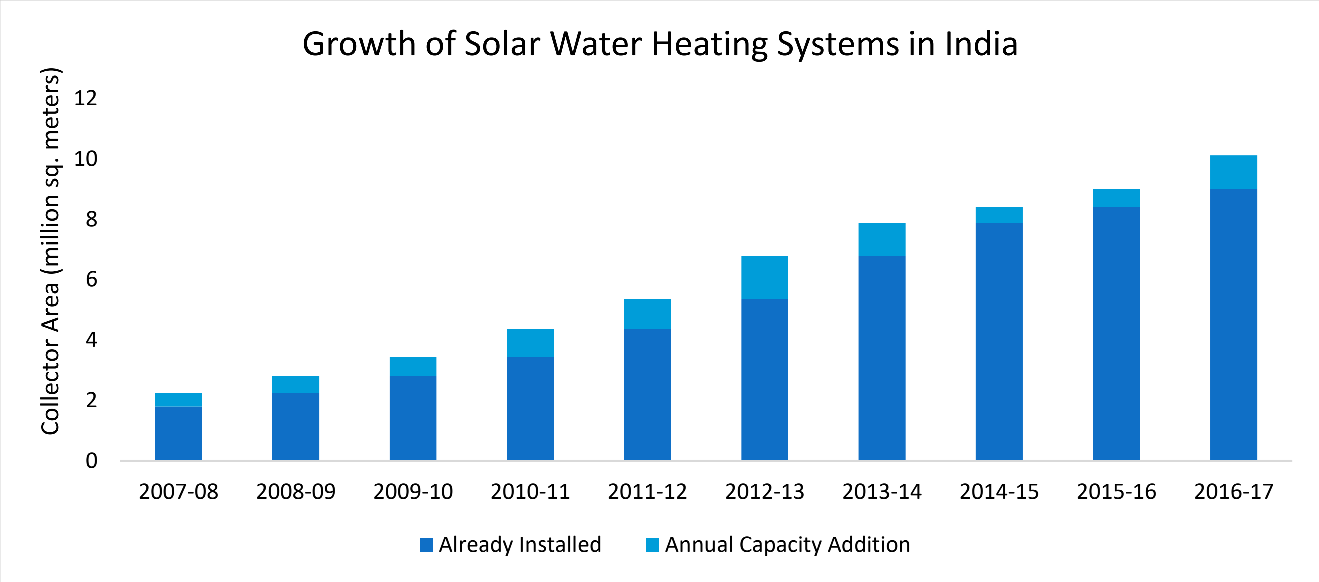
India is endowed with vast potential for solar energy. The National Institute of Solar Energy (NISE), an autonomous institute under Ministry of New & Renewable Energy, Government of India has estimated the total solar potential of India at a little less than 750 GW. With about 300 clear, sunny days in a year, India's theoretical solar power reception, only on its land area is about 5,000 trillion kWh per year. The daily average solar energy incident over India varies from 4 – 7 kWh/m^2 with 1,500 – 2,000 sunshine hours per year (depending on the location)[15]. The map alongside provides an estimation of the variance in solar radiation across India. Western part of India has maximum radiation and this level decreases gradually as we progress from the west towards the east.



JNNSM had established targets of implementing a cumulative of 15 million square meters by 2017 and 20 million square meters of solar thermal collector area by 2022. As of December 2015, India had installed a cumulative collector area of around 10 million square meters under solar thermal technologies.[16]

The lion's share of this area under implementation comprises of solar water heating systems, whose growth over the years is depicted in the graph below. The growth can be attributed to a number of policy enablers to increase the usage of solar thermal technologies that even made their installation mandatory on certain categories of buildings with high energy demand. As a result, solar thermal systems of capacity 1.06 GW_{th} were installed in 2017 in India, taking the nation's total installed capacity to 7.086 GW_{th} by the end of 2017.[17]

[15] 51 Solar Radiation Resource Assessment (SRRA) stations have been installed by the MNRE to monitor the resource availability across India.
[16] Annual Report 2015-16, Ministry of New and Renewable Energy
[17] http://www.ren21.net/wp-content/uploads/2018/06/17-8652_GSR2018_FullReport_web_final_.pdf



2.8. Current Status of CST installations in India

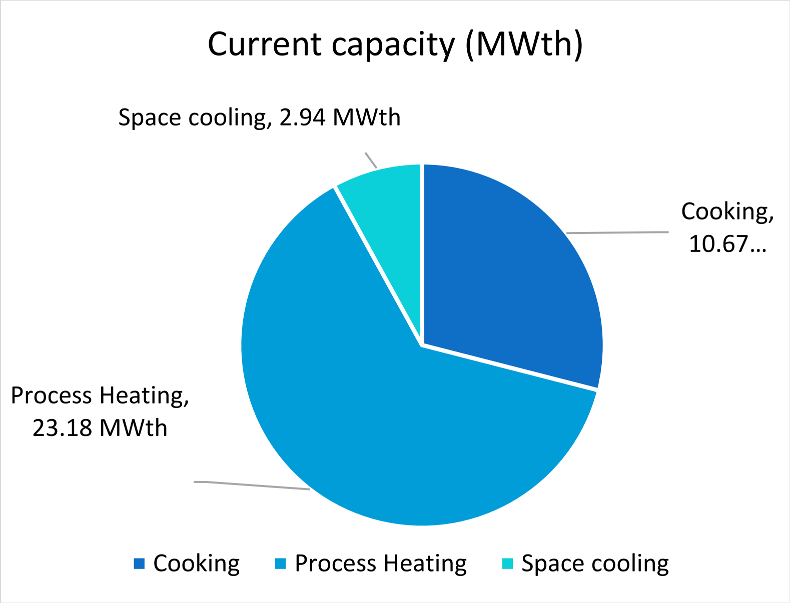
India is seen as a favorable market globally for the growth of CST's. This is primarily because of the high irradiance and also the existence of local manufacturers with access to cheap labour. Although the country has its own barriers to growth, such as the non-existence of solar grade reflector manufacturers, CST's in India find diverse usage with systems being used for cooking purposes, in automotive industries, textile industries, food industries, etc. for varied uses.

Currently, India has a cumulative of 154 projects with a total area under installation of 44,949 m^2. India currently has the maximum area under implementation for CST's for process heating and cooking purposes and has herein a very viable opportunity to become the unanimous global market leader for CST's for such utility.

Furthermore, a total of 183 projects with an aggregate area of 54,079 square metres have already been submitted to MNRE for approval

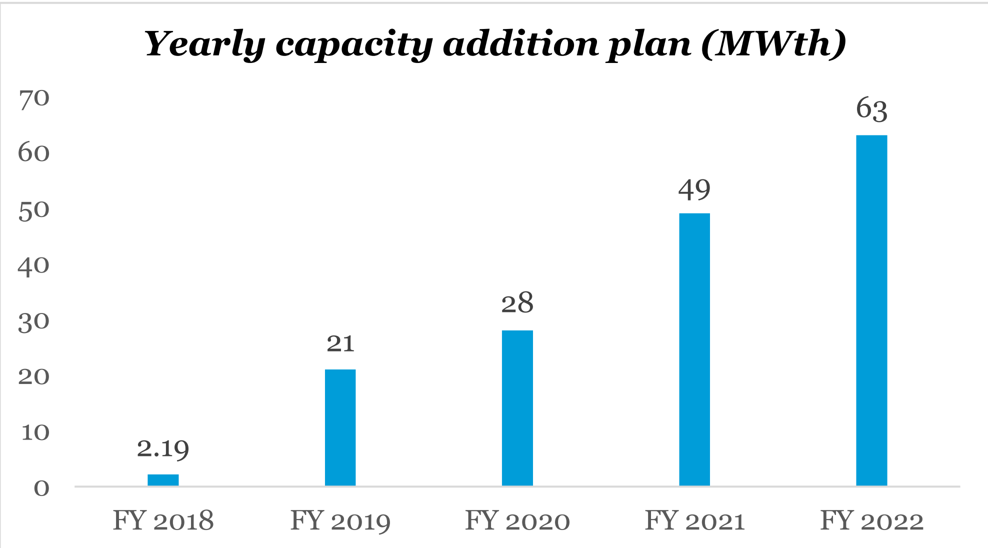
Current Installed Capacity in India

Currently, India has a total installed capacity of 36.8 MWth of CST applications with majority of the implementation being utilized for process heating and cooking purposes amounting to 23.2 and 10.67 MWth respectively[18]. The break-up of capacity is shown in the table below. There are a cumulative 154 projects installed with a total area of 44,949 m^2. (*Note: A conversion factor of 0.7 kWth/sqm has been taken as per IEA*)



Maximum projects under CST implementation belong to Tamil Nadu, Maharashtra and Gujarat and the three states comprise of a total area of 20,792 m^2. This quantity is just a fraction of the vast untapped potential of CST in India.

2.8.1. Expected Growth in Solar Thermal



India is seen as a favourable market for the growth of CST's. This is primarily because of the high irradiance and also the existence of local manufacturers with access to cheap labour. India has a vast potential of Solar Thermal installations and it is expected to reach 200 MWth in installations by 2022 against the current installations of a mere 36.8 MWth. This would require collector area of approximately 2,85,700 m^2 and a shade free land/roof area of 7,14,000 m^2. The installation targets are ambitious and can only be achieved if driven by the inclination of the industry towards Solar Thermal along with the support from the government and funding agencies.

The total market potential for CST's is estimated at 6.45 GWth, which will be driven by various market forces including financial viability of the projects, willingness to implement such projects on the part of the industry and most importantly the availability of land for these projects. In monetary terms, this roughly translates into an investment opportunity of INR 25,800 Cr (considering the cost to be INR 40/Wth). Although the country such huge potential but also has its own barriers to growth, such as the non-existence of solar grade reflector manufacturers, CST's in India find diverse uses with systems

[18] MNRE

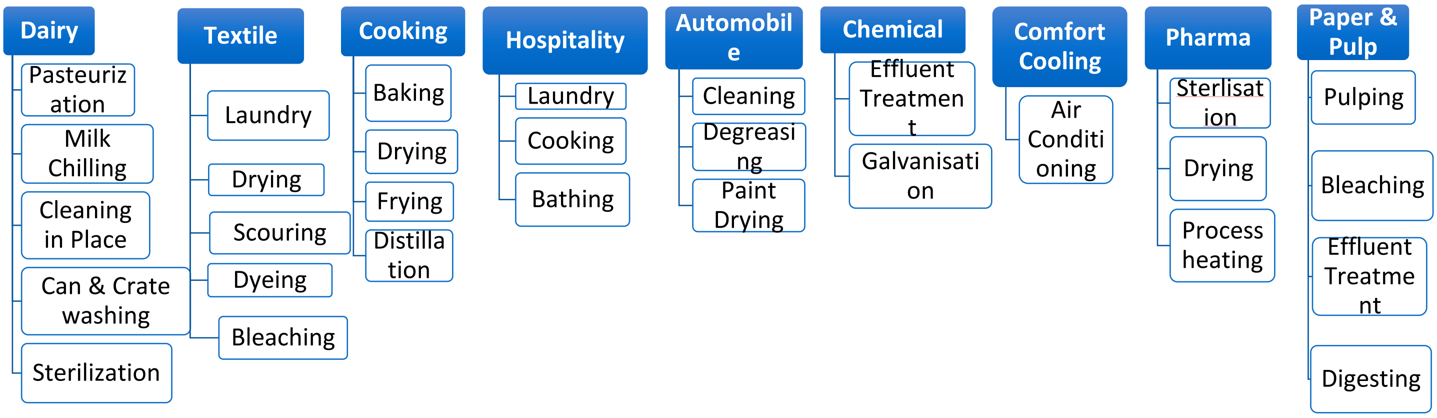
being used for cooking purposes, in automotive industries, textile industries, food industries, etc. and for varied uses in a whole lot of different sectors.

2.9. CST Applications

CSTs can produce a range of temperatures, between 50°C and up to over 400°C, which can be used in a variety of industrial and commercial heating applications. The industries showing good potential for implementation of solar concentrators are food processing, dairy, paper and pulp, chemicals, textiles, fertilizer, breweries, electroplating, pharmaceutical, rubber, desalination and tobacco sectors. Any industrial/commercial establishments currently using steam/hot water for process applications can also employ CSTs with a minimum tinkering to the existing setup.

CST basically offers solutions in solar steam generation, direct cooking, thermic fluid cooking, waste water evaporation and hot water applications. It also offers innovative solutions in steam generation particularly for desalination purposes.

Major applications for CST in various sectors are shown in the diagram below.



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Advantages of CST's to industries

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- Reduces fuel and operational costs
- Incentives as may be offered on usage by the Government from time to time

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- Heating
- Space and Process Cooling

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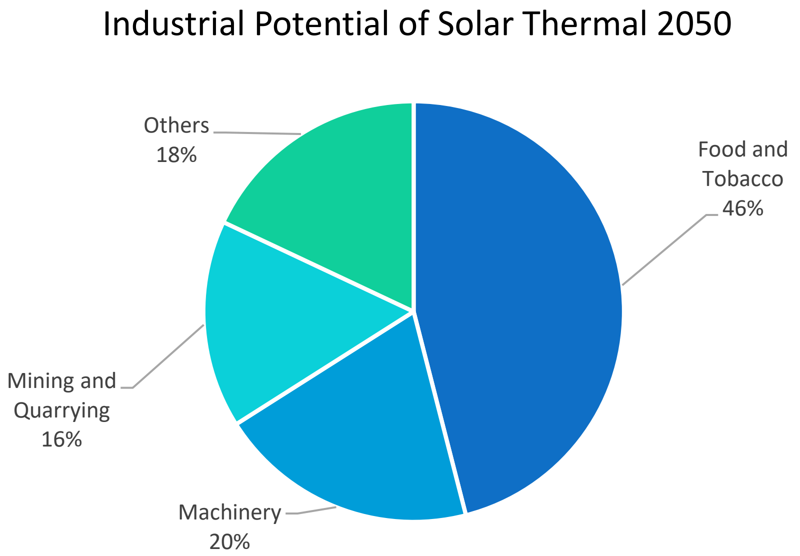
Source: Renewable Energy in Industrial Applications – An Assessment of the 2050 Potential, UNIDO



2.10. Solar Energy Infrastructure

In the last decade India added GW scale solar PV and Wind Parks into fragile electric grids and have amended frameworks for large solar PV and Wind energy adoption. The Renewable Energy infrastructure landscape plays a key role in propelling investments in energy sector. Infrastructure encompasses different components ranging from manufacturing, Logistics, Execution, Testing/Evaluation and Operation and Maintenance.

"Renewable energy infrastructure refers to the physical and structural framework which enables RE deployment. This includes various systems or their components such as manufacturing, logistics, execution, testing, commissioning and operation & maintenance".

Manufacturing infrastructure:

Manufacturing has emerged has one of the key drivers of clean energy growth. Renewable energy projects and their products components consists of different processes and integration of electronics and other hardware. The landscape for any infrastructure depends on the technology availability, ease of doing business for RE, Raw material availability and trained man power.

[19] Renewable Energy in Industrial Applications – An Assessment of the 2050 Potential, UNIDO

Logistics infrastructure:

In country transportation and accessibility to the projects hinterlands is prerequisite any power infrastructure projects. In case of renewable energy projects especially solar PV and thermal, the components are sensitive and often exposed harsh environment conditions. It is vital to have logistics and inventory support to transport the equipment to the project locations.

Getting transport infrastructure right is critical. The presence or absence of transport networks which facilitate efficient supply chains is already a factor in investment decisions around the world; the ability to offer a solid infrastructure is likely to become an even more important criterion in determining a country's or region's competitiveness in the future. Transport infrastructure remains a deciding factor for the renewable energy prospects of a country.

Execution Infrastructure

Renewable energy projects engineering and design are the key elements of infrastructure, the typical life of non-conventional plants are up to 30 years. It is important to assess the infrastructure elements like power evacuation facilities, technology support, electrical, mechanical and civil infrastructure and credible and experienced vendors.

Testing/Evaluation infrastructure

Test & Evaluation in renewable energy infrastructure is the process by which a system or components are compared against requirements and specifications through testing. The results are evaluated to assess progress of design, performance, supportability, etc. to reduce the risk throughout the life-cycle of the project.

Quality assurance enables smooth transition of projects from concept to commissioning. It is important to have quality inventory framework to scan all the components for sustainable and reliable performance. This report highlights the different sections of quality infrastructure like standards, metrology, conformation assessment and performance standards and their role in adoption of large scale of renewable energy projects.

Operation and Maintenance infrastructure

Renewable energy projects consists of different components and each of the sub-system requires different skill sets and support infrastructure, which encompasses structure, electrical sub systems, civil sub systems, communication support, warranty management, spare parts and inventory management. It is important to assess the above components and their services availability to support the lifetime of the projects.

The importance of O&M is often overlooked by many developers. Considering the fact that the plant has to generate returns over a period of 25 years, reliable infrastructure, a good monitoring system and above all, a very good O&M process is very critical for the success of the plant.

The below figure depicts the key areas of renewable infrastructure and their elements:

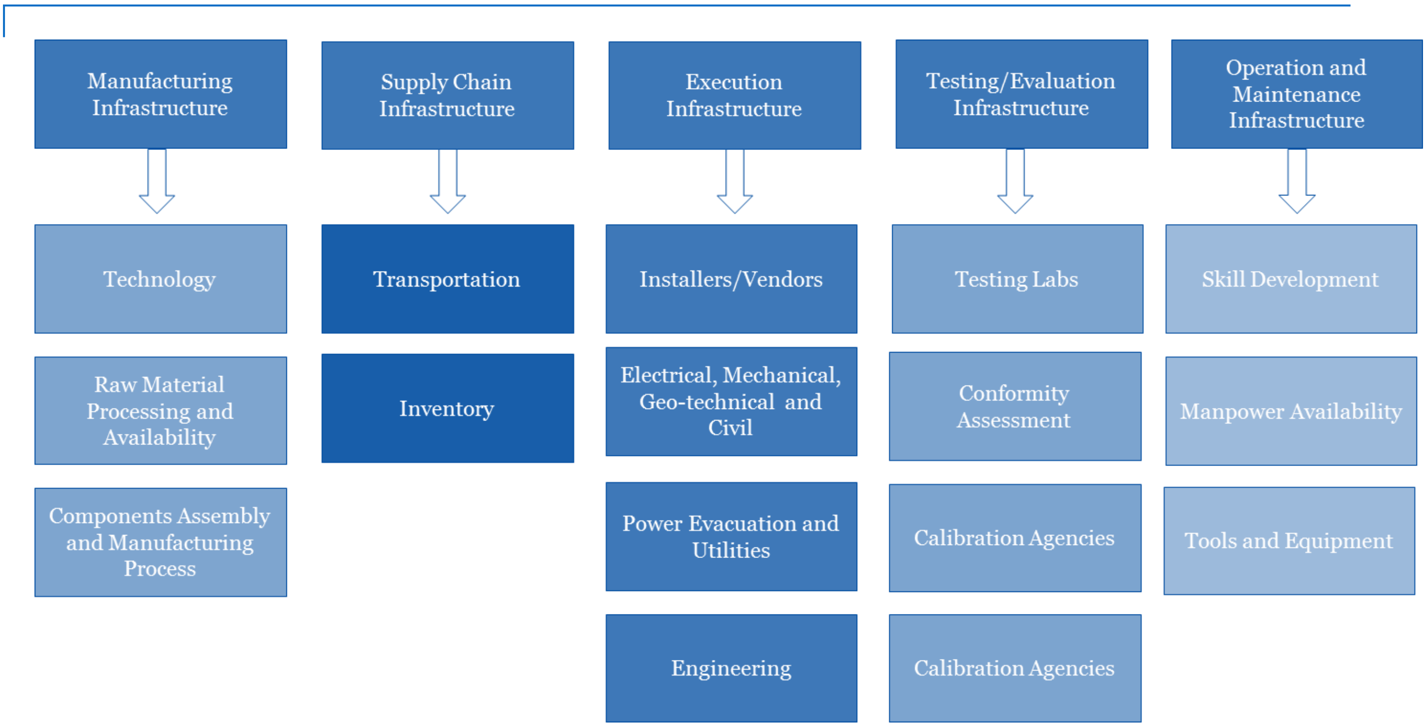
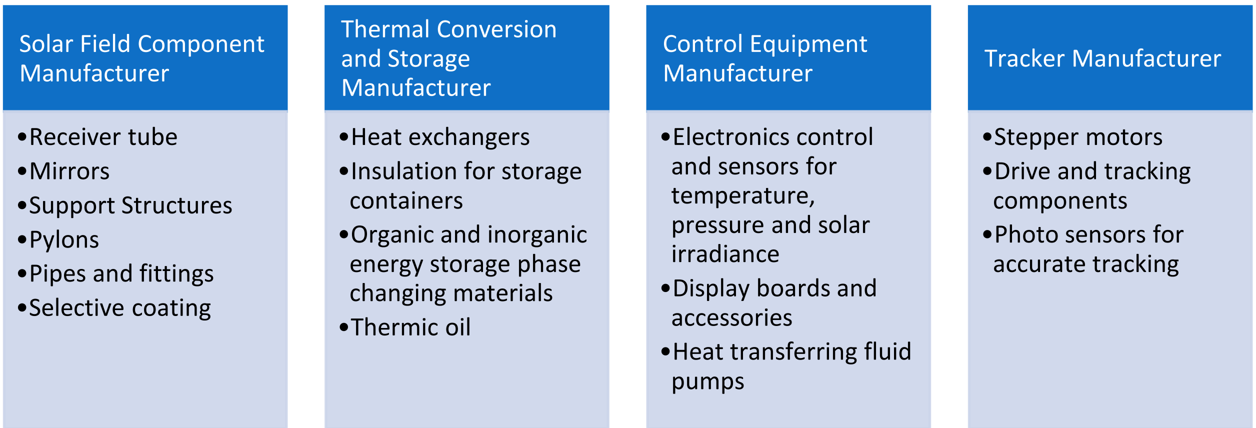


Figure 12: Renewable infrastructure and their elements

2.10.1. Solar thermal manufacturing landscape in India

The solar thermal value chain in India is majorly attributed to the fewer components which are manufactured indigenously and integrated at the site with the imported mirrors and supporting structures In the recent times the local developers are collaborating with international players to enhance the technologies. The list of various stakeholders in thermal manufacturing is depicted in the figure below:



Mirror Manufacturing Landscape:

Mirrors used in solar thermal technologies based applications are different from the traditional mirrors in terms of their performance characteristics like reflectivity, durability and strength. The fabrication for the extra clear glass requires low ferrous sand which is scarce in India, furthermore the glass no other applications other than in solar thermal technologies.

From our discussions with key stakeholders and empaneled partners with MNRE, currently the installers are paying in the range of INR 3800-4000 per sq.m, which is expensive. Although the actual cost for solar grade mirrors is around INR 300 per sq.m. To increase the life span and performance of solar grade mirrors it has to be sealed and with selective coating the cost shoots to INR 4000 per sq.m which is not economical. Cost reduction because of local manufacturing is expected to be in the range of 20 percent, but this may require the development of local glass handling and logistics skills. Specialized tools, such as specialized trucks with air suspension and custom-tailored steel frames for mirror transportation, should be provided by the manufacturers. The reduction can be attributed to lower shipment costs, lower labor costs, and ease of handling.

Fabrication for support structures

Support structures for solar thermal installations include mirror support, pylons and support arms for different equipment. The concentrating mirrors are installed on a rigid metal structure, which aligns the mirrors in the required parabolic shape to concentrate the radiation in the linear focus. Structures are typically manufactured by high precision fabrication processes with galvanized steel or aluminum depending on the strength required and type of roof/ground.

The fabrication industry in India is fairly mature. Fabrication components are made locally for several applications and industries. There are many companies in India capable of manufacturing support structures in India, especially the automotive industry.

From our discussions with key stakeholders and empaneled partners with MNRE, the quality standards are in place for the support structures, since they are used for wider application including solar PV. If the market relies purely on local manufacturing the cost reductions caused due to domestic manufacturing are around 20 percent, because of differences in labor costs and savings in logistics costs and custom duties.

Local manufacturers who claim to have the capability to manufacture the structures on their own are suggesting cost reductions of around 30–40 percent. However, at this time, it is difficult to know the precision and quality of products to be supplied by companies that are attempting to fabricate these components for the first time.

Receiver tubes

The receiver tube plays a critical role in the application of solar thermal technologies, the optimal flow, surface coating, type of HTF, optical properties of the material surface will impact on overall thermal efficiency of the solar thermal system. The selective surfaces of the receivers must be highly absorbent and have low thermal emissivity at the operating temperature.

While India have been trying to gain expertise in selective coatings, expertise in the metal-glass seal is still lacking, even if the Indian electronics industry has some experience in this field. If Indian companies develop the technology indigenously, a large number of patents for receiver tubes internationally will force them to work on new concepts, which will require extra efforts in R&D.

To improve the efficiency and heat transfer from the absorber tubes, it is prerequisite to have regular cleaning and maintenance activities. Currently receiver tubes with high absorption and selective coating are imported. Large cost reduction are possible with local manufacturing.

Trackers and drive mechanism

The purpose of the drive mechanism is to ensure that the reflectors are optimally positioned during the whole day to track the sun's position. Thus, these mechanisms are a decisive parameter to attain a high degree of efficiency.

	Complexity	Current status
Hydraulic Power	Standardized	imported/local
Cylinder	Specialized	imported/local
Sensors	Specialized	imported
Controllers	Specialized	imported

Since the market for tracking devices will be dependent to a large extent on the CSP plant installation, the key growth driver for local manufacturing will be clarity on the demand side. Some of the components for tracking devices are similar to the ones being used for wind power. Hence, the capital expenditures (capex) required will mostly be incremental. Local manufacturing for tracking devices will require a minimum demand of 500 MW/ year of CSP plant installation to justify the incremental capex (for international players with an established manufacturing base in India).

India's National Solar Mission includes measures aiming at driving down costs and encouraging domestic solar manufacturing in order to rapidly expand the use of PV and CSP systems.

2.10.2. Solar PV manufacturing landscape in India

Indian solar PV module manufacturing capacity have grown from 200 MW in 2008 to 8398 MW in 2017, the impetus for growth in manufacturing was largely driven by adopting domestic content requirement (DCR) and incentives linked mechanisms. Consolidation of the sector has already been happening at the global level and India is not going to be immune to that trend. The future growth of the Indian solar sector is likely to be shaped in the coming years, from both policy and technology perspective with introduction of Make in India and other clean technology initiatives.

In the recent times after the revision of solar PV targets to 100GW from 20GW, manufacturers are in beeline to reap the benefits of large scale solar PV parks from the developers.

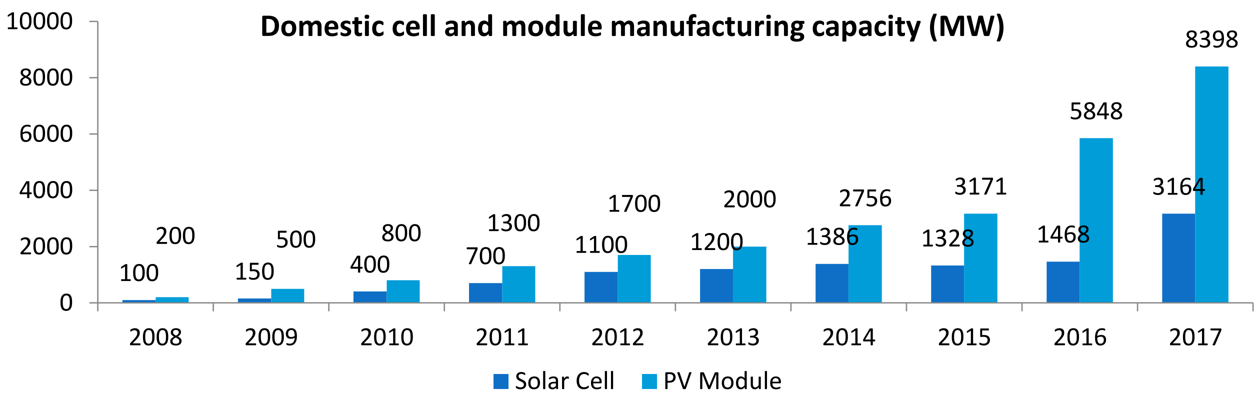


Figure 13: Domestic cell and module manufacturing capacity (MW), Source: MNRE[20]

Manufacturing in India lacks scale as the largest manufacturers are only operating at close to 500 MW capacities, compared to GW scale units in China. India also lacks vertical integration, with majority of manufacturing skewed

[20] https://mnre.gov.in/file-manager/UserFiles/information-sought-from-all-Solar-Cell-&-Module-manufacturers-as-on-31052017.pdf

towards module assembly, which is the final stage in module manufacturing. Polysilicon is the key raw material for Solar PV cell/module manufacturing and the country has minimal or no operational polysilicon production facility and manufacturers are relied upon importing ingots and manufacturing the downstream products.

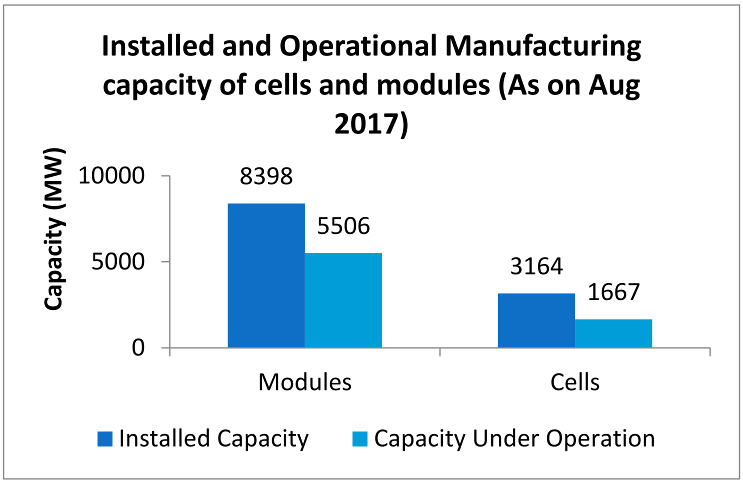


Figure 14: Installed and Operational Manufacturing capacity of cells and modules (As on Aug 2017), Source: MNRE

While the DCR was mandated by the MNRE with the good intention of catalyzing the growth of the domestic PV manufacturing sector, the DCR did not have the desired impact because of a loophole in the DCR policy framework. In the Batch 1, Phase 1 of the JNNSM, it was mandated that all the crystalline silicon (c-Si) modules used in the projects should be of Indian origin. For the Batch2 of the Phase 1, this mandate was extended to solar cells also. However, Thin Film technology was exempt from the DCR, probably because there were hardly any domestic manufacturer of Thin Film PV.

The current manufacturing capacity is not able to cater to deployment of targets of 100GW by 2022. The manufacturers are facing heavy competition from Chinese players with the scale and technology and the availability of polysilicon raw material. Although there are several factors which need to be addressed to boost manufacturing sector the picture below depicts the key areas to be focused for improvement.

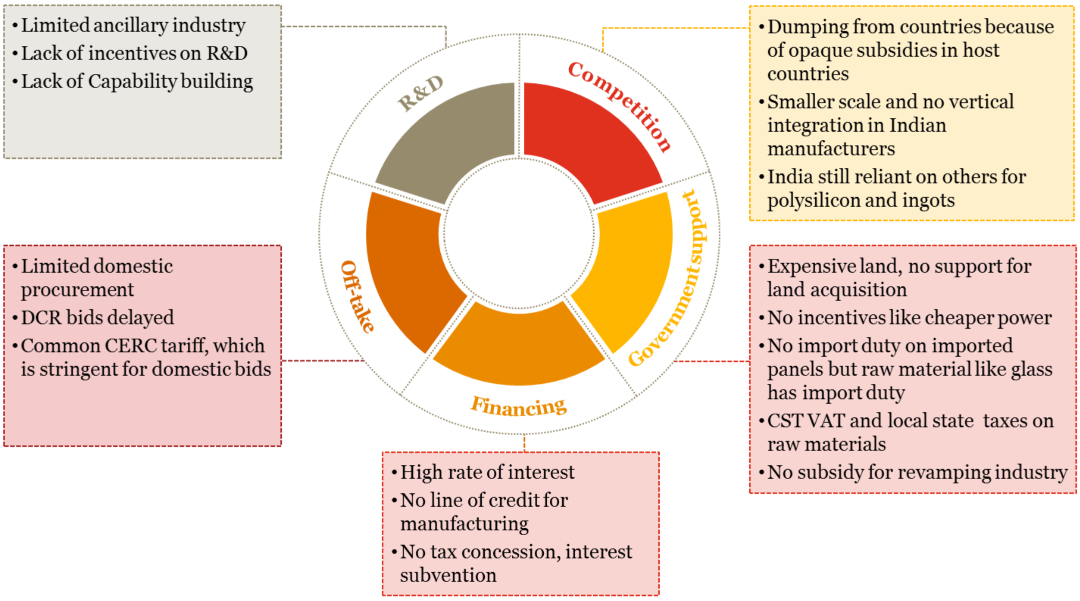


Figure 15: Challenges faced by solar PV domestic manufacturers

Majority of the Solar PV modules are manufactured from C-Si solar cells and occupies a major chunk with almost 90% of installed capacity. This trend is expected to continue and dominate in the near future. Research is still underway to improve the efficiency at cell and module level. Commercially available solar PV modules have efficiency levels up to 23% and some laboratories have managed to achieve 25.6% and 29.1% is the theoretical limit. There is also room to improve efficiency at module level by improving the quality of the etching and materials used while fabrication. Key components include glass panels on the front and back, concentrators, the density of silicon (g/Watt) used to manufacture and a shift to better metals.

Table 2: Snapshot of c-Si technologies

Crystalline silicon technologies	2010-2016	2016-2020
Efficiency achieved/targets	Single Crystalline -20% Multi Crystalline- 17%	Single Crystalline -22% Multi Crystalline- 19%
Industry Manufacturing aspects	Silicon (Si) consumption < 5 grams / watt (g/w)	Si consumption < 3 g/W
R&D aspect	• New silicon materials and processing • Cell contacts, emitters and passivation	Improved device structures Productivity and cost optimization in production

Table 3: Snapshot of thin film technologies

Thin Film technologies	2010-2015	2015-2020
Efficiency achieved/targets	• Thin film Si: 10% • Copper-indium/gallium (CIGS): 14% • Cadmium-telluride (CdTe): 12%	• Thin film Si: 12% • Copper indium/gallium (CIGS): 15% • Cadmium-telluride (CdTe): 14%
Industry Manufacturing aspects	• High rate deposition • Roll-to-roll manufacturing • Packaging	• Simplified production processes • Low cost packaging
R&D aspect	• Large area deposition processes • Improved substrates and transparent conductive oxides	• Improved device structures • Improved deposition techniques

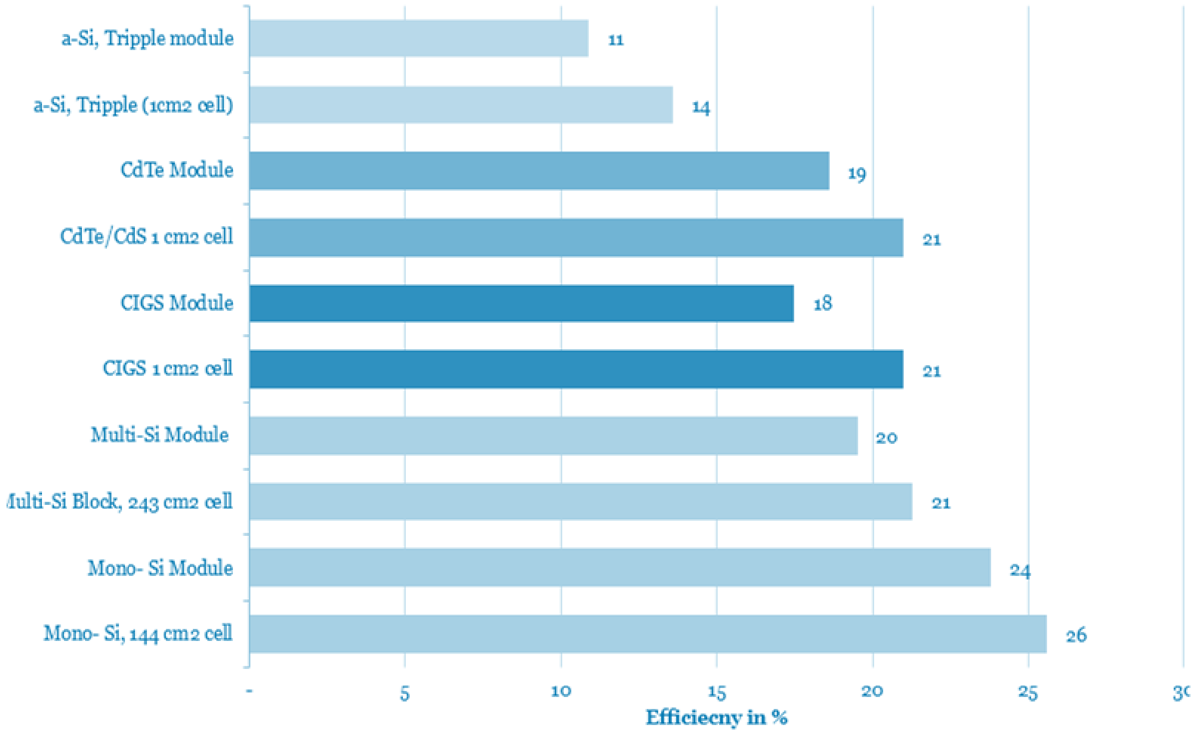


Figure 16: Efficiency Comparison of Solar Technologies

2.10.2.1. Solar PV cell/module imports in India

The current manufacturing capacity in India is unable to accommodate the pace of installations which are happening at GW scale. Developers are relied upon Chinese and other countries to import cheaper modules which are lower in price than the indigenous modules. The country has increased its imports from $0.7 billion in 2013-14 to $ 3.84 billion[21] by 2017-18.

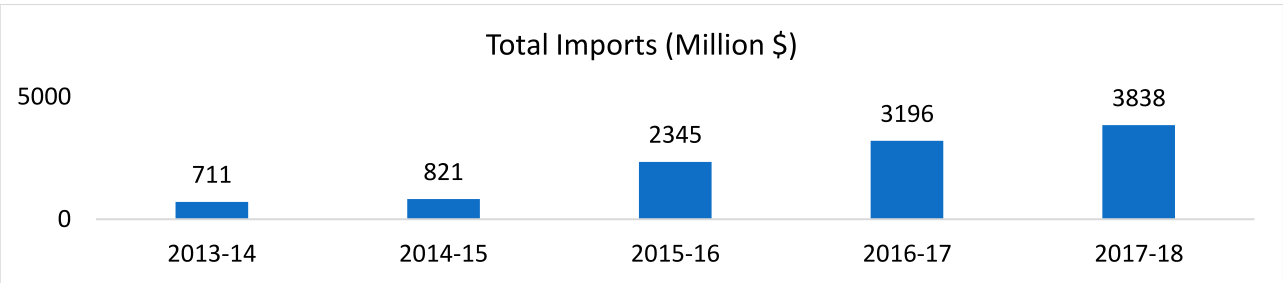


Figure 17: Total Imports (Million $) from 2013-2018

The industry by its sheer volume is capable of changing the landscape of Indian economy through industrial growth. According to ministry of commerce, India imported $ 3.84 billion solar panels in financial year 2017-18. Of these, $ 3.26 billion, or 85%, were imported from China. The share of Chinese modules in India has been the highest for the obvious reasons of India not imposing import duties on Chinese modules and the panel price which is Rs. 5 to Rs.6 cheaper than other modules. The total import expenditure of India on solar panels across the world in past 7 years is represented below:

[21] https://commerce.gov.in/writereaddata/UploadedFile/MOC_636691658509921558_LS-06-08-2018.pdf

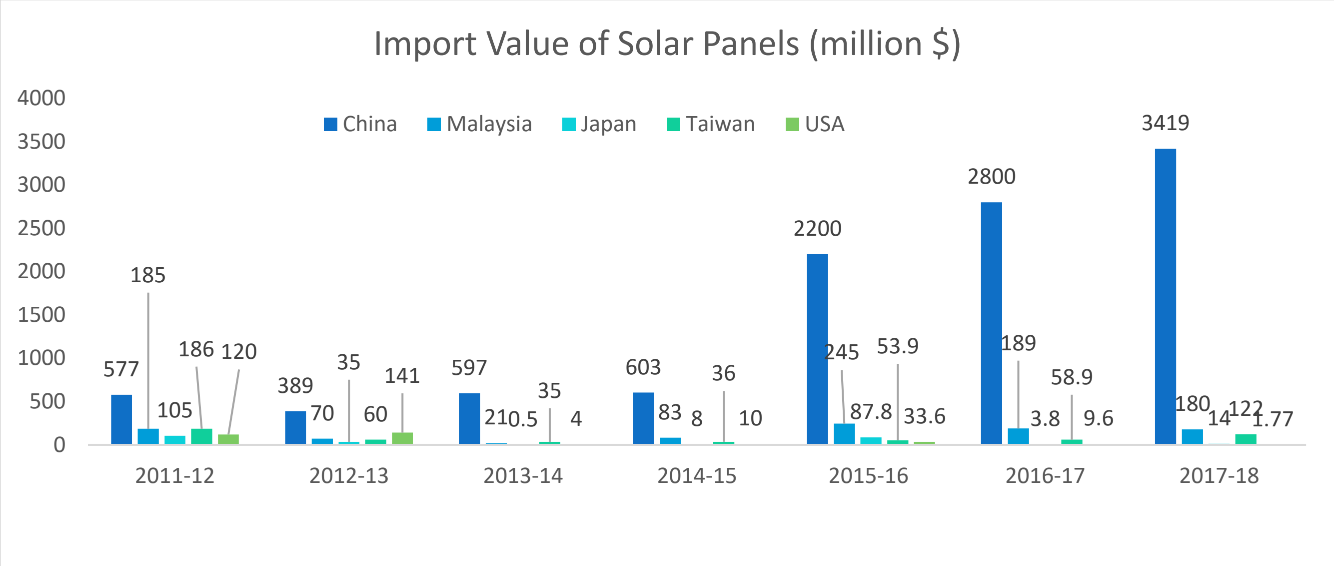


Figure 18: Import Value of Solar Panels (million $) from different countries[22]

Thus India's import of solar panels across the world have risen from $821 million in 2014-15 to $ 3.84 billion in 2016-17. The price trends for imported and Indian made modules is depicted in the figure below, it is clear from that the landing price of solar PV modules from china are cheaper than the Indian made.

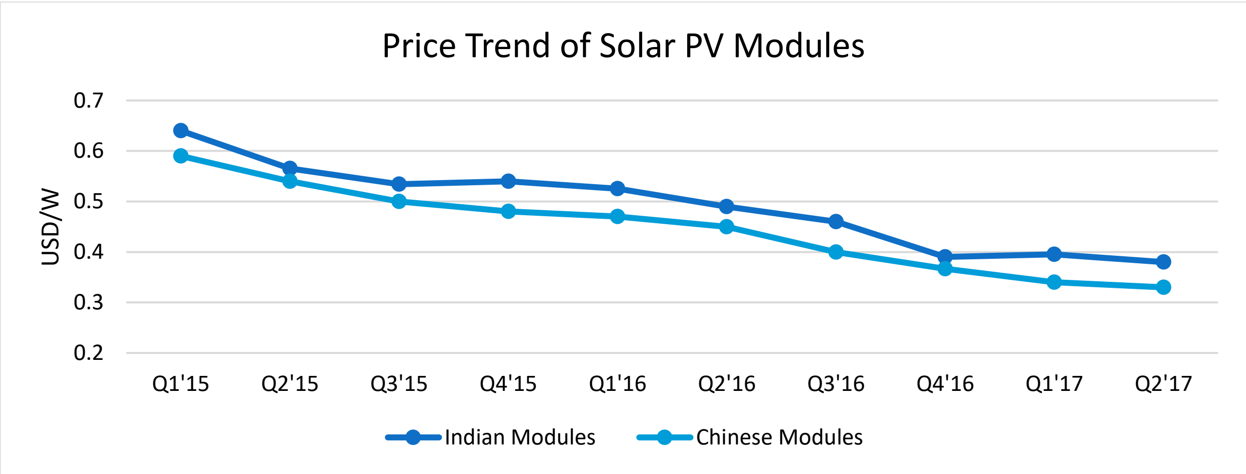


Figure 19: Price trend of solar PV modules

Price of modules in India dropped down to USD 0.35-0.40 per watt, depending on the quantity and size of the plants. The record low bids in India are mostly driven by extremely low Chinese module prices which have enabled developers to aggressive in reverse auctions in anticipation of falling Chinese modules.

2.10.2.2. Quality concerns over plummeting solar PV tariffs in India

India has seen new low in the Solar PV tariffs, with a favourable investment climate, conducive policies, reverse auction mechanism and large scale of projects has resulted in the tariffs for solar power falling from ₹ 17.91/KWh in 2011 to record lows at ₹ 2.44/KWh[23], providing a boost to the government's green energy drive. Lowest tariff discovered in

[22] http://commerce-app.gov.in/eidb/Icomcnt.asp
[23] Tariff of INR. 2.44/KWh for 200 MW (Acme) and 2.45/KWh for 300 MW (SBG Cleantech) determined after reverse auction carried out by Solar Energy Corporation of India (SECI) for 500 MW solar PV projects in Bhadla Phase 3 solar park in Rajasthan.

Andhra Pradesh has been ₹ 2.62/KWh and in Madhya Pradesh has been INR3.30/KWh. In certain states the tariff for solar and wind is below the Average Pooled Power Purchase Cost (APPC) and now offers distribution companies a very economical proposition for green power.

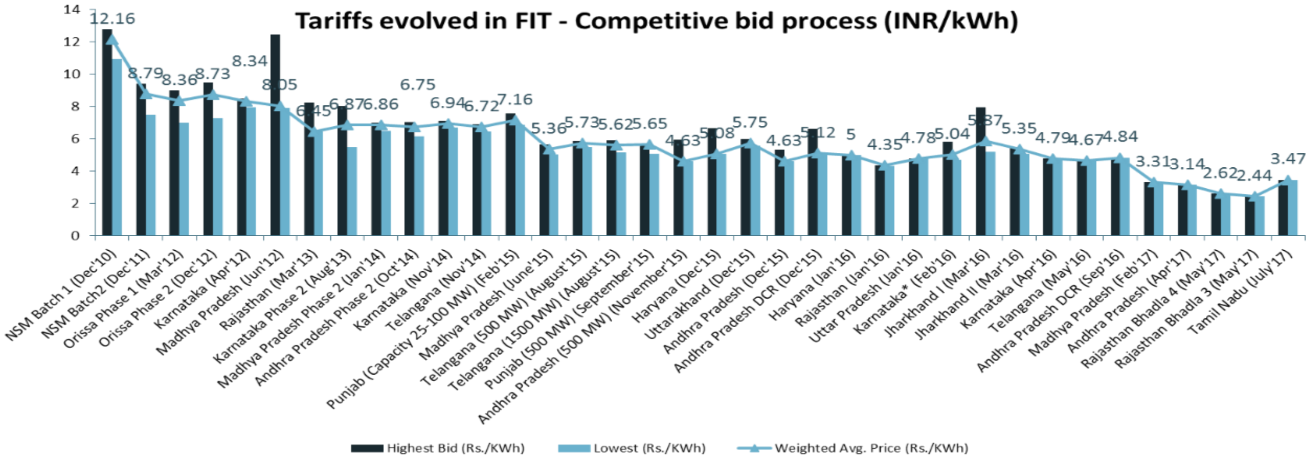


Figure 20: Evolution of Solar PV tariffs in India

This was achieved by engaging high credit rating power off-takers and introducing three-tier payment security mechanism to insulate the project developers from delayed payment risks. At the first level the developing agency will provide a letter of credit equivalent for one month of the energy bill payments. In the second level, a payment security funds were instituted and at the third level, the state guarantees. If the first two layers are breached then the state government will be responsible for the delayed payments.

Aggressive competition and strong price pressure have led to compromise on the quality of the components, predominantly solar PV modules. As per the report published by PI Berlin, which highlights the quality and installations flaws that could have been avoided in the PV projects, due to lack of quality framework.

Figure 21: Factors behind the low solar PV tariffs from developers' perspective

3. Quality in Renewable Energy Infrastructure

Quality assurance is an underlying requirement for establishing an enabling environment for swift uptake of renewable energy technologies. Quality assurance includes standards intended to assist in enabling the products and services perform as expected, as well as on the mechanisms to verify that such requirements are fulfilled, such as testing, certification and inspection. QA consists of activities which makes sure that a product or service meet the expectations of consumers, investors and other stakeholders. Quality Infrastructure of any country is guided by the regulations applicable over there.

In the context of renewable energy, QA enables the quality control of products and services used in installation of renewable power plants. Along with their capacity, the reliability and service life of equipment used are the key factors while considering installation of a solar power plant. There arises the need of generating a framework for technology policy aimed at accelerated renewable energy development and deployment. Quality assurance (QA) for renewable energy technologies is an important instrument to achieve this goal, as it will be an enabling factor in strengthening the rapidly growing markets and reducing the transaction costs for such technologies. This also helps in mitigating the risks and build up market trust to scale up its deployment.

Majority of the IPPs and developers are now relying on the products that are tested and certified in order to ensure the quality, safety, reliability, and performance of their power plants. They need to implement Quality Assurance mechanisms in order to prevent underperforming and failure-prone products from ruining perceptions of the technology and hence bringing the market to a standstill.

In India, the quality is predominantly focused on the components certification and less on the design and engineering of the solar energy plants, which has led to accelerated degradation of solar PV projects. Quality infrastructure should focus on the overall value chain to have a sustainable operation and long term growth of the solar energy.

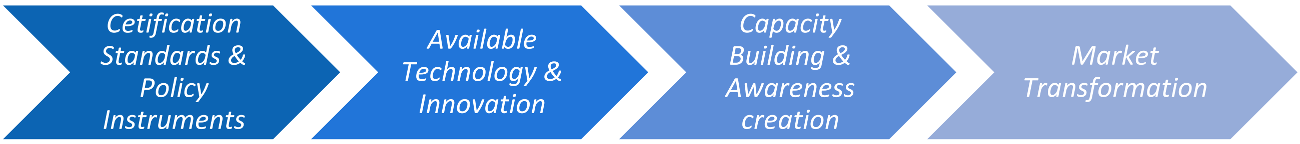
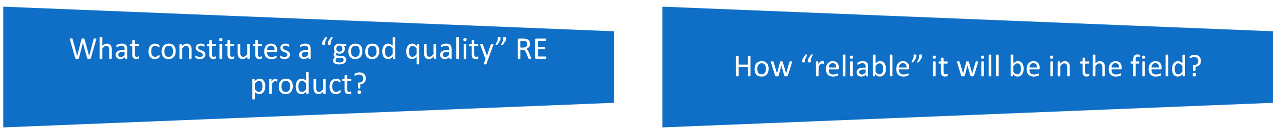


Figure 22: Requirement of REQI across the project phases

3.1. Quality Process in Solar PV and Thermal Value chain

Renewable energy products often used to produce electricity and heat and sometimes both. The functionality of the products depends on the configuration of the products integrated into one system. It is necessary to understand the quality process standardized by IEC and UL globally which are followed and implemented from cradle to gate of the product life cycle. There are various quality assurance standards, tests and certifications right from the products manufacturing, shipments, integration and installation, operation and maintenance and reliability testing.

The solar industry has experienced incredibly fast transformation after year 2000 as a result of extraordinary technology breakthrough, from material level up to large-scale manufacturing. With the solar PV and Thermal industry expected to grow consistently in the coming years, two main questions are capturing the attention among market operators:



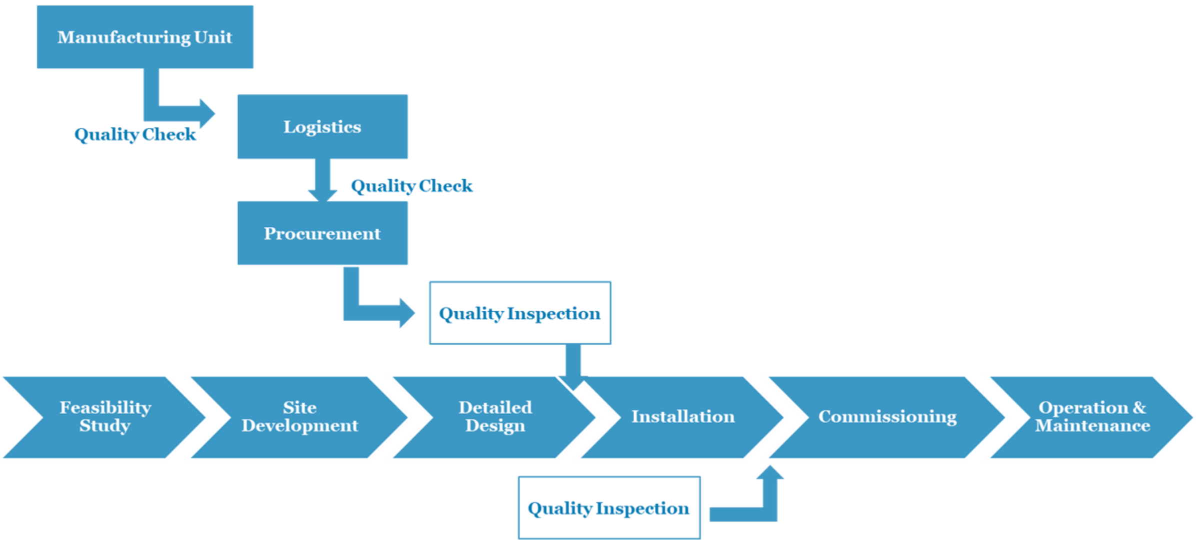
In the certification field, design qualification is based on type testing according to IEC, EN or other national standards. When type testing is combined with periodic factory inspections by a certification body constitutes the basis for the certificates issued by that certification body (thus bearing their particular mark/logo).

The trend in the recent times can be outlined by the reliability and longevity etc. of the solar PV and thermal products, solar PV panels bearing the center part of the system that will greatly contribute to the achievement of low carbon society.

The importance of quality and its application will begin right from the raw material procurement to consumer applications. Globally, quality process is being followed right from the production of PV/Thermal products and also during and post production. Once the products are manufactured, it is important to test the performance in terms of electrical, mechanical and other environment impact parameters to have robust operating life cycle.

The end user and the manufacturing unit are located at different geographic locations, it is necessary to impart shipment quality process and standards to avoid the risk of damage during shipment. Batch selection and random checks are followed globally to detect the damaged components before supplying it to the end user.

The Indian solar market is always facing price pressures that leads to little attention to PV module quality. India expects diverse climatic conditions in different regions and hence the performance varies due to not only quality issues of modules, but also the design framework and the Operations & Maintenance (O&M) techniques used at project site. Various stages involved with construction of solar plant are Feasibility study, site development, detailed design, installation, commissioning and operations & maintenance. The quality checks are meant to be performed across the value chain at each stage of project development starting from site development to Operations & maintenance.



All the failures of modules are not because of the quality issues, but also because of the commissioning and lack of proper operation & maintenance. There are few sites identified in India where faulty electrical joints and delamination were observed. Defects like these could be avoided before and during production of the PV modules. PV modules were observed at all sites with cracked cells that were likely caused during transport, installation and maintenance. These defects could have been prevented if the PV modules were handled proficiently.

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In most regions, PV projects are primarily affected by a few climatic stress factors, such as salt in the air, high UV radiation, high humidity, heat, sand or strong winds. In several areas of India PV Projects often face a large number of these factors at the same time. Example: Rajasthan faces problems due to the high level of solar radiation leading to damaging of solar PV modules because of climatic stress factors. India has some of the highest solar irradiation rates in the world but that can also lead to faster component degradation. The report by **PI Photovoltaik-Institut Berlin AG (PI Berlin**) studied six PV plants in India to conduct a pilot study on quality aspects of PV power plants in India. The report highlighted that apart from quality defects there were other reasons for improper functioning of PV plant. The issues identified are classified as : pre installation issues, during installation and post installation issues.

Problems identified are:

Pre-Installation

- Civil Works:
  - Foundation of mounting structures not robust
  - Water accumulation at site
  - No row labelling
- Damage during logistics
- Damage by workers

During Installation

- Improper module fixing
- Cleanliness of the combiner boxes
- Low bending radius in the string cables
- Degraded cable pipes
- Loose fixation of the PV modules to the cross beam
- Improper anchorage of the mounting structure foundation to the roof top surface

Post Installation

- Potential Induced Degradation (PID)
- Snail trails
- Hot spots
- Soldering failures during module manufacturing
- Cell breakage and micro-cracks
- Back sheet scratches
- Yellowing of Solar Panels
- String cables damaged by monkey bites
- Damaged modules due to strong winds
- Dirty air filters due to dust accumulation

All the above defects arise not due to the quality issues, but improper handling, installation and non – monitoring at the project sites. There is a need for design and installation framework for proper monitoring of site, skill development of workers at site, improving the quality of manpower, having insurance of modules & equipment, etc.

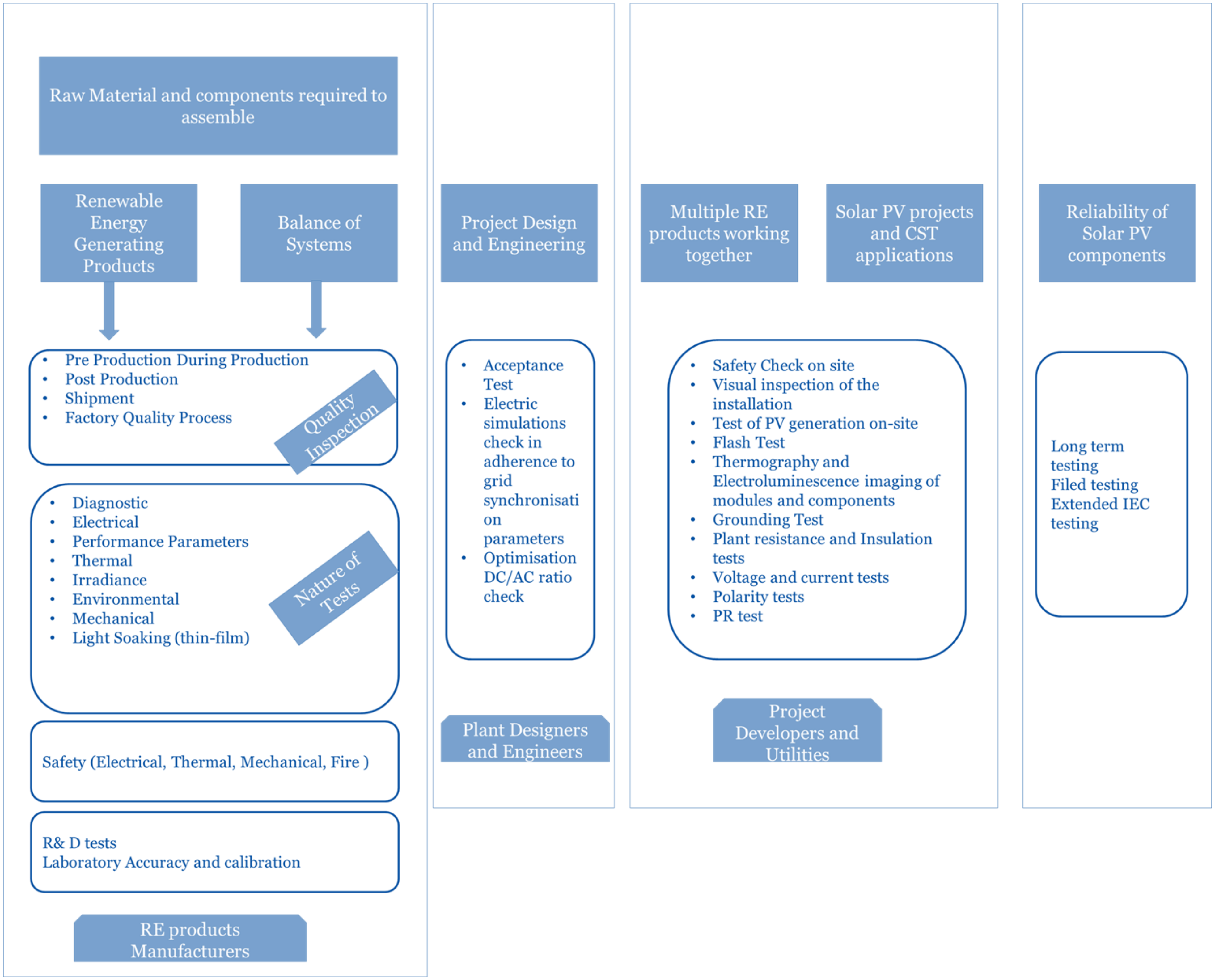


Figure 23: Quality across RE value chain

3.2. Requirement of Quality Infrastructure for Renewables

With the ambitious target of 100 GW solar installation in India by 2022, there has been an abrupt growth in this sector and a lot of new players have entered the market in a very short span of time. The tariffs are falling continuously with every passing bid (a historic low of INR 2.44/ KWh was achieved for Bhadla Solar Park). Thus, in order to realize a significant return on their investments, the developers will certainly compromise on the quality of the products and services required for the installation of solar power plants. Hence, in order to safeguard quality assurance of these solar power plants, it is critical on the part of MNRE to ensure performance testing and standardization of the equipment installed, to maintain a certain quality, reliability and life of the power plant.

There are three phases in the execution of a solar power plant:

I. Manufacturing of components such as modules, inverters, cables, mounting structure etc.

II. Project Execution – It consists of three stages:

  a) Development – Site selection, leasing, purchasing of the site, permitting

  b) Engineering, procurement and construction – Plant design, electrical and civil engineering works, construction,

  c) Financing – Financial due diligence, sale to investors

III. Operations & Maintenance - Monitoring, insurance, regular maintenance

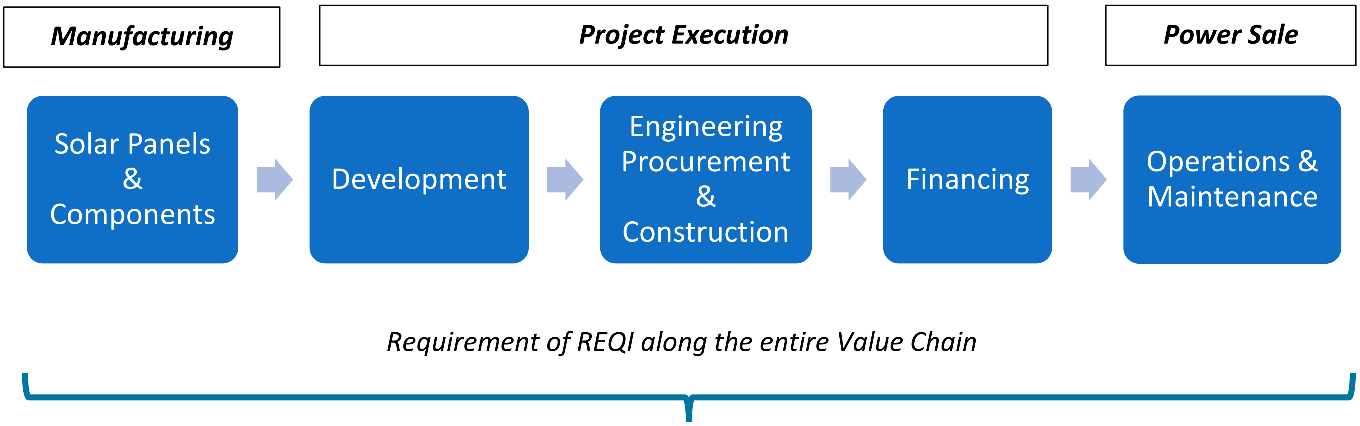


Figure 24: Solar Plant Value Chain

3.3. Current status of Quality Infrastructure for Solar Energy

The Ministry of New and Renewable Energy (MNRE) is engaged in promotion of development and deployment of renewable energy for addressing the growing energy needs and climate change concerns of the country. Performance testing and standardization is essential to ensure quality and reliability of products installed to achieve the enhanced targets set by the ministry. Test facilities have been set up for carrying out performance testing of various renewable energy systems. Indian Standards are available for most of the renewable energy systems by Bureau of Indian Standards (BIS). Some of these standards as applicable on various equipment at a solar facility are depicted in the table below:

S. No.	Product	Indian Standard No.	Title of Indian Standard
1.	Crystalline Silicon Terrestrial Photovoltaic (PV) modules (Si wafer based)	IS 14286	Crystalline Silicon Terrestrial Photovoltaic (PV) modules - Design Qualification and Type Approval
2.	Thin-Film Terrestrial Photovoltaic (PV) Modules (a-Si, CiGs and CdTe)	IS 16077	Thin-Film Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval
3.	PV Module (Si wafer and thin film)	IS/IEC 61730 (Part 1) IS/IEC 61730 (Part 2)	Photovoltaic (PV) Module Safety Qualification Part 1 Requirements for Construction Photovoltaic (PV) Module Safety Qualification Part 2 Requirements for Testing
4.	Power converters for use in photovoltaic power system	IS 16221 (Part 1) IS 16221 (Part 2)	Safety of Power Converters for use in Photovoltaic Power Systems Part 1- General Requirements Safety of Power Converters for Use in Photovoltaic Power Systems Part 2- Particular Requirements for Inverters
5.	Utility – Interconnected Photovoltaic inverters	IS 16169	Test Procedure of Islanding Prevention Measures for Utility - Interconnected Photovoltaic Inverters
6.	Storage battery	IS 16270	Secondary Cells and Batteries for Solar Photovoltaic Application General - Requirements and Methods of Test

Table 4: Standards for major PV plant components

With a target of 100 GW solar to be installed by 2022, MNRE has already prepared a "**National Lab Policy**" for Testing, Standardization and Certification in Renewable Energy Sector in order to prevent poor quality of imported goods from entering into Indian market. These technical regulations will guide the quality infrastructure in the sector, hence making standardization of all goods mandatory and maintain quality to protect human health and safety.

National Lab Policy brought out a strategic action plan and structure for developing a comprehensive plan in establishing a robust system for testing, standardization and certification process and in meeting the renewable energy deployment goals with quality and reliability. It provides a strategic plan and the framework for the coordinated development and delivery of quality and accessible testing and certification services in renewable energy sector. It outlines the major issues that need to be addressed, including organizational and management structure, human resources, laboratory infrastructure, care and maintenance of equipment, a functional information management system, a quality management system and adequate financial support.

All equipment of the solar power plant shall conform to international standards including IEEE (Institute of Electrical and Electronics Engineers) for design and installation of grid connected PV system. The standards cover various aspects such as PV modules, cable types and selection, temperature considerations, voltage ratings, BOS wiring, inverter wiring, blocking diodes, bypass diodes, disconnect devices, grounding requirements, surge and transient suppression, load center, power qualities, protection features and safety regulations. These standards are already well recognized but due to lack of regulations, it is difficult to assess whether quality of the installations is meeting these standards.

The following codes and standards are followed during construction of the power plant:

- Indian Electricity Rules for design of the electrical installation
- National Fire Protection Association (NFPA) 70-1990(USA) or equivalent national standard
- National Electrical Safety Code ANSI C2 -1990(USA) or equivalent national standard
- IEEE 928 - 1986: Recommended criteria for terrestrial PV Power Systems
- IEEE 929 – 1988: Recommended practice for utility interface or residential and intermediate PV systems
- IEC 61646: Standard for PV Modules

There are various tests that are done to ensure Solar Thermal quality standard, which are as follows:

- Collector testing on flat and vacuum tube collectors that comply with European standard EN 12975 and SRCC standard 100
- Performance testing of warm water storage in compliance with European standard EN 12977-3
- Inspection of absorbers and internal thermal shock test
- Inspection of standardized systems
  Performance and quality testing based on European standard EN 12976, for example, for integrated storage collectors and thermo-siphon systems
- Inspection of customer-specific systems
  Testing of collectors, regulators, and storage systems with component testing system simulation (CTSS) based on the European pre-standard ENV 12977

3.4. Implementation of Quality Assurance for Renewable Energy

With the amount of influx of Renewable energy in the Indian Power sector in recent years and the ambitious target of taking the installed Renewable capacity to 175 GW by 2022 (of which 100 GW is solar), it becomes imperative that the processes and the equipment deployed are reliable, certified and of designated standards which is possible with the implementation of quality assurance instruments.

Thus, in order to implement quality assurance instruments, it is required to first establish a Quality Infrastructure (QI). A quality infrastructure for Renewable energy consists of various elements such as:

Regulatory Authorities, Accreditation bodies, Metrology institute, certification bodies, test laboratories, inspection bodies, calibration laboratories, standards body, manufacturers and suppliers and RETs, consumers.

These elements are co-related and are administered by the organizations that define these standards, following the consensus-based approach of all the stakeholders.

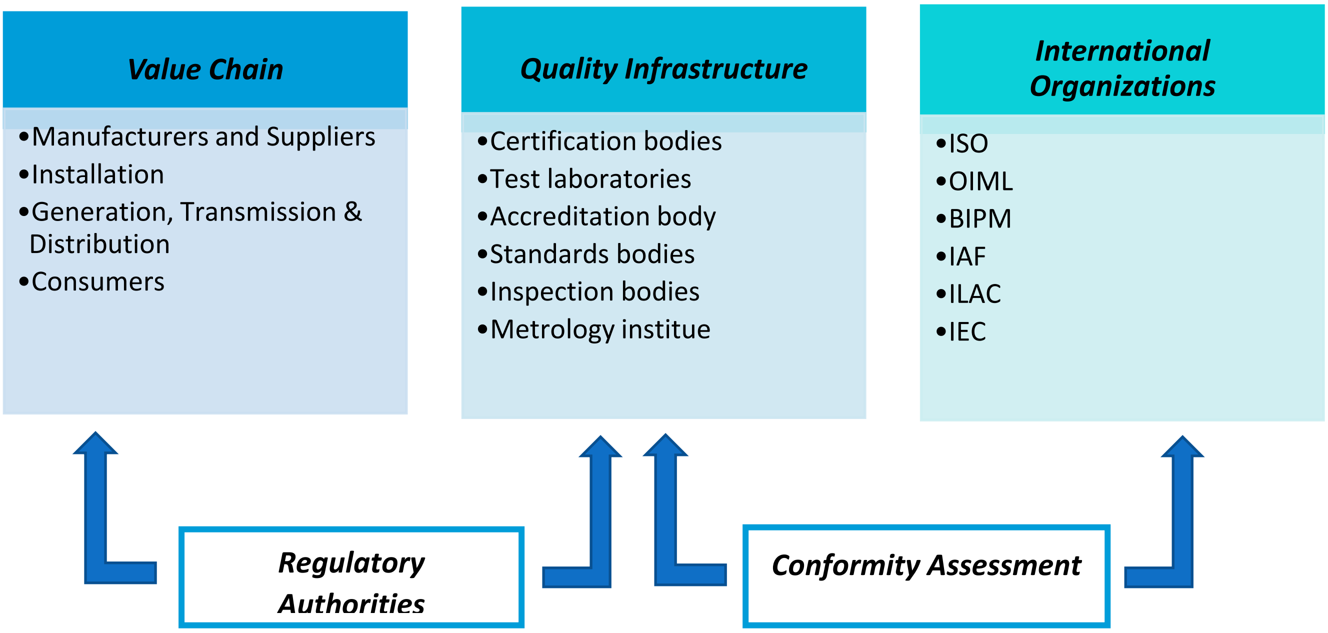


Figure 25: Organizations involved in Quality Infrastructure

Hence, to implement quality assurance for renewables and for the development of quality control and standards, all the elements of REQI need to work in close cooperation. There is a need to bridge the gap and enable a proper channel for communication between all the stakeholders involved in quality assurance and renewable energy space. Regulatory authorities, industry and quality infrastructure institutions specifically need to work in cognizance for effective of establishment of a Quality Infrastructure (QI).

Methodology –

Proposed methodology that has been developed consists of three key steps:

1) Assessment of key situational components

2) Determination of the level of REQI

3) Formulation of recommendations for transitioning to the next level of REQI

The integration of quality infrastructure for Renewable energy with focus on reduction of energy costs and demonstration of energy efficiency forms the core of developing business models for Energy sector in current scenario. With the continuous reduction in prices of solar installation equipment such as solar modules, inverters, BOS etc., the focus is not only on the cost effective measures but how to deliver quality projects with reliable and a much improved infrastructure.

This will not only improve the financial status of the company by reducing overall expenses and costs, but also develop the brand image of the company along with trust of the customers.

4. Standards and Testing Assessment

A Standard is a technical specification designed to be used regularly as a rule, guideline, or definition. These standards are agreed upon, documented and increase the reliability and the effectiveness of the products and services associated with them. Standards are formed as a result of the dedicated effort by a group of experts and when they arrive at a consensus, standards are developed. As standards are established on a consensus and stakeholder consultation basis, they represent what can be agreed upon. Hence, a standard is the coordinated synthesis of what the group has agreed upon to publish.

It is not mandatory that standards are only developed by standardisation bodies, such as ISO or the IEC. Any organisation can develop standards to meet their desired requirements. These tailored standards developed by an organisation to meet its specific needs constitute Organisation's standards.

Standards are also an effective tool for protection of consumer rights beyond the existing policies of the government. This becomes vital in the backward areas of the developing economies like India, where consumers do not have the luxury of selecting a product after comparing them. Thus, it is imperative for the standards to ensure that whatever product or service is provided to the consumers is reliable, safe, durable, worthy of its cost and performs as specified.

Renewable energy standards and conformity assessment can help in promotion of renewable energy technologies as an alternative to conventional sources which are generally detrimental to human health and operate with low efficiency. The consumers can be entrusted and provided confidence in using these renewable energy products by standardizing them such that they operate safely, efficiently and reliably. This will be achieved by adopting the practices in designing, specifying, installing and maintaining the systems.

Formation of standards is a complex and tedious process but must always be formed in alignment with regulations, policies and legislations of the applicable territory. The types of standards developed depend on the requirements, which can include whether there is global relevance, regional mandates or support required for legislation and regulation, or whether the standard is intended to support national or stakeholder deployment. Also, the implementation requirements for standards vary depending on who has developed them, the type of standard being published and its hierarchical status.

4.1. Standards making bodies

Standards can be developed and published by anyone who has a requirement to establish a set of formal parameters to work within. However, for standards to be acceptable, they need to come from a credible body, which can demonstrate that the standards have been developed with due diligence and on a consensual basis. This is the reason most countries and regions have official standards bodies. There are generally four levels of standards bodies, which are shown in the figure alongside.

Figure 26. Levels of standard making bodies

Figure 27: Levels of Standard making bodies

4.1.1. International Standards:

The International standards bodies relevant to renewable energy are the International Organization for Standardization (ISO) and the International Electro-technical Commission (IEC). Both these organisations cover different technologies but work in a coordinated manner with agreement over various issues.

ISO and IEC are member driven organisations, providing a vast coverage of standards, either developed or under development, for products covering most current renewable energy technologies. These international standardisation bodies continue their efforts to accelerate the development process of standards as much as possible. Their best practices are also adopted for the development of standards at the national or regional levels.

In cases, where international standards are adopted for performance testing and certification, harmonization of standards adapting local conditions is essential for effective promotion of technology.

4.1.2. Regional Standards:

There is also a notion that international standards don't take local requirements fully into consideration. Different markets have different and specific requirements, hence the renewable energy standards for a particular market are developed to meet their specific needs, such as to comply with legal directives and regulations. For e.g. there will be different standards for the same set of renewable energy products in Asia than in Europe or Americas or Africa.

Regional standards are basically developed in adaptation to the local requirements and in cohesion with the applicable legislations and regulations. Most of the regions have only a fragmented system of standardisation and there is no apparent association between countries in other regions. However, efforts are being made to encourage the acceptance of international standards.

4.1.3. National Standards:

All the developed countries and most of the developing countries in the world have their own national standardisation body (NSB). For e.g. India follows IS standards as prescribed by the ***Bureau of Indian Standards*** (BIS, the national Standards Body of India working under the aegis of Ministry of Consumer Affairs). These bodies are responsible for the development and implementation of standards. NSBs can become members of both the International and Regional Standards bodies.

Most of the countries have established their own standards but in case of any conflicts between standards, the national standards are generally withdrawn in favor of regional or international standards.

4.1.4. Organisation's Standards:

Organisation's standards are developed to meet the specific needs within the organisation and are documented by the people within the organisation or some external consultants (experts who have been previously involved in the development of national, regional and international standards) are hired for this very purpose. These standards are developed in consensus with the internal as well as the external experts.

The table below shows the standardisation bodies involved in the global development of standards.

Table 5: Standardization bodies at different levels

Level	Geographic coverage	Standards making organisations involved in Renewable Energy and Energy Efficiency
International	Global	ISO – International Organization for Standardization (Members = 163) IEC – International Electro-technical Commission (IEC Family: 82 Members + 81 Affiliates)
Regional	Europe	CEN – European Committee for Standardization (National Members = 31)

		CENELEC – European Committee for Electro-technical standardization (National Members = 32 plus 11 National Committees)
	Africa	ARSO – African Organisation for Standardisation (Members = 29) SADCSTAN – Southern African Development Community Cooperation in Standardization (Members = 15) AFSEC – African Electro-technical Standardization Commission (Members = 18) AFRAC – African Accreditation Cooperation (Members = 8)
	Asia Pacific	PASC – Pacific Area Standards Congress ASEAN – Consultative Committee for Standards and Quality
	Eurasia	EuroAsian Interstate Council for Standardization, Metrology and Certification
	Americas	COPANT – Pan American Standards Commission AMN – Asociación Mercosur De Normalización CROSQ – CARICOM Regional Organization for Standards and Quality CANENA – Council for Harmonization of Electro-technical Standards in the Nations of the Americas
	Middle East	Regional Center for Renewable Energy and Energy Efficiency (RCREEE)
National	National standards bodies	164 NSBs globally are members of ISO and listed on ISO website 82 National Committees Members of the IEC and 81 Affiliate Countries are listed on IEC website
Others, national and international	Standards-developing organisations	There are many independent standards development organisations such as - ASTM, FSC, PEFC, RSB, RSPO, Bonsucro etc.

4.2. Solar PV Testing

Solar photovoltaic (PV) systems are being installed in ever increasing numbers, and are expected to safely and reliably produce electrical energy over several decades of operation. Any electrical system can be tested to verify performance and to evaluate the status of wiring systems and equipment. This is particularly important for PV installations, which are subjected to extreme environmental conditions and deteriorating effects of the elements over their entire lifetime. In order to ensure the long-term safe operation of these systems, execution of quality PV installations is a basic requirement prior to commissioning followed by a regular periodic testing and maintenance program. These practices can help promote safety and optimize performance, and provide essential information required to effectively troubleshoot, diagnose and remedy problems with the system.

Performance testing and standardization are the key pre-requisites for spreading confidence of quality assurance, and for extensive use of renewable energy for the benefit of society. Thus, standards and test labs are critical components for quality assurance, and hence for industry to maintain consistency in manufacturing their products. This requires adequate test labs equipped with modern equipment and instrumentation and scientific methodology and test protocols for testing and performance evaluation of technologies/systems.

There are a number of testing facilities in India which are involved in the testing of solar photovoltaic modules, inverters and related products like solar home lighting systems, solar street lighting system & solar lantern, solar battery, solar charge controller etc. as per IS & IEC standards and directed by MNRE specifications. Testing facilities would probably also be required for a designated region, and might be required to be built locally. Such facilities would require specific environment and equipment, which needs to be provided.

Below is the list of accredited test centers in India for MNRE Off-Grid Programme.

Accredited Test Centers by MNRE

Lab/Organization	PV Module	Lightning Systems		Battery	Inverter >100W		Charge Controller	
		As per MNRE Specifications	Environmental		Efficiency	Environmental	Protections	Environmental
NISE, Gurgaon	Yes (IEC61215 up to 100 Wp) NABL Accredited	Yes MNRE Accredited/NABL	Yes (Including IP) MNRE Accredited/NABL	Yes MNRE Accredited	Yes (up to 10 KVA) MNRE Accredited	Yes(Including IP) MNRE Accredited	Yes MNRE Accredited	Yes (Including IP) MNRE Accredited
ERTL (East)	STC Test Facility MNRE Accredited	Yes NABL/MNRE Accredited	Yes NABL/MNRE Accredited	Yes Up to 1000 Ah	Yes NABL/MNRE Accredited	Yes NABL/MNRE Accredited	Yes NABL/MNRE Accredited	Yes NABL/MNRE Accredited
ETDC	Yes (IEC61215) under ICEEE-CB, IEC 61701 (up to 100 Wp) NABL Accredited	Yes NABL/MNRE Accredited	Yes NABL/MNRE Accredited	Yes Up to 100 Ah	Yes (up to 3 KVA) NABL/MNRE Accredited	Yes NABL/MNRE Accredited	Yes NABL/MNRE Accredited	Yes NABL/MNRE Accredited
CPRI	No	Yes NABL/MNRE Accredited	Yes NABL/MNRE Accredited	Yes Up to 1000 Ah	Yes (up to 10 KVA) NABL/MNRE Accredited	Yes NABL/MNRE Accredited	Yes NABL/MNRE Accredited	Yes NABL/MNRE Accredited
ERTL (North)	No	Only Electronics & luminaire NABL Accredited	Yes NABL Accredited	No	Yes (up to 5 KVA) NABL Accredited	Yes NABL Accredited	Yes (up to 5 KW)	Yes NABL Accredited
UL	Yes (IEC 61215, IEC 61730 part II and IEC 61701) up to 400 Wp NABL Accredited	Yes (except battery) NABL Accredited	Yes NABL Accredited	No	Yes (up to 6 KVA) NABL Accredited	Yes NABL Accredited	Yes (up to 6 KW) NABL Accredited	Yes NABL Accredited
TUV Rheinland	Yes (IEC 61215 and IEC 61730 part II) up to 400 Wp NABL Accredited	No	Yes NABL Accredited	No	Yes (up to 10 KVA) NABL Accredited	Yes NABL Accredited	Yes (up to 10 KW) NABL Accredited	Yes NABL Accredited
Intertek	No	Only Electronics & luminaire NABL Accredited	Yes NABL Accredited	No	Yes (up to 5 KVA) NABL Accredited	Yes NABL Accredited	Yes (up to 5 KW) NABL Accredited	Yes NABL Accredited

Table 6: Accredited Test centers by MNRE

In the renewable energy sector, testing, certification and inspection laboratories are typically based on ISO/IEC standards. Third-party independent certification also falls under a number of certification process which we can broadly categorize into Product Certification (e.g., ISO/IEC Guide 67 & ISO/IEC Guide 65), Personnel Certification (ISO/IEC 17024), Laboratory Testing (ISO/IEC 17025) and Management Systems Certification (ISO/IEC 17021). There are a large volume of standards that cover the design, manufacture and testing (laboratory and in the field), installation and commissioning of products. Majority of the standards in the renewable energy field have been developed for the testing, sampling and analysis of products and systems, and the majority of these are in the solar PV field.

As PV systems now cover a range of applications from standard panel modules for electricity generation to building integrated PV (BIPV), the requirement for more testing methods is likely to grow. New testing methods would enable manufacturers to substantiate their claims and will also ensure their manufacturing processes are not compromised.

The testing facilities in India are private as well as government and are guided by the regulations as per Bureau of Indian Standards (BIS). These testing facilities are accredited by the National Accreditation Board for Testing & Calibration Laboratories (NABL), Government of India. All the testing facilities provides standards in accordance with IS and IEC. The figure below illustrates different testing facilities in India.

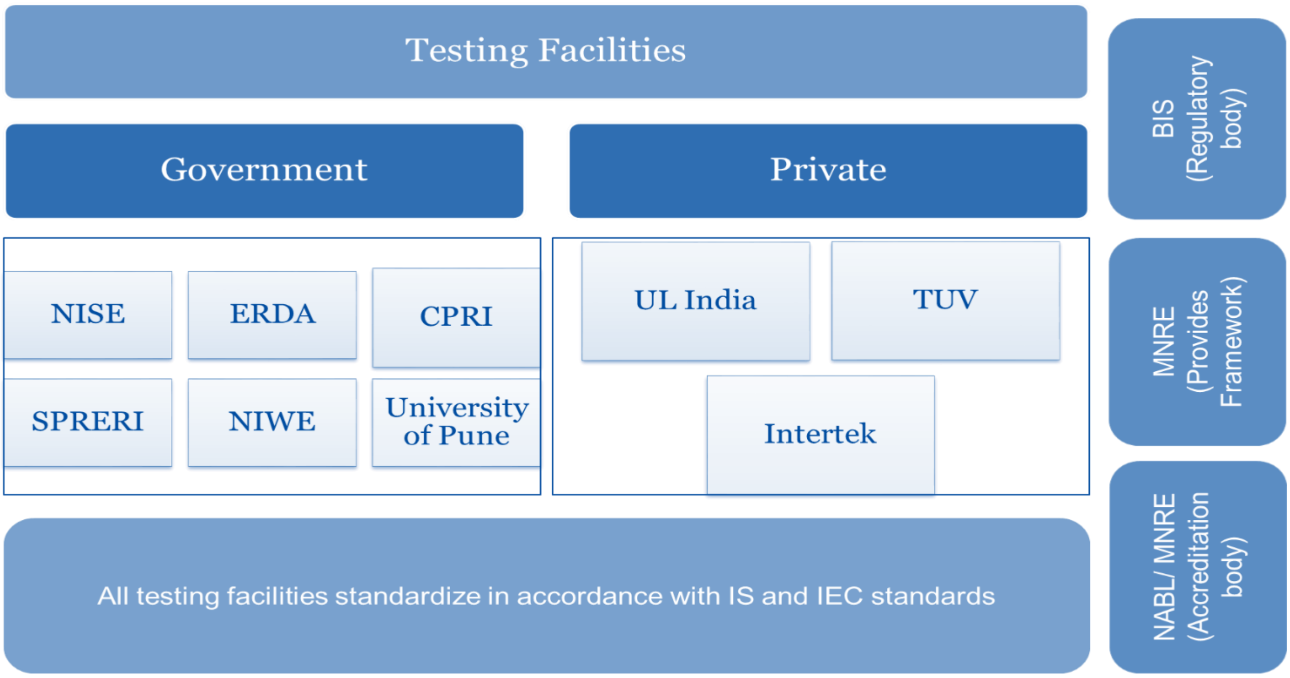


Figure 28: Testing facilities in India

Electrical Research & Development Association (ERDA) is one of the premier testing laboratory in the country accredited by the National Accreditation Board for Testing & Calibration Laboratories (NABL), Govt. of India and its testing facilities and capabilities are recognized by a number of national and international bodies. ***Testing capabilities of ERDA*** are shown in the table below.

Table 7: Testing standards of ERDA

S. No.	Product	IS Standard	IEC Standard
1	Crystalline Silicon Terrestrial Photovoltaic (PV) Modules	IS 14286 : 2010	IEC 61215 : 2005
2	Thin-film terrestrial Photovoltaic (PV) Modules	-	IEC 61646 : 2008

3	Solar Home Lighting System	As per MNRE Specifications	-
4	Solar Street Lighting System	As per MNRE Specifications	-
5	Solar Lantern	As per MNRE Specifications	-
6	CFL based Luminaire	IS 10322 : 2012	IEC 60598 : 2008
7	LED based Luminaire	IS 16107 (Pt-2/Sec-1) : 2012 IS 16106 : 2012	IES LM-79-08
8	Stationary Lead Acid Battery Associated with Solar Panel	IS 1651 : 1991	IEC 60896-11 : 2002
9	Stationary VRLA GEL type Battery Associated with Solar Panel	IS 15549 : 2005	-
10	Stationary Lead Acid Battery in Mono Block Container Associated with Solar Panel	IS 13369 : 1992	-
11	Solar Inverter Associated with Solar Panel	-	IEC 61683: 1999
12	Charge Controller Associated with Solar Panel	-	IEC 62093 : 2005

UL India Pvt. Ltd. is one of the private leading testing facility in the country and is one of the accredited testing center by MNRE for testing, certification and standardization of modules, inverters and other related components such as solar pumps, solar lanterns, solar street lighting etc.

UL has a global network of testing facilities and laboratories which help customers substantiate that products and services comply with government framework and regulations and meet proprietary specifications as well as consumer expectations.

UL provides testing facilities in almost all the fields with advancements and innovation across various categories such as electromagnetic compatibility, product performance, transaction security and equipment testing. Testing standards by UL for PV modules and inverters are shown in the table below.

Table 8: Testing standards of UL

S. No.	Component	Standards	Time Required for Testing
1	PV Modules	IEC 61215 /61646 /61730 - 350 Wp	10 weeks
		IEC 61701 Ed 2 SL1 - 350 Wp	4 weeks
2	PV Inverters	IEC / IS 61683 - 50 KVA	1 week
		IEC 60068 - 250 KVA	4 weeks
		IEC 62116 - 50 KVA	2 weeks
		IEC 61000 - 1 MW	1 week

Central Power Research Institute (CPRI) is a centre for applied research serving as an independent authority for testing and certification of power equipment. It has state-of-the art infrastructure and expertise and has made significant contributions to the power sector in the country for improved planning, operation and control of power systems. Solar PV modules are not tested in CPRI but it has a perfect lab accredited by NABL and MNRE for testing of inverters. Other components such as solar lanterns, pumps and home lighting systems are also tested in CPRI.

The facilities of the Institute are accredited as per ISO/IEC 17025 quality norms and the Institute has acquired international accreditations like Short Circuit Testing Liaison for its global acceptance. Certifications provided by CPRI are widely accepted in the countries of Middle East, Africa and South East Asia.

The test protocols and standards need to be updated with technology progression ensuring quality and reliability of the products. This requires well skilled and experienced scientific and technical manpower, adequate test labs equipped with modern equipment and instrumentation. Hence, it is imperative that test labs are critical for quality assurance and timely delivery of performance test results to industry/project developers.

4.3. Indian Test Methods for Photovoltaic Systems

The Indian test methods for PV systems defined the test methods and best practices to be followed during the quality inspection of PV modules: The steps are:

- **Visual Inspection:**

  Procedure: The modules are integrated in the service workflow through scanner

  Result: Loose junction boxes, faulty cables, deformed frames, cell inclusions and breakages, delamination, visible spots and scratches on the rear are detected

- **Insulation Test According to IEC61215:**

  Procedure: The modules are placed in a water bath and 1,000 volts direct current is passed

  Result: Quality modules that can uphold a resistance for 2 minutes pass the insulation test

- **Infra-Red Tests under Load:**

  Procedure: The modules are powered backwards during the infra-red test to identify possible weak spots in the cell area, connectors and above all the junction box by means of thermal imaging and infra-red camera

- **Other Tests:**

  Apart from tests identified above the other tests include: STC Performance Measurements (Flash Test); Electroluminescence and UV-Fluorescence test

Photovoltaic Balance of System Component Testing and Certification

The service provider offers support with BOS component testing during research and development (R&D). Tests are conducted according to ISO/IEC 17025, which comprises verification of scope and accreditations, testing structure and laboratory layout, operations and maintenance requirements. All the components according to BOM are tested according to the IEC standards like :

- PV inverters are tested in accordance with IEC 62109
- PV mounting systems are tested in accordance with PPP 59029
- PV batteries and energy storage systems (ESS) are tested according to IEC 62619 and IEC 62620
- PV trackers and storage systems are tested according to a combination of IEC standards

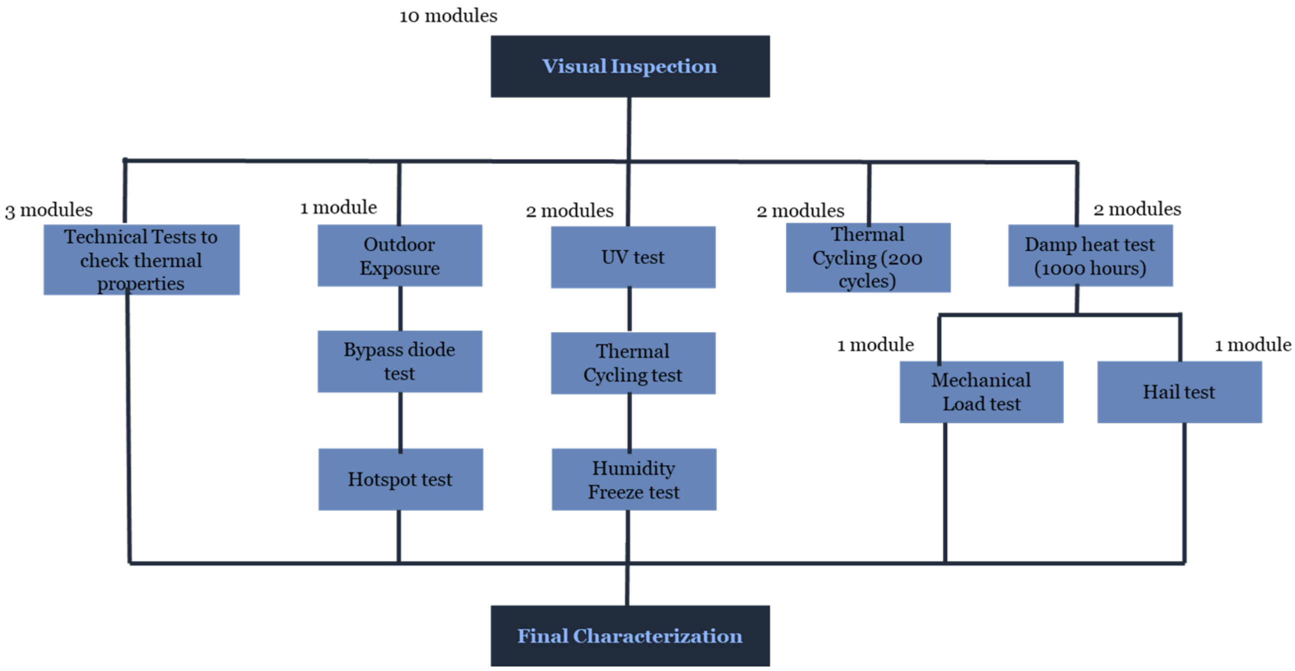
In addition to this the performance and safety-related environmental testing is also done. The Performance and Safety-Related Environmental Testing is carried for corrosion resistance and long-term durability performance.

Construction Monitoring

The test method includes the procedure and steps to be followed during construction of the plant. The steps include:

- Monitoring of overall quality of work during construction
- Time Schedule Monitoring
- Technical Monitoring i.e. the BOM should be as per with international and best practice requirements and standards
- The civil, electrical and mechanical components should be as per standards specified in the EPC contract

The flow chart below shows the test procedure according to IEC 61215: 2016



4.3.1. Quality Standards, Specifications for Solar PV Systems

The Solar PV plant components must conform to the IEC / equivalent BIS standards for design qualification and performance testing at standard test conditions and approved by one of the MNRE/ NABL accredited testing laboratories. It is also imperative to put in place an efficient and rigorous monitoring mechanism, adherence to these standards.

Detailed technical requirements and the relevant standards to be adhered for each component in ground mounted and rooftop PV power plants are mentioned in Section 5 below.

However, the significant minimum technical requirements, quality standards and specifications for Grid-connected Rooftop Solar PV Systems (component wise - Solar modules, battery, inverters and power plant testing and commissioning) are enlisted as follows:

A. Solar Module Testing

Standard Name	Title
IEC 60904-1/ IS 12763	Photovoltaic devices - Part 1: Measurements of photovoltaic Current-voltage characteristics
IEC 60904-3:/IS 12762:Part3	Photovoltaic devices - Part 3: Measurements principles for terrestrial Photovoltaic (PV) solar devices with reference spectral irradiance data
IEC 60891	Procedures for temperature and irradiance corrections to measured I-V Characteristics of crystalline silicon IEC photovoltaic devices
IS/IEC 61730 (Part 1,2)	Solar photovoltaic Safety qualification testing
IEC 61215/IS 14286	Design qualification test for Crystalline Silicon terrestrial photovoltaic module
IEC 61646/IS16077	Design qualification and type approval of thin film module
IEC 61804	PID test

Table 9: Quality standards for Module testing

PV modules used in solar power plants must be warranted for their output peak watt capacity, which should not be less than 90% at the end of 10 years and 80% at the end of 25 years.

B. Battery Testing

Standard Name	Title
IEC 61427	Battery Life Cycle endurance test
IS /BIS:15539	VRLA battery(2V/12V) Stationary valve regulated lead acid Battery
IS/BIS 13369	Stationary lead-acid batteries – Vented types – General requirements and methods of test (2V,12V) batteries
IS 1651	GEL Type battery testing

Table 10: Quality standards for Battery testing

C. Inverter Testing

Standard Name	Title
IEC 61683	Procedure for measuring efficiency (Performance evaluation testing of Solar PV Power Conditioning Unit)
IEC 62116	Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures
IEC 61727	Parallel operation of inverter
EN 50530-	Measuring the efficiency of MPPT algorithm of charge controller
IEC 60068-2	Environmental tests of inverters
IEC 62509	Battery charge controllers for photovoltaic systems - Performance and functioning

IEC 62109-2	Safety of Power Converters for Use in Photovoltaic Power Systems

Table 11: Quality standards for Inverter testing

D. Power plant testing and commissioning

Standard Name	Title
IEC 62548: Ed 1	Installation and Safety Requirements for Photovoltaic (PV) Generators
IEC 61194: 1992 Ed 1, /IS 14244	Characteristic parameters of stand-alone photovoltaic (PV) systems
IEC 62446: 2009	Grid connected photovoltaic systems -Minimum requirements for system documentation, commissioning tests and inspection
IS/IEC 61829	Crystalline silicon photovoltaic (PV) array - On-site measurement of I-V characteristics
IEC 61725	Analytical expression of solar daily profiles
IEC 62446	Requirements For System Documentation, Commissioning Tests Inspection

Table 12: Quality standards for Power plant testing and commissioning

These quality standards and specifications enable the components to meet the requirements of the best quality PV systems by ensuring high performance, long term reliability and safety and a rewarding life cycle return. In order to achieve these, it is imperative to create high quality testing laboratories and adopt latest development in the technologies in coherence with the growth of the industry.

4.3.2. BIS Guidelines

In July 2018, MNRE issued guidelines to facilitate labs/manufacturers in formation of series of products for approval of product family including change in design, materials, etc. for performance testing of SPV Modules in test labs for compulsory registration with BIS for implementation of the Solar Photovoltaics Systems, Devices and Component Goods.

IS Codes	Type	Sampling	Details
IS 14286: 2010, IS 16077:2013	Design Qualification and type approval of crystalline silicon (including bifacial) and Thin Film terrestrial PV modules	Eight modules shall be taken at random from a production batch or batches	All the modules should contain the following clear and indelible marking laminated inside the glass as per IS/IEC 61730-1. The label should specify: i. Name, monogram or symbol of manufacturer ii. Model number iii. Unique serial number iv. Nominal wattage v. Year and country of origin vi. Brand name if applicable In case of thin film modules information should be provided as per IS/IEC 61730-1 at an appropriate place with clear and indelible marking Apart from this, information should also be provided for: i. Polarity of terminals ii. Maximum system voltage for which the module is suitable
IS/IEC 61730-2: 2004	PV module safety qualification and; Requirement for testing	7 Nos. of PV modules (6 Nos. normal modules and one laminate)	All the modules should fulfill the requirement as per IS 14286: 2010 and IS 16077:2013

		shall be taken for testing	
IS/IEC 61730-1: 2004	PV module safety qualification and; Requirement for construction	-	-
IS 14286 and IS 16077	**Pass criteria**	-	Pass criteria for module should be as per the clause number 6 of IS 14286 and IS 16077
-	**Fire Test**		For conducting fire test, the requirement of number of fire tests samples will depend on the size of the PV panel and fire safety class declared by the manufacturer and for this additional 3 nos. modules are required to be submitted to the test lab

4.4. Infrastructure requirement for Solar Energy Quality Testing

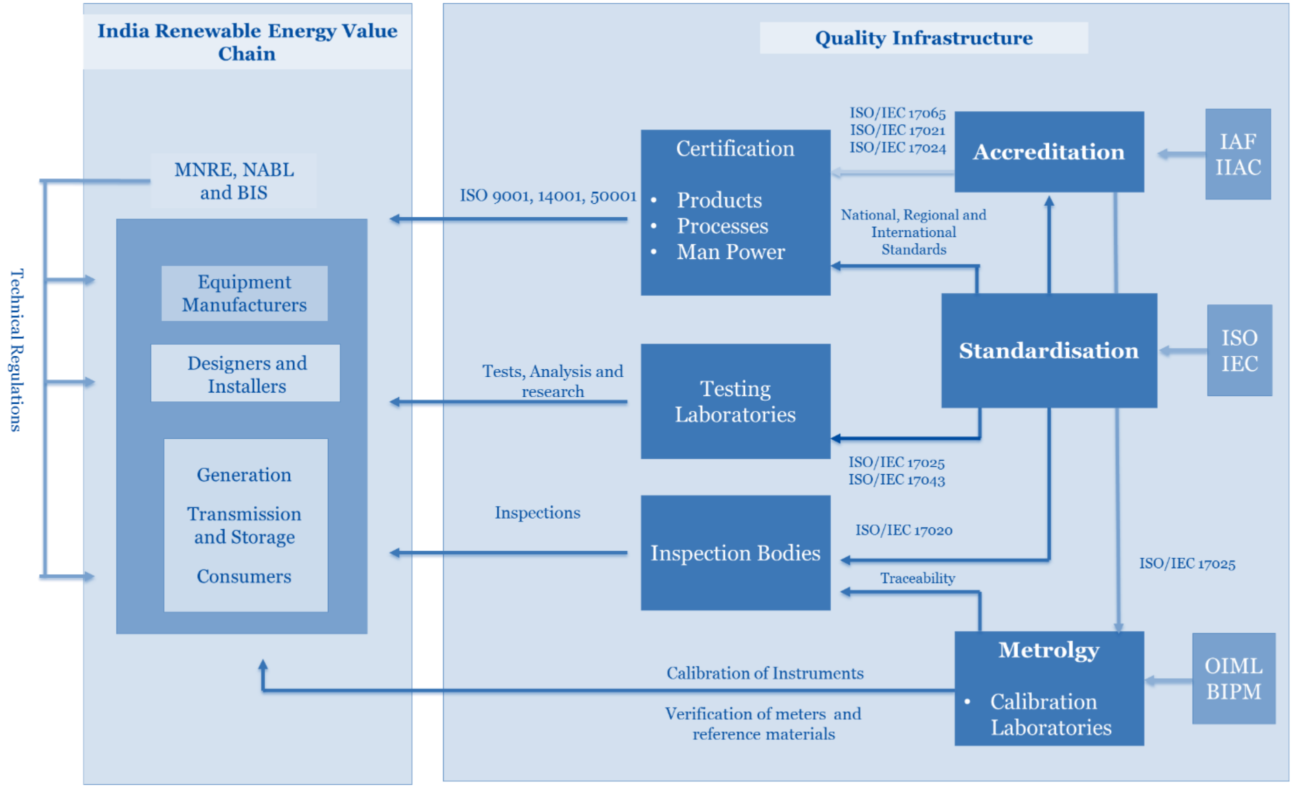


Figure 29: Quality Infrastructure along the solar value chain, Source: Physikalisch-Technische Bundesanstalt Report

The concept mentioned above is from the report published by Physikalisch-Technische Bundesanstalt, which depicts the quality infrastructure for solar PV value chain in Indian context. For long term sustainable adoption of renewable energy technologies and their hassle free operation, the country should be equipped with required infrastructure for testing and certification of renewable energy related products. It is important to assess the country's quality testing infrastructure capacity and geographic footprint to mitigate technical risk, attract FDIs in renewable energy sector and public acceptance, and meet all the key stakeholder expectations to foster billion dollars investments to reach 175GW target by 2022. The figure above depicts the international standards and conformity assessment schemes which can be mapped into Indian renewable energy value chain.

Globally the RE quality infrastructure follows ISO and IEC standards above that regional and national standard are also in place to better suit the in country performance parameters. In India, in order to qualify a system or component it is proposed to conduct as per the following standards proposed to ensure long term reliability.

4.4.1. New component testing

In India whenever a new product or application related to RETs testing is required, the application is scrutinized through a technical committee. Based on the requirements, available standards, a procedure will be developed and the sample will be tested by at least three labs. If the measurements and reported data match within the permissible error limit or uncertainty of measurement, the same procedure is formalized to be adopted by other labs for performance testing. The procedure then reviewed and revised in case of any fault which is detrimental, with the consultation of all test labs in the network and final decision is done by MNRE.

4.4.2. Sample Collection

The samples should be collected at three stages of life cycle; prototype to establish design, production at the factory and supply from the field. If the performance of the sample is found similar within the specified measurement range, then only the product can be considered reliable and useful.

It was found from site visits and stakeholder discussions that there is no standards for sample collection procedure. Eight random components are selected by manufacturer for each lot and transported to testing facility for certification.

4.4.3. Transportation

Transportation of the samples is a key element for testing. Damage to the samples occur during transportation, and mishandling of the samples. Electroluminescence technique is an excellent tool to find damages caused in the case of PV modules. Similar techniques should be used for other systems. The necessary transportation and shipping condition tests are mandatory as per national/international standards.

4.4.4. Infrastructure assessment and availability factor of testing facilities in India

It is envisaged for complete qualification of a System/component testing at least at three stages.

The first stage will be at design stage, known as prototype. Here all required qualifications certifications are the responsibility of the manufacturer. Even for the imported products the manufacturer should get these tests before the product is introduced in the market.

Further, it is necessary to conduct bench marking tests/ certification from the production (from the factory) site and/or supply (field) site at the time of supply, in case imported at the customs before it enters the country. Without this certification products cannot be used. The type of test can be complete range of qualification or only bench marking tests. This will be the responsibility of manufacturer or supplier or EPC or Developer.

Surveillance tests will be organized by BIS or MNRE or their authorized representative. Under this the samples can be picked up from the manufacturing site or field supply site and the sample is tested as per bench mark test or qualification tests.

Considering annual addition of 15 GW[24] per year, the requirement of test facilities in India is tabulated below:

[24] http://mnre.gov.in/file-manager/UserFiles/LP-OM-for-comments.pdf

Total number of module qualifications tests/lab/year	Number of qualification tests/ lab / year	Assumed Wattage of Modules	Total Number of modules of 250Wp Required per year	Total Qualifications and benchmark tests per year
Total number of module benchmark tests/lab/year	24	250	640,00,000	340
Total number of qualification test lab available	3			14
Total number of Bench Mark test labs Available	3			
Additional Labs Under Development July 2017	3			
Additional Labs or Facilities Required	6			

4.5. Certification and Auditing

Certification against standards is observed through a verification and auditing process based on benchmarking against criteria and scheme documents. Auditing can be done internally within an organisation (i.e. first party) or by second-party conformity assessment organisations that provide an independent, but not necessarily accredited, process of conformity assessment. Also, third-party conformity assessment is often carried out by independent certification, inspection and laboratory accreditation organisations where the certification body, inspection body or laboratory is in itself "accredited", for the particular testing schemes it offers, by an accreditation body operating under international standards and agreements.

The standards and certification practice being followed in SPV are the standards of International Electro-technical Commission (IEC) adopted by BIS. The standards and specifications adopted are adequately addressing the operational, environmental and performance requirements of users. Uniform procedures, equipment and data formats are followed in all test labs in SPV. It's important to check the quality of imported goods and hence the field level testing should also be conducted by test labs to check the quality of the products deployed against lab tests.

In module testing, certifications are awarded based upon two types of tests, qualification testing and benchmarking testing. For qualification and benchmarking testing requirements for SPV modules and components for 100 GW target, as of now there are three PV modules test labs well equipped and also accredited as per IS17025 quality system standard. Two more labs are in the process of accreditation and within near future, they will be available for testing modules. As per the MNRE lab policy, one additional lab will be required in order to meet the ambitious target of 100 GW solar installations with quality infrastructure in the country.

However, third party independent certification, inspection and laboratories activities are typically based on ISO and IEC standards. This provides a framework that enables accreditation bodies to provide consistency through a common approach. Third-party independent certification also falls under a number of types of certification process. They fall broadly into Product Certification (e.g., ISO/IEC Guide 67 & ISO/IEC Guide 65), Personnel Certification (ISO/IEC 17024), Laboratory Testing (ISO/IEC 17025) and Management Systems Certification (ISO/IEC 17021).

A certified product must include the following information:

- The specific product or type of product certified
- The qualification standard that the product is expected to meet
- The date of certification and expiration of the product

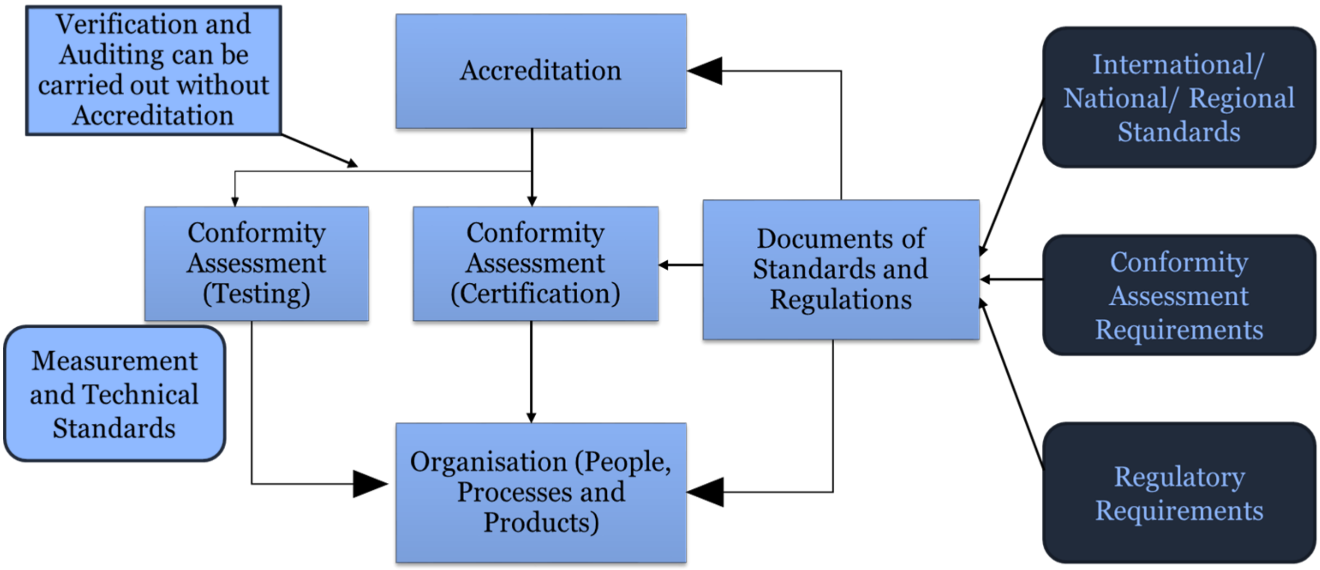


Figure 30: Process flow in Certification and Auditing

Certification schemes are typically written to include both the performance test methods that the product must be tested to, as well as the criteria that the product must meet to become certified. Furthermore, Accreditation is not an essential requirement for all aspects of conformity assessment as shown in the figure above and thus Conformity assessment of products, services, management systems, etc. can be carried out in the same way as performed by accredited organisations but by bodies without formal accreditation. But, formal accreditation does allow a level of confidence that whatever product or service is being provided the desired certification, it is being provided by an organisation that is competent and capable enough to provide the certification.

Product certification involves Gap Analysis to focus on the specific areas that might require attention, Pre assessment of the product and Type testing of the product design against the standard specification involving actual examination of a sample as well as performance in tests. It is also desirable that technical support is provided by the trained and competent experts during the certification process. It is necessary that the certified product meets qualification criteria stipulated in contracts and regulations.

4.5.1. Stages in Product Certification

There are four stages in product certification which are Application, Evaluation, Decision and Surveillance and are explained in the illustration below. These stages ensure that the product meets the designated standards and criteria listed in the certification scheme, a review of the product is done in order to rectify any qualification criteria that does not match with the test data.

Figure 31: Product Certification stages

4.5.2. Requirements of PV plant Audit

The objective of PV plant audit is to ensure grid safety and improve the power plant performance. The auditing of a PV power plant identifies the root causes of the losses occurring in the system and help to maximize its performance. A simple PV audit starts with the data analysis process with in-depth analysis of the available wind, temperature, irradiation, DC power output and AC power output data. This allows the auditors to understand the system behavior and conduct the audit in a systematic manner.

An analysis of the design documents allow the auditors to validate the design process according to the best practices available and as per the designated industry standards. Bill of material audit is also a critical step in ensuring PV plant durability and reliability. This involves benchmarking the quality of installed components with our internally developed metrics and PV audit experience.

PV power plant audit is necessary in the following circumstances:

- The performance ratio (PR) of the power plant is below 90% of designed/ expected value
- The plant is not working as desired during peak time
- There is frequent tripping and shutdown of the power plant for known or unknown reasons
- The plant degradation is higher than the expected

4.5.3. Compulsory registration under BIS act for solar PV modules and its components

In a move to catapult India's young solar industry into greater prominence by eliminating quality concerns, the Ministry of New and Renewable Energy on August 30, 2017 issued an order notifying new standard specifications governing six Solar PV products – PV modules, films, wafers, power converters, solar inverters and storage battery. The act came in to enforcement in Nov 2018, the new regulations, legislated under the Bureau of Indian Standards (BIS) Act 1986 will mandate manufacturers engaged in the production, storage, sale or distribution of photovoltaic systems to register with BIS.

Sending a strong message on adherence to the quality norms, the order mentions that 'the substandard or defective Goods which do not conform to the Specified Standard mentioned in Column (3) of the Schedule shall be deformed beyond use and disposed of as a scrap by the manufacturer or the representative of overseas manufacturer from liaison office or branch office located in India or by any agency authorized by the manufacturer as its authorized representative in India' and 'unclaimed consignment of such Goods shall be deformed and disposed as scrap by such agency or department or agency as may be authorized by Appropriate Authority'.

Players in the Indian solar industry must comprehend that the regulations are not hindering their growth but consolidating it, and helping them ensure that the projects they are participating in will give the right return on investment for all stakeholders. Quality certification is not merely a document or label, it is a critical tool to leverage investor and consumer confidence in the project, an invaluable asset that comes at a fraction of the cost of the installation itself.

The new regulations will improve the investments and build investors' and bankers' confidence-2017 has been a dramatic year for the Indian solar industry, where tariffs have fallen as low as Rs. 2.44 / unit. This is a third of what they were in 2012. While falling prices may be favorable for DISCOMs and consumers, it may push IPPs and developers to find cost competitive solutions that may compromise quality.

Further, in the current scenario where more than 85% of modules are imported, the absence of regulatory control has created a climate of doubt about whether the products are certified and if they would provide the necessary yield. In abiding by ground rules, the PV industry will benefit from making quality an uncompromising factor – resulting in bankability of projects, even in the face of attractive tariffs.

Adequacy of the testing labs for the upcoming surge: As discussed in the report section 4, the impact of testing load on the current infrastructure. It was identified. The current testing lab infrastructure is sufficient to meet the rising demand from the industry. Testing laboratories in the country are not only capable of handling the rising demand for their services, but are also gearing up to expand capacities within the one year window before once the rule is enforced fully.

It is critical for the industry to earnestly start complying with the requirements at the earliest rather than hurry at the eleventh hour, which has been the case with prior regulations, especially in other industries.

While the new regulation is a good step, it focuses on safety and performance criteria in the short term. India needs a mechanism to ensure that the plants are not only furnished with high quality equipment but are also designed & installed properly, and yielding the appropriate output as a whole. Reliability is a crucial aspect because no amount of operation and maintenance intervention will revive a low yielding plant. The project may then witness reduced output within 2-3 years itself, rather than the 18-25 years that it is designed for. Robust standards and regulations will ensure that precious tax payer money is making meaningful contribution to the country's renewable future.

5. Regulatory Guidelines

5.1. Solar PV

5.1.1. Current Technical Requirements for Grid Connected Solar PV Power Plants

Ministry of Power has specified some technical measures required to ensure the quality of the equipment in grid connected solar PV projects. These specifications mentioned by the ministry are applicable to PV modules, inverters and other sub systems and it is imperative for the power plants to conform to these specifications to make sure that quality infrastructure is being deployed. The technical requirements for grid connected solar PV power projects are as follows:

Solar PV Modules

The SPV modules used in the grid connected solar power projects must qualify to the latest edition of any of the IEC PV module qualification test or equivalent BIS standards as mentioned hereby:	Crystalline Silicon Solar Cell Modules - IEC 61215
	Thin Film Modules - IEC 61646
	Concentrated PV modules - IEC 62108

In addition, the PV modules must qualify to IEC 61730 standard for safety qualification testing at 1000V DC or higher. The modules that are used in a highly corrosive atmosphere throughout their lifetime must qualify to IEC 61701 standard.

Inverters

The Inverters or the Power conditioning unit installed in the Solar PV power plants must conform to the latest edition of IEC/ equivalent standards specified as follows:

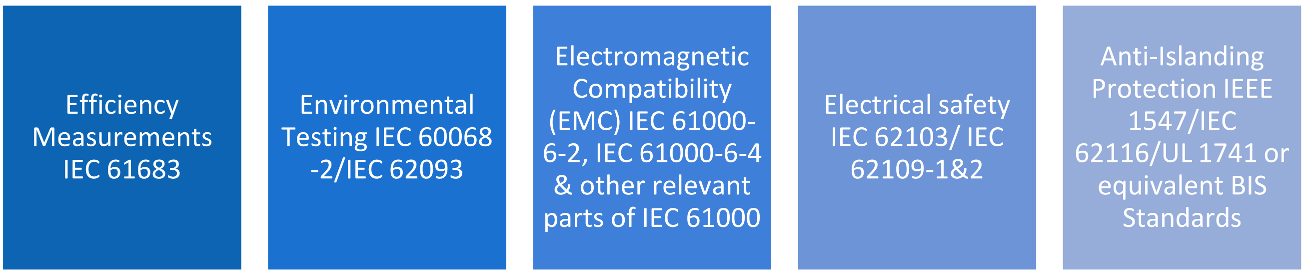


Figure 32: IEC Standards for Inverters

Other Sub systems

Other subsystems or components used in the PV power plants such as cables, connectors, Junction boxes, Protection Devices, etc. must also conform to the relevant international and national standards for Electrical Safety besides that for Quality required for ensuring Expected Service Life and Weather Resistance.

The ministry has recommended that the cables of 600-1800 Volts DC for outdoor installations should comply with the BS EN 50618:2014/2pfg 1169/08.2007 for service life expectancy of 25 years.

Authorized Test Centers

The PV modules, Power Conditioners and other components installed in the power plants must have valid test certificates for their qualification as per above mentioned IEC/ BIS Standards from anyone of the NABL accredited test centers in India. In case of module types like Thin Film and Concentrated PV or the equipment for which such test facilities may not exist in India at present, test certificates from reputed ILAC member labs abroad will be acceptable.

Warranty

PV modules installed in the grid connected solar power plants must be warranted for output wattage, which should not be less than 90% at the end of 10 years and 80% at the end of 25 years.

Identification and Traceability

It is obligatory for all the PV modules installed in any solar power project to use a RF identification tag. The following information must be mentioned in the RFID used on each module (the information can be inside or outside the laminate, but must be able to withstand harsh environmental conditions)

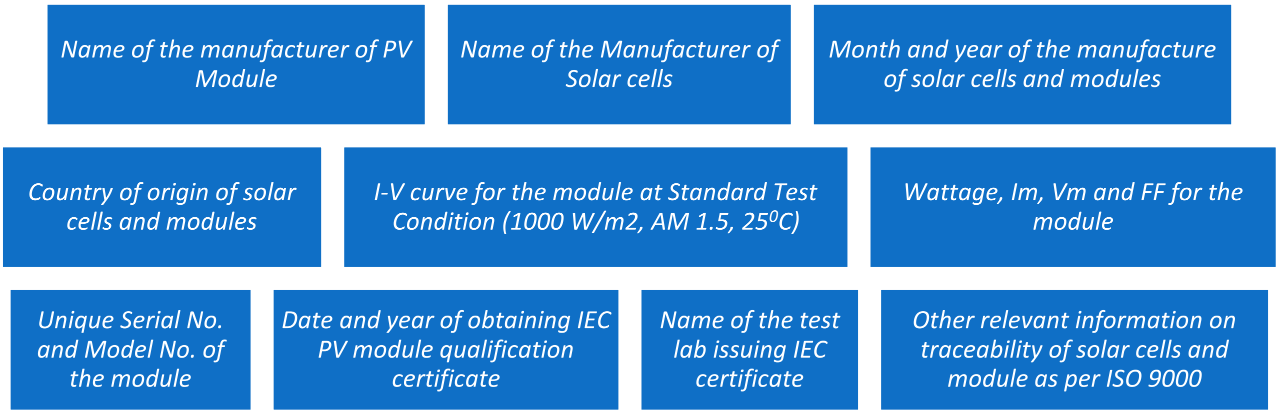


Figure 33: Information requirement on RFID tag

Also, the site owners would be required to maintain accessibility to the list of Module IDs along with the above parametric data for each module.

Performance Monitoring

All grid connected solar PV power projects must install necessary equipment to continuously measure solar radiation, ambient temperature, wind speed and other weather parameters and simultaneously measure the generation of DC power as well as AC power generated from the plant.

They will be required to submit this data to the power purchaser and MNRE or any other designated agency online or through a report on regular basis every month for the entire duration of PPA. In this regard they shall mandatorily also grant access to power purchaser and MNRE or any other designated agency to the remote monitoring portal of the power plants on a 24x7 basis.

Safe disposal of PV modules

The developers must ensure that all Solar PV modules from their plant after their operation is over (or when they become defective and non-operational) are disposed off in accordance to the "e-waste Management and Handling Rules, 2011", notified by the Government of India and as revised and amended from time to time.

Current Technical Requirements for Grid Connected Rooftop PV Power Plants

Solar Energy Corporation of India (SECI) has detailed out the technical specifications to be followed in case of commissioning of any grid connected rooftop Solar PV project. A Grid connected rooftop Solar PV power plant consists of SPV array, module mounting structure, Power Conditioning Unit (PCU) along with remote monitoring system, controls & protections, interconnection cables and switches.

SECI has specified that the components and parts used in the PV power plants including the PV modules, metallic structures, cables, junction boxes, switches, PCUs etc., must conform to the BIS or IEC or international specifications, wherever such specifications are available and applicable.

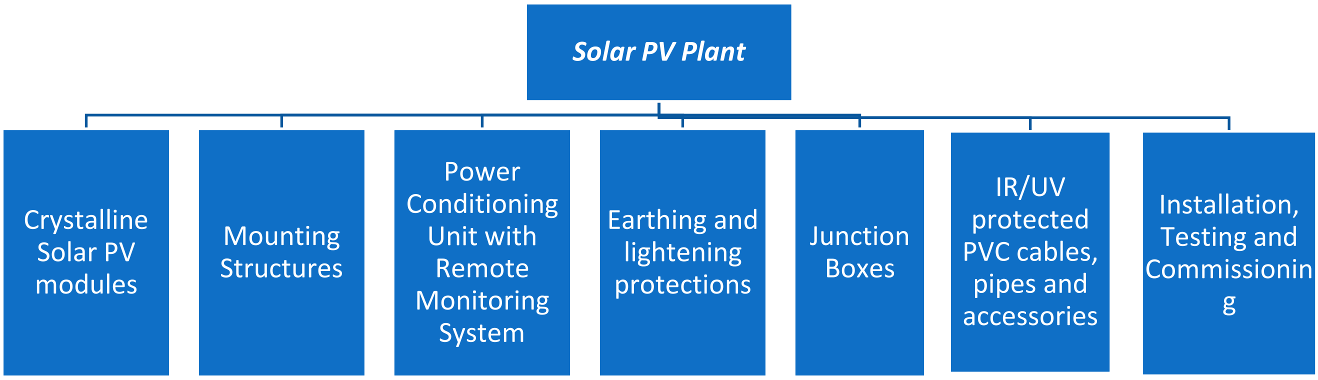


Figure 34: Major components of a Solar PV plant

In order to facilitate the usage of quality infrastructure in the installation of any rooftop solar PV plant, SECI has specified the technical guidelines for all the components (individually), to be followed during the erection of the PV plant which are detailed below. It is imperative to adhere to these guidelines as non-compliance will lead to the cancellation of the subsidy provided by SECI and might even lead to disqualification of the PPA.

Solar PV Modules

1. The PV modules used must qualify to the latest edition of IEC PV module qualification test or equivalent BIS standards for Crystalline Silicon Solar Cell Modules IEC 61215/IS14286. In addition, the modules must conform to IEC 61730 Part-2- requirements for construction & Part 2 – requirements for testing, for safety qualification or equivalent IS.
2. The total solar PV array capacity should not be less than allocated capacity (kWp) and should comprise of solar crystalline modules of minimum 250 Wp and above wattage. Modules having capacity less than minimum 250 watts should not be accepted.
3. For the PV modules to be used in a highly corrosive atmosphere throughout their lifetime, they must qualify to IEC 61701/IS 61701
4. Protective devices against surges at the PV module shall be provided. Low voltage drop bypass diodes shall be provided.
5. PV modules must be tested and approved by one of the IEC authorized test centers and the module frame shall be made of corrosion resistant materials, preferably having anodized aluminum.
6. The rated output power of any supplied module shall have tolerance of +/- 3%.

7. The peak-power point voltage and the peak-power point current of any supplied module and/or any module string (series connected modules) shall not vary by more than two percent.

8. The module shall be provided with a junction box with either provision of external screw terminal connection or sealed type and with arrangement for provision of by-pass diode. The box shall have hinged, weather proof lid with captive screws and cable gland entry points or may be of sealed type and IP-65 rated.

9. Modules deployed must use a RF identification tag. The following information must be mentioned in the RFID used on each modules: Name of the manufacturer of the PV module and solar cells, month & year of the manufacturing, country of origin, I-V curve for the module Wattage, Im, Vm and FF for the module, Serial No and Model No of the module, date and year of obtaining IEC PV module qualification certificate, name of the test lab issuing IEC certificate and other relevant information on traceability of solar cells and module as per ISO 9001 and ISO 14001.

10. PV module must be highly reliable and shall have a service life of more than 25 years with predicted electrical degradation of power generated not exceeding 20% of the minimum rated power for 25 years and not more than 10% after ten years period of the full rated original output.

11. The modules shall withstand relative humidity up to 85 % and module temperatures up to 85°C of the site location.

Mounting Structures

1. The mounting structure should be designed for a fixed tilt of 21 degrees. The fixed tilt angle is chosen such that the PV array will occupy minimum space without sacrificing the power output from the PV panels. However to accommodate more capacity the angle inclination may be reduced until the plant meets the specified performance ratio requirements.

2. The support structure and the foundation shall be designed to withstand wind speed of up to 200 kmph.

3. The mounting structure steel shall be as per latest IS 2062: 1992 and galvanization of the mounting structure shall be in compliance of latest IS 4759.

4. Structural material shall be corrosion resistant and electrolytically compatible with the materials used in the module frame, its fasteners, nuts and bolts. Necessary protection towards rusting need to be provided either by coating or anodization.

5. The fasteners used should be made up of stainless steel. The structures shall be designed to allow easy replacement of any module. The array structure shall be so designed that it will occupy minimum space without sacrificing the output from the PV panels.

6. The minimum clearance of the structure from the roof level should be in the range of 500 mm to 1 meter.

Power Conditioning Unit

The power conditioning unit should convert DC power produced by PV modules into AC power and adjust the voltage levels to match the grid voltage. Conversion shall be achieved using an Inverter and the associated control and protection devices. All these components of the system constitute a “Power Conditioning Unit (PCU)”. In addition to these components, the PCU also has a MPPT (Maximum Power Point Tracker), an interface between Solar PV array & Inverter, the power conditioning unit must also be DG set interactive. Typical technical features of the power conditioning unit shall be as follows.

Table 13: Technical features of Power conditioning unit

Properties	Specifications
Switching devices	IGBT/MOSFET
Control	Microprocessor /DSP
Nominal AC output voltage and frequency	415V, 3 Phase, 50 Hz
Grid Frequency Synchronization range	+ 3 Hz or more
Ambient temperature considered	- 20^0 C to 50° C
Protection of enclosure	IP-20 (minimum) for indoor and IP-65 (minimum) for outdoor
Ambient temperature considered	- 20^0 C to 50° C
Humidity	95 % non-condensing
Grid Frequency Tolerance range	+ 3 or more
Grid Voltage tolerance	- 20% & + 15 %
No-load losses	Less than 1% of rated power
Minimum inverter efficiency	>93% (for 10 kW and above) and >90% (for less than 10 kW)
THD and Power Factor	< 3%, > 0.9

1. Three phase inverter shall be used with each power plant system (10kW and above) but in case of less than 10kW single phase inverter can be used.
2. The inverter shall be capable of complete automatic operation including wake-up, synchronization & shutdown.
3. The output of power factor of PCU must be suitable for all voltage ranges and the inverter should have internal protection arrangement against any sustainable fault in feeder line such as the lightning on feeder.
4. Built-in meter and data logger to monitor plant performance through external computer shall be provided.
5. The power conditioning units / inverters should comply with applicable IEC/ equivalent BIS standard for efficiency measurements and environmental tests as per standard codes IEC 61683/IS 61683 and IEC 60068- 2(1,2,14,30) or equivalent BIS standards.
6. The MPPT units environmental testing should qualify IEC 60068-2(1, 2, 14, 30) or equivalent BIS standards. The junction boxes should be IP 65(for outdoor)/ IP 54 (indoor) and as per IEC 529 specifications.
7. The Power Conditioning Unit must be tested from the MNRE approved test centers and NABL /BIS /IEC accredited testing- calibration laboratories. In case of imported power conditioning units, these should be approved by international test houses.

Protections

The PV system should be provided with all necessary protections as illustrated in the figure below:

Figure 35: Protections in a PV plant

1. ***Lightning Protection*** – The PV power plants shall be provided with lightning & overvoltage protection. The main aim in this protection shall be to reduce the over voltage to a tolerable value before it reaches the PV or other sub system components. The source of over voltage can be lightning, atmosphere disturbances. The entire space occupying the PV array shall be suitably protected against Lightning by deploying required number of Lightning Arrestors. Lightning protection should be provided as per IEC 62305 standard. The protection against induced high-voltages shall be provided by the use of metal oxide varistors (MOVs) and suitable earthing such that induced transients find an alternate route to earth.

2. ***Earthing Protection*** – Each array structure of the PV plant must be grounded/ earthed properly as per IS: 3043-1987. In addition the lighting arrester should also be earthed inside the array field. Earth Resistance shall be tested in presence of the personnel from the respective department as and when required after earthing by calibrated earth tester. PCU, ACDB and DCDB should also be earthed properly. Earth resistance shall not be more than 5 ohms. It shall be ensured that all the earthing points are bonded together to make them at the same potential.

3. ***Surge Protection*** – Internal surge protection shall consist of three MOV type surge-arrestors connected from positive and negative terminals to earth via Y arrangement.

4. ***Grid Islanding*** – In the event of a power failure on the electric grid, it is required that any independent power-producing inverters attached to the grid turn off in a short period of time. This prevents the DC to AC inverters from continuing to feed power into small sections of the grid, known as "islands." Powered islands present a risk to workers and they may also damage grid-tied equipment. The PV system must be equipped with islanding protection.

   In addition to this, disconnection due to under and over voltage conditions shall also be provided. A manual disconnect 4-pole isolation switch beside automatic disconnection to grid should also be provided at utility end to isolate the grid connection by the utility personnel to carry out any maintenance.

Junction Boxes

DC Distribution Board

DCDBs must have a sheet conforming to IP 65 for protection from dust & vermin. The bus bars must be of copper and suitable capacity MCBs shall be provided for controlling the DC power output.

AC Distribution Board

All switches, circuit breakers, connectors should conform to IEC 60947, part I, II and III/ IS60947 part I, II and III.

Variation in Supply Voltage: +/-10%
Variation in Supply Frequency: +/-3 Hz

1. The junction boxes are to be provided in the PV array for termination of connecting cables. The junction boxes shall be made of GRP/FRP/Powder coated aluminium /cast aluminium alloy with full dust, water & vermin proof arrangement. All wires/cables must be terminated through cable lugs.
2. Copper bus bars/terminal blocks housed in the junction box with suitable termination threads must conform to IP65 standard and IEC 62208 hinged door with EPDM rubber gasket to prevent water entry. Provision of earthing must be there. It should be placed at the height of 5 feet or above for ease of accessibility.
3. Each Junction Box shall have high quality suitable capacity Metal Oxide Varistors (MOVs) / SPDs, suitable Reverse Blocking Diodes. The Junction Boxes shall have suitable arrangement for monitoring and disconnection for each of the groups.
4. Suitable markings shall be provided on the bus bar for easy identification and the cable ferrules must be fitted at the cable termination points for identification.

Cables, Connectivity and Tools & Spares

Cables used in the PV power plant must have the following characteristics:

1. They must meet IEC 60227/IS 694, IEC 60502/IS1554 standards
2. Temp. Range: –10o°C to +80o°C and Voltage rating shall be 660/1000V
3. The cables must be flexible and should have excellent resistance to heat, cold, water, oil, abrasion and UV radiation
4. Sizes of cables between array interconnections, array to junction boxes, junction boxes to Inverter etc. shall be selected to keep the voltage drop of the entire solar system to the minimum. The cables (as per IS) should be insulated with a special grade PVC compound formulated for outdoor use.
5. Cable Routing or marking: All cables and wires need to be routed in a GI cable tray and suitably tagged and properly marked such that the cable easily identified.
6. The cables selected must be compatible up to the life of the solar PV panels i.e. 25 years.
7. All cable schedules and layout drawings need to be approved prior to installation.
8. PVC/XLPE insulation to be used for UV protection and armored cable for underground laying. All cable trays including covers to be provided. All cables must conform to the latest edition of IEC or equivalent BIS Standards: PVC/XLPE insulated cables for voltage up to and including 1100 V, UV resistant for outdoor installation IS /IEC 69947.
9. The size of each type of DC cable selected shall be based on minimum voltage drop, however the maximum drop shall be limited to 1%.

10. The size of each type of AC cable selected shall be based on minimum voltage drop, however the maximum drop shall be limited to 2 %.

Connectivity

The maximum capacity for interconnection with the grid at a specific voltage level shall be as specified in the Distribution Code/Supply Code of the State and amended from time to time. Following criteria is suggested for selection of voltage level in the distribution system for ready reference of the solar suppliers.

i. The maximum permissible capacity for rooftop shall be 1 MW for a single net metering point.

ii. DISCOMS may be consulted before finalization of the voltage level and specification be made accordingly.

iii. For large PV system (above 100 kW) and for commercial installation having large load, the solar power can be generated at low voltage levels and stepped up to 11 kV level through the step up transformer.

Plant Capacity	Connecting Voltage
Up to 10 KW	240V-single phase or 415V-three phase at the option of the consumer
10 to 100 KW	415V – three phase
Above 100 KW	At HT/EHT level (11kV/33kV/66kV) as per DISCOM rules

Table 14: Plant connectivity voltages

Tools & Spares

After completion of installation & commissioning of the power plant, necessary tools have to be provided free of cost by the installer for maintenance purpose. A list of requisite spares in case of PCU/inverter comprising of a set of control logic cards, IGBT driver cards, junction boxes, fuses, MOVs, MCCBs etc. along with spare set of PV modules need to be indicated, which shall be supplied along with the equipment. A minimum set of spares shall be maintained in the plant itself for the entire period of Warranty and Operation & Maintenance.

Installation, Testing and Commissioning

The installation of the PV arrays, Inverters and other components should be as per the IEC 61173, IEC 62548, IEC 61140 and IEC 62109-1 & 2 standard.

After completion of installation works, the solar power plant shall be on trial run for a period of 8 - 10 clear sunny days to test smooth functioning of power plant in every aspect. Only after satisfactory inspection the power plant shall be deemed commissioned.

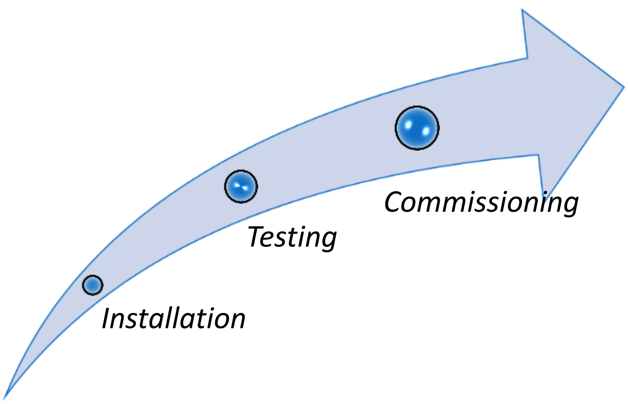


Figure 36: Phases in a PV plant

Data Monitoring

1. The plant parameters shall be measured by using SCADA or an equivalent system to monitor, maintain, and control the plant and also to study the plant performance. The system should meet IEC 61724 standard for this provision.

2. The plant monitoring parameters shall include:

   - ☐ PV array energy production: Digital Energy Meters to log the actual value of AC/ DC Voltage, Current & Energy generated by the PV system

- ☐ Solar Irradiance: An integrating Pyranometer (Class II or better) shall be provided, with the sensor mounted in the plane of the array. Readout shall be integrated with data logging system.
- ☐ Temperature: Temperature probes for recording the solar panel temperature and ambient temperature shall be provided.

5.2. Technical Requirements from EPC perspective for PV Power Plants

The procurement of equipment such as solar modules, inverters, conductors, circuit breakers, transformers etc. by EPC contractors for installation of a power plant are in addition to the standards mentioned above and are more stringent since the EPC contractors are liable for any kind of damages arising in the system and they are bound by the EPC contact to compensate for such damages to the developers. These technical requirements followed from the EPC perspective for various equipment are mentioned below.

Solar PV Modules

The solar PV modules to be supplied should have relevant IEC standards under Standard Temperature Conditions (STC). The mono or poly crystalline PV modules must have the specifications as follows:

1. The solar PV modules should have efficiency more than 16 % for multi-crystalline, 18% for mono-crystalline silicon based modules with positive tolerance only. Fill factor of the module shall not be less than 72%. Minimum module rating shall be 250 Wp @ STC.
2. The cells used for module making shall be free from all defects like edge chipping, breakages, printing defects, discoloration of top surface etc.
3. The glass used to make the crystalline silicon modules shall be toughened low iron glass with minimum thickness of 4.0 mm for 72 cell module and 3.2 mm for 60 cell module. The glass used shall have transmittance of above 90%.
4. The back sheet used in the crystalline silicon based modules shall be a 3 layered structure. Outer layer of fluoropolymer, middle layer of Polyester (PET) based and Inner layer of fluoropolymer or UV resistant polymer. Back sheet with additional layer of aluminium with a thickness of minimum 300 microns with water vapour transmission rate less than 3 g/m2/day. The back sheet shall have voltage tolerance of more than 1000 V.
5. The EVA used for the modules should be of UV resistant in nature. No yellowing of the back sheet with prolonged exposure shall occur.
6. The sealant used for edge sealing of PV modules shall have excellent moisture ingress protection with good electrical insulation (Break down voltage >15 kV/mm) and with good adhesion strength.
7. The junction box used in the modules shall have protective bypass diodes to prevent hot spots in case of cell mismatch or shading. The material used for junction box shall be made with UV resistant material to avoid degradation during module life and the Junction sealing shall comply IP 65 degree of protection.
8. The crystalline silicon based modules supplied should be of Potential Induced Degradation (PID) resistant modules and the test certificate from third party lab complying with the same shall be provided.
9. The rated output of the modules shall have positive tolerance of +5W and no negative tolerance is allowed.
10. Modules should have rugged design to withstand tough environmental conditions and high wind speeds suitable for site condition. Modules shall perform satisfactorily in relative humidity up to 95% and temperature between -10oC and 85oC (module temperature).

11. PV modules must be warranted for their output peak watt capacity, which should not be less than 90% of the initial value at the end of 10 years and 80% of the initial value at the end of 25 years.
12. The modules shall be warranted for minimum of 10 years against all material/ manufacturing defects and workmanship, starting from date of Operational Acceptance.
13. All modules shall be certified as follows:
    - IEC 61215 2nd Edition (Design qualification and type approval for Crystalline Si modules).
    - IEC 61730 (PV module safety qualification testing @ 1000 V DC or higher)
    - IEC 61701: Salt Spray test for highly corrosive environment, if applicable
    - IEC 62716: Ammonia Resistant certified, if applicable
    - Test certificate from NABL approved or /ILAC member body approved labs shall be provided.
14. The Contractor would be required to maintain accessibility to the list of module IDs along with the parametric data for each module.
15. The temperature co-efficient of power for the modules shall not be more than 0.45% /°C.
16. The current mismatch of the modules connected to an inverter should be less than 2%.
17. Solar PV module shall have module safety class-II and should be highly reliable, light weight and must have a service life of more than 25 years.
18. The module frame shall be made of anodized aluminium or corrosion resistant material, which shall be electrically & chemically compatible with the structural material used for mounting the modules. In case of metal frames for modules, it is required to have provision for earthing.
19. Module frame thickness and height should be minimum 40 mm, the anodization thickness shall not be less than 15 micron. Junction box of IP 67 rated with min 3 no. of bypass diode and MC4 connectors with 1 meter of TUV 2pfg 1169/09.07 certified Cu cable of 4 mm sq.
20. Modules shall perform satisfactorily in relative humidity up to 95% with ambient temperature between -10°C to +50°C. The material shall withstand adverse climatic conditions, such as high speed wind, blow with dust, sand particles, and saline climatic and soil conditions.

Power Conditioning Unit

1. Power Conditioning Unit (PCU) or Inverter shall consist of an electronic inverter along with associated control, protection and data logging devices.
2. The rated power/name plate capacity of the inverters shall be the AC output of the inverter at 500C.
3. The inverter shall have minimum of 10% additional DC input Capacity.
4. All PCUs should consist of associated control, protection and data logging devices and remote monitoring hardware and compatible with software used for string level monitoring.
5. The minimum European efficiency of the inverter shall be 98% load as per IEC 61683 standard for measuring efficiency.
6. The inverters shall have minimum protection to IP 65(Outdoor)/IP 21(indoor) and Protection Class II.

7. Grid Connectivity: Relevant CERC regulations and grid code as amended and revised from time to time shall be complied.

8. The inverter output shall always follow the grid in terms of voltage and frequency. This shall be achieved by sensing the grid voltage and phase and feeding this information to the feedback loop of the inverter. Thus control variable then controls the output voltage and frequency of the inverter, so that inverter is always synchronized with the grid.

9. Operational requirements for Inverter or PCU are as follows –

    - The PCU must have the feature to work in tandem with other similar PCU's and be able to be successively switched "ON" and "OFF" automatically based on solar radiation variations during the day.
    - The PCU shall be capable of controlling power factor dynamically.
    - Maximum power point tracker (MPPT) shall be integrated in the power conditioner unit to maximize energy drawn from the Solar PV array. The MPPT should be microprocessor based to minimize power losses and shall confirm to IEC 62093 for design qualification.
    - PCU shall have provisions to allow interfacing with monitoring software and hardware devices. The PCU shall include appropriate self-protective and self-diagnostic feature to protect itself and the PV array from damage in the event of PCU component failure.
    - The PCU shall have following minimum protection against various possible faults - Grounding Leakage Faults, Over Voltage & Current, Galvanic Isolation:, Protection against Islanding of grid (IEEE 1547/UL 1741/ equivalent BIS standard)

The PCU shall confirm to the following standards and compliances which need to be appropriately certified by the labs:

- Efficiency measurement: IEC 61683
- Environmental Testing: IEC 60068-2 or IEC 62093
- EMC, harmonics, etc.: IEC 61000 series, 6-2, 6-4 and other relevant Standards.
- Electrical safety: IEC 62109 (1&2), EN 50178 or equivalent
- Recommended practice for PV – Utility interconnections: IEEE standard 929 – 2000 or equivalent Protection against islanding of grid: IEEE1547/ UL1741/ IEC 62116
- Grid Connectivity: Relevant CEA/ CERC regulation and grid code (amended up to date)
- Reliability test standard: IEC 62093 or equivalent

Desired Technical Specifications of PCU are as follows –

- Sinusoidal current modulation with excellent dynamic response.
- Compact and weather proof housing (indoor/ outdoor)
- Comprehensive network management functions (including the LVRT and capability to inject reactive power to the grid)
- Total Harmonic Distortion (THD) <3%

- No load loss < 1% of rated power and maximum loss in sleep mode shall be less than 0.05%
- Optional VAR control
- Power factor Control range: 0.9 (lead – lag)
- Humidity: 95% Non – Condensing
- Operating Temperature Range should be -20^{0}C TO + 60^{0}C
- Unit wise & integrated Data logging
- Dedicated Ethernet for networking

Solar Photovoltaic Power Plant Electrical System

The technical requirements of design & engineering, testing at works, supply, installation testing & commissioning of all electrical equipment required for the Solar PV plant starting from the local control panel of plant and up to the grid tie up with the State grid including all control protection, metering equipment, step up generator voltage transformer, indoor or outdoor switchgears and balance of equipment shall be of high standard and quality meeting the requirement of respective Indian standards. The brief particulars and requirement of equipment are as under –

Table 15: Standard requirements in a PV Electrical system

IS/ IEC Reference	Specification
IEC-298	A.C. Metal – enclosed and control gear for rated voltages above 1KV and including 72.5 KV
IS-3427	A.C. Metal – enclosed and control gear for rated voltages above 1KV and including 52 KV
IS-8623	Specification for Low Voltage Switchgear and Control gear assemblies
IS-13118/ IEC-56	Specification for High Voltage AC Circuit Breakers
IEC-529	Degrees of Protection
IS-5578 & 11353	Making and arrangement for switchgear bus bar main connections and auxiliary wiring
IS-325	Specification for 3 Phase Induction motors
IS-2629	Recommended practice for hot dip galvanizing of iron and steel
IEC-137	Bushing for AC Voltages
IS-3347	Porcelain Transformer Bushings
IS-5561	Terminal Connectors
IS-3156	Voltage Transformers
IS-2705	Current Transformers
IS-3231	Electric relays for power protection.
IS-13010	Watt hour meters
IS-13779	Static Energy Meters
IS-8686	Static Protection Relays

IS-1248	Electrical measuring instruments
IS-2099	High Voltage Porcelain Bushings
IS-10118	Minimum clearances for Outdoor Switchgear
IEC-694	Common Clauses for High Voltage Switchgear and Control gear
IEC-60255 & IEC- 61330	Numerical Relays

Power Transmission system

These specifications provides for designing, manufacturing, supply, installation & testing of power transmission system. It shall conform to the latest revision with amendments thereof the following Bureau of Indian Standards and corresponding International Standards

Table 16: Standard requirements in a Power Transmission system

Standard as per BIS	Title
IS:209	Specification for Zinc
IS:2062	Structural steel (standard quality)
IS:432	Mild steel and medium tensile bars and hard drawn steel wire for concrete reinforcement
IS:802	Code of practice for use of structural steel in Overhead transmission line Part I : Loads and permissible Stresses Part II : Fabrication, Galvanizing, Inspection & Packing
IS:1367	Supply conditions for threaded fasteners
IS:2016	Plain washers
IS:2551	Danger Notice Plates
IS-2629	Recommended practice for hot dip galvanizing of iron and steel.
IS:2633	Method of testing uniformity of casting of zinc coated articles
IS:3063	Single coil rectangular section spring washers for bolt nuts, screws
IS:5358	Hot dip Galvanized coatings on fasteners
IS:6610	Specification for heavy washers for steel structures
IS:12427	Hexagonal bolts for steel structures
IS:6745	Methods of determination of weight of zinc coating of zinc coated iron and steel articles
IS:5613	Code of practice for Design Part I & II Installation & Maintenance of Section of Overhead Power Line
IS:8500	Structural Steel Micro Alloyed (medium and high strength quality)
IS: 4759	Hot dip zinc coating on structural steel and other allied products, plain and heavy washers, spring washers Electro galvanization.

Power Conductors

Standards for design, manufacturing, testing, inspection, packing and delivery of Steel Cored Aluminium Conductors are specified in the table below for their satisfactory operation. The power conductors shall conform to the Indian Standards as applicable, which shall mean latest revisions, amendments or changes have been adopted and published, unless otherwise specified.

Table 17: Standard requirements in Power Conductors

Standard	Title
IS:209 -1990	Specification for Zinc
IS:398 Part I to Part V	Specification for Aluminium Conductors for overhead Transmission purpose
IS:1778	Reels and drums for Bare wires
IS:1521	Method of Tensile Testing of Steel wire
IS:2629 -1990	Recommended practice for Hot Dip galvanizing Iron and Steel
IS:2633 -1990	Method of Testing Uniformity of Zinc coating of Zinc coated Articles.
IS:4826	Galvanized coating on Round Steel wire
IS:6745 -1990	Method of Determination of weight of Zinc coating of zinc coated Iron and Steel Articles
IS:8263	Method of Radio Interference Tests
IS:1841	EC Grade Aluminium Rod produced by rolling
IS:5484	EC grade Aluminium Rod produced by continuous casting and rolling
IS: 2141 -1990	Method of Elongation test of steel wire

Transformers

The transformer shall be copper wound, 3 phase, naturally cooled, core type, and oil immersed and shall be suitable for outdoor applications along with 3 phase 50Hz in which the neutral is effectively earthed and they should be suitable for service under fluctuations in supply voltage up to +10% to -15%. Basic requirement for the transformers shall be as follows

Table 18: Standard requirements in Transformers

Standard	Specification
IS: 2026 (Part 1 to 4)	Specification for Power Transformer
IS: 2099	Bushings for alternating voltage above 1000 V
IS: 3639	Fittings and accessories for power transformer
IEC: 60076 (Part 1 to 5)	Specifications for Power Transformer
IS: 9921 Part 1 to 5	Alternating currents dis connectors (isolators) and earthing switches rating, design, construction, tests etc.
IS: 2705 Part 1 to 4 & IEC: 185	Current transformer

IS: 3156 Part 1 to 4	Voltage Transformer
IS: 3070 part 1 to 3	Lightning arrestors
IS: 2544	Porcelain insulators for system above 1000 V
IS: 5350	Part III – post insulator units for systems greater than 1000V
IS: 5621	Hollow Insulators for use in electrical equipment
IS: 5556	Serrated lock washers – specification

Circuit Breakers

The circuit breakers shall be capable of rapid and smooth interruption of currents under all conditions completely suppressing all the undesirable phenomenon even under the most severe and persistent short circuit conditions or when interrupting small currents or leading or lagging reactive currents. The circuit breakers shall be 'Restrike-Free' under all operating conditions. The materials shall conform in all respects to the relevant Indian Standard Specifications or corresponding IEC Standards, with latest amendments as indicated below

Table 19: Standard requirements in Circuit Breakers

Standard	Specification
IS-13118/1991	General requirements for Circuit breakers for voltage above 1000 V
IS-2705/1992	Current Transformers
IS-2099/1986	Bushings for alternating voltages above 1000 V
ISS-2633/1964	Methods of testing uniformity of coating of zinc coated articles
IS-3231/1986	Electrical relays for power system protection
IS-1248/1983	Specification for Ammeters & Voltmeters
IS-335/1983	New insulating oils Electrical IEC 71 (For oils in CTs) Clearances
IS-2147/1962	Degree of protection provided by enclosures for low voltage switchgear & control gear

5.3. Solar Thermal

Minimum specifications required for solar thermal technologies

MNRE stipulates minimum technical requirements for solar thermal technologies as per IS standards. Solar water heaters and cooking application based technologies like flat plate collector, evacuated tube and box and dish type cookers are quite common for domestic applications and have standards in place for components and performance of the products Whereas, solar CST based technologies are still in the developing stage and the applications are customized as per the user demand. Although, there are no performance standards in place, MNRE stipulate minimum technical requirements for the components used to generate solar thermal based steam and heat through concentrated and non-concentrated technologies.

The required IS standards for different technologies is discussed in the testing and certification section of this report. The table below stipulates the minimum technical specifications required for different components used in solar thermal technologies.

Table 20: Minimum specifications required for solar thermal components

Parameter	Current Specifications
Shape and make of each concentrator	Of any shape fixed to a supporting frame/structure
Aperture area	10 m^2 (for Scheffler Dishes, it will be π/4* lengths of major and minor axis
Reflecting mirrors	
a) Material **b) Reflectivity** **c) Mirror Fixing**	○ High quality glass mirrors for outdoor use with protective layers of coating on black surface and side to protect from exterior weathering effect or any other reflecting material of similar reflectivity and durability. For coastal and colder regions, special protections to be made ○ 90% minimum with a maximum degradation of 10% over its life span. Warranty/guarantee provided for a period of 5 years. To be replaced immediately by the supplier if found deteriorating during this period ○ With positive locking or sticking by industry proven outdoor-rated adhesives. Due protection of mirror coatings be taken while fixing the mirrors. Tying of wires is not acceptable. For high wind areas, special protection to be made For newer upcoming technologies, reflectors other than glass mirrors will also be acceptable subject to fulfillment of above requirement
Tracking Arrangement	• Any reliable automatic tracking mechanism with motorized reverse in evening & park at morning position including safe position in case of abnormal operating conditions. • Made of standard components; to be protected from rain, dust & outside environment • Tracking accuracy : +/- 0.5 degree (to be ensured using field-calibrated inclinometer)
Heat Receivers and piping	• Tested working fluid pressure: 1.5 times of designed pressure ○ Receivers : Of boiler/ standard industry quality to sustain required temperature and pressure ○ Header material and piping : Designed & manufactured as per IBR/ standard industry quality
Insulation	• All working fluid piping to be insulated with minimum thickness of 50 mm of PUF or rock wool. Headers or water-steam tank, insulated sides of receiver etc. to have minimum insulation of 75 mm. For colder regions facing sub zero temperatures, minimum thickness will be 100 mm and 150 mm respectively. In such regions cold water pipe lines including valves etc. will also be insulated. Insulation on receivers should withstand a minimum temperature of 600c. • All insulated components to have Al sheet or powder coated steel sheet cladding
Frames and supporting structure	• Strong enough to avoid any deformation of any reflector dish during manhandling/ tracking/under wind pressure of 200 km/hr • Of mild steel/ any other strong material with epoxy/anti-rust coating
Instrumentation and Control	• Complete with all instrumentation such as pressure gauge, temperature indicator, fluid level indicators, safety valves, fluid meter etc. Data acquisition and control system with online monitoring to be installed for automatic monitoring, control and record of all important process parameters in installations above 500 sq. m. of dish area.
Other Requirements	• System with Scheffler dishes having single axis automatic tracking arrangement will not be installed with more than 30 dishes at a place. For bigger systems, the dishes have to be of 2 axis automatic tracking mechanism

	• All parts/components will be of weather resistant design/specifications to withstand natural weathering outdoors under local climatic conditions, for a minimum period of 15 years. Warranty for a minimum period of 5 years will be provided by the supplier. Necessary spares will also be provided so that the user do not face any problem atleast during the warranty period. • The steel structures provided to support various components of the system will be fabricated in such a way that they are able to take load (both wind load and static dead load) of the whole system. In case the terrace where the system is to be installed is not strong enough to bear the loads, these should be transferred into columns and beams and the proposed load arrangement must be discussed with the concerned civil engineering department and their approval obtained. • The personnel of the buyer/user institution will be trained by the supplier in the operation and maintenance of the system and its back-up system. Proper manuals will be prepared and provided to the user. Log book will also be supplied to the and user so that proper documentation is maintained. • The other important features of system will be i) it will have easy access to the user and proper walkway and platforms will be supplied for easy operation and maintenance of the system wherever necessary ii) safety features such as safety valves etc will be incorporated in the system so that system does not explode under pressure and iii) proper instrumentation as mentioned above will be provided so that user could see the status of system and take precautions corrective steps if the system does not behave as expected.

6. Testing, standardization and quality control in solar thermal value chain

The solar thermal value chain broadly consists of raw material suppliers, component manufacturer, Solar thermal finished, developers and end user. The below diagram depicts the key stakeholders and their areas of view and operation.

Developer and Manufacturer view	Supply chain	Infrastructure
• Reflectors • Receiver tubes • Vaccum tubes • Solar steam turbines • Thermal energy storage devices • Reflector coatings • Absorber coatings	• Reflector stands • Solar grade mirrors • Steam equipment • Controllers • Pressure and Temperature sensors • Valves and fittings • Sun Trackers • PLCs • Support Structure	• Manufacturing parks • Dedicated solar thermal parks • Testing and certifications labs • Policy and regulatory institutions

As solar thermal technologies become more widespread, the need to implement and further develop product and performance standards for solar thermal has increased. Certification and quality assurance contribute to a trouble free use of solar water heating and subsequently increase consumer confidence in the technology. As such, it should be seen as an explicit part of awareness campaigns and all other incentives to stimulate the market and gain public acceptance.

A quality control scheme typically consists of:

- Product standards looking at safety, performance and durability of the system components (such as collectors, tanks etc.) as well as the system as a whole (i.e. configuration of the components);
- Methodology for testing; and
- Certification procedure (basically a surveillance system that guarantees constant quality).

6.1. Overview of standards and quality assurance in India

In India, MNRE is tasked with overseeing the National Standards Infrastructure under the guidance of Bureau of Indian Standards. MNRE is also tasked with managing the country's participation in international standards development activities. Therefore solar thermal technology related standards and certification program in India will be spearheaded by MNRE, Government of India. It is advisable that the government makes quality control of solar thermal systems mandatory. The responsibility for the certification will be laid upon representatives of the supply side of the market, which would need to submit their products for independent testing before they can label their products.

To meet ambitious targets of off-grid/heating application through solar thermal set by government of India, the country needs a holistic framework to supplement heating requirements for various applications. To improve the quality and reliability of solar thermal components manufactured indigenously and imported from other countries, it is necessary to establish QI pertaining to standards, quality assurance and testing facilities in India. Further, it is necessary to create awareness on implementing and following the standards and adhering to quality compliance.

Although there are various applications which can be utilized from the heat that generates from solar energy. MNRE has identified the below technologies and applications which are adopted through government programs in India.

Box type solar coker	Dish type solar cooker	Flat plate collector	Evacuated tube	CST
• IS 13429 (part 1 to part 3): 2000	• MNRE specfied minimum technical specifications for components used in Dish type	• IS 12933(part 1 part 5): 2003	• IS 16543 : 2016 • IS 16544 : 2016 • IS 16542:2016	• Specifications drafted by MNRE for different technlogies • testing prtocols need to be developed

Indian standards are available for domestic water heating and cooking applications viz. flat plate collector, evacuated tube and solar cookers. There are performance testing procedures available for parabolic dish concentrating cookers and also for parabolic concentrators for fixed and tracking type industrial process heat applications. The technology evolved in terms of material science related to reflectors reflectivity and absorbers absorptivity crossing more than 90 percent. The benchmarks and standards needs to modify and should update accordingly. The standards and testing procedures for the key components such as glass covers, absorber tubes, insulation thickness optimization, fins and receivers etc. should be established.

Thermal energy storage plays a vital role in solar thermal applications, the thermal energy storage depends on the applications and the temperature range. There are various technologies available to store the heat through organic and inorganic materials. Phase changing material (PCM) and inorganic salts are widely adopted in many countries to store the heat and utilize it has a backup source to generates steam. Currently, there are no standards available for thermal energy storage applications in India.

To meet the standards and quality assurance it is vital to have necessary infrastructure for performance and component testing, qualification and certification for the products to have a level playing field. It is pre-requisite to have all the testing facilities are adhered ISO/BIS standards and quality management process. Currently there are eight regional centers for testing of flat plate water heating systems, evacuated tube collectors, box and dish type solar cookers and apart from that there are two regional test centers for testing concentrated technology. The picture below depicts the list of test centers currently active in India.

National Institute of Solar Energy	•CST (Mobile and Immobile) •Non-concentrated
University of Pune	•CST (Mobile and Immobile) •Non-concentrated
RTC Indore	•Non-concentrated solar thermal systems
RTC SPRERI	•Non-concentrated solar thermal systems
RTC Madurai	•Non-concentrated solar thermal systems
RTC Hamirpur	•Non-concentrated solar thermal systems
RTC Murthal	•Non-concentrated solar thermal systems
RTC Silchar	•Non-concentrated solar thermal systems

Figure 37: Solar thermal testing facilities in India

Few salient features of CST testing facility at University of Pune

The facility has two different immobile testing facility test setups: one is based on steam/pressurized water and the other based on thermic fluid.

6.2. Immobile test setup facility (off-site testing)

- Testing temperature range is 100-200 ^{0}C and both the systems can withstand temperature up to 300 ^{0}C
- Various CST technologies, Scheffler, LFTR, PTC, paraboloid Fresnel Dish etc. can be tested.
- The test center is working on the impact of azimuth angle on design for different locations for single and double axis tacking technologies. And, also to develop testing protocols for different technologies.
- Passive tests, reflectivity, absorption, emission, characterizing reflectors and receiver are also performed indoors using UV visible-IR spectroscopy on the reflector and receiver material samples.

To evaluate the impact of different parameters on thermal output of the CSTs, it is necessary to test the system under quasi-stable state, rather than testing at stable and optimum thermal output conditions. Under quasi stable state, one can evaluate the dependence of solar radiation, inlet temperature, and ambient temperature on the thermal output of the system. This test is applicable for all types of CSTs including:

- Manually tracked Dish solar cooker.
- Fixed focus E-W automatically tracked dishes for direct indoor cooking, steam generation for the purpose of community cooking, laundry, space cooling etc. popularly known as Scheffler Concentrator.
- Reflecting Fresnel Dish Type Solar Concentrator (Dish Dual axis fully tracked Fresnel dish type solar concentrator for process heat, cooling, laundry application etc.)
- Parabolic Trough Collector.
- New technologies such as paraboloid dish and linear Fresnel reflectors.

6.3. Mobile testing facility (on-site testing)

For few applications the systems are customized and shipped and installed directly to the user premises. The prescribed equipment would be fitted by the customer in the system before the testing. Various sensors will be provided to measure fluid flow rate, temperatures and weather parameters. The manufacturer or beneficiary of the system must ensure appropriate arrangements to incorporate all the sensors complying with recommended pipe dimensions and lengths for faithful indication of measured parameters.

Measurements to carry out on various parameters to determine the thermal performance of the system installed in the field are as below:

- Intensity of solar radiations (DNI)
- Ambient temp
- Wind velocity
- Inlet and outlet temperature of the fluid going through the receiver
- Flow rate of heat extracting fluid
- Data collection during the starting time of the system to the end time and on the clean days (No cloud coverage) all data is to be recorded using a data logger having data logging facility to log the data at a minimum 1 minute time interval

6.4. Testing and certification of solar thermal systems in India

- The sequence to be adopted in India to qualify and certify a component or solar thermal product to ensure long term reliability and efficient field operation:
- In the first stage, during the design or prototype stage the manufacturer has to make sure all the qualifications certifications has to get through, even though the components or products are imported.
- In the second stage the products or the components has to qualify for benchmarking tests
- In the last stage an authorized third party has to do the surveillance tests, with random samples as per the benchmark and Qualification tests.

The existing labs and testing facilities need to be revamped with both skilled manpower and equipment to match the advancement in technologies to meet the ambitious targets envisaged by government of India. Although test protocols are available for domestic water heating and cooking applications, in all other cases where the same are not available for industrial process heating, institutional cooking, power generation, thermal energy storage and solar thermal and PV hybrid systems. In the recent times the technology has evolved due to improvements in material science and the Transmitivity of glass cover and absorptivity of the absorber have increased to more than 90 percent, so the current benchmarks has to be revised to meet the global standards.

Solar thermal collectors' performance is largely influenced by micro climate, since the generation of heat is dependent on direct solar radiation rather than the diffused as in the case of solar PV. Onsite field testing infrastructure should be developed with required sensors and equipment to understand the impact of different ambient parameters, it allows independent, flexible and traceable performance assessment of the products.

Most of the solar thermal products operation is studied at stable condition, to reach the final temperature the overall circulation time to heat the HTF is approximately 60-90 minutes which is time consuming. The labs should be developed with necessary infrastructure to emulate the stable conditions to understand the performance of the products.

Table 21: Performance Testing charges for solar thermal technologies

S.No	Product/technology	Testing Fee in INR	
1	Flat plate collector (FPC)	Capacity	Amount
		Upto100LPD	15000
		100to200LPD	18000
		200to500LPD	20000
2	Evacuated Tube Collector (ETC) based hot water system	Upto100LPD	20000
		100to200LPD	23000
		200to500LPD	25000
3	Box type solar cooker	8000	
4	Dish type solar cooker	Capacity	Amount
		Upto1.4sq.m.	10000
		Above1.4sq.m	10,000/-plus 2,000/-persqm
5	Concentrated Solar Technologies	Testing at test center (Immobile testing	Testing at site (mobile testing)
		18000	18000

6.5. CST Testing and Certification

There are no particular standards for CST, manufacturers/beneficiaries of systems installed in the field were not sure of their actual performance on heat delivery. Under UNDP-GEF project both mobile and immobile labs have been established at two regional centers as tabulated in the table-x. These test set ups are also helping manufacturers and new entrepreneurs in improving quality of their products and getting certification for participation in Ministry 'programme. The test set ups are expected to help beneficiaries in raising their confidence in the technologies, thereby giving a big push to the CST programme in the country.

Status of testing procedures for different CST:

Technology	Status of test protocol
Parabolic Dish	Developed
Arun Dish	Developed
Parabolic trough	Rotating platform required for tracking sun
Scheffler Dish	Year around data required to develop test protocols
Fresnel Reflector	Year around data required to develop test protocols
Central Tower	Year around data required to develop test protocols
Compound Parabolic Collector	Developed
Receiver tube Testing	Developed

Table 22: Concentrator Specifications as per MNRE

Parameter	Current Specifications
Shape and make of each concentrator	Of any shape fixed to a supporting frame/structure
Aperture area	10 m^2 (for Scheffler Dishes, it will be π/4* lengths of major and minor axis
Reflecting mirrors	
a) Material	○ High quality glass mirrors for outdoor use with protective layers of coating on black surface and side to protect from exterior weathering effect or any other reflecting material of similar reflectivity and durability. For coastal and colder regions, special protections to be made
b) Reflectivity	
c) Mirror Fixing	

	○ 90% minimum with a maximum degradation of 10% over its life span. Warranty/guarantee provided for a period of 5 years. To be replaced immediately by the supplier if found deteriorating during this period ○ With positive locking or sticking by industry proven outdoor-rated adhesives. Due protection of mirror coatings be taken while fixing the mirrors. Tying of wires is not acceptable. For high wind areas, special protection to be made For newer upcoming technologies, reflectors other than glass mirrors will also be acceptable subject to fulfillment of above requirement
Tracking Arrangement	• Any reliable automatic tracking mechanism with motorized reverse in evening & park at morning position including safe position in case of abnormal operating conditions. • Made of standard components; to be protected from rain, dust & outside environment • Tracking accuracy : +/- 0.5 degree (to be ensured using field-calibrated inclinometer)
Heat Receivers and piping	• Tested working fluid pressure: 1.5 times of designed pressure ○ Receivers : Of boiler/ standard industry quality to sustain required temperature and pressure ○ Header material and piping : Designed & manufactured as per IBR/ standard industry quality
Insulation	• All working fluid piping to be insulated with minimum thickness of 50 mm of PUF or rock wool. Headers or water-steam tank, insulated sides of receiver etc. to have minimum insulation of 75 mm. For colder regions facing sub zero temperatures, minimum thickness will be 100 mm and 150 mm respectively. In such regions cold water pipe lines including valves etc. will also be insulated. Insulation on receivers should withstand a minimum temperature of 600c. • All insulated components to have Al sheet or powder coated steel sheet cladding
Frames and supporting structure	• Strong enough to avoid any deformation of any reflector dish during manhandling/ tracking/under wind pressure of 200 km/hr • Of mild steel/ any other strong material with epoxy/anti-rust coating
Instrumentation and Control	• Complete with all instrumentation such as pressure gauge, temperature indicator, fluid level indicators, safety valves, fluid meter etc. Data acquisition and control system with online monitoring to be installed for automatic monitoring, control and record of all important process parameters in installations above 500 sq. m. of dish area.

Other Requirements	• System with Scheffler dishes having single axis automatic tracking arrangement will not be installed with more than 30 dishes at a place. For bigger systems, the dishes have to be of 2 axis automatic tracking mechanism • All parts/components will be of weather resistant design/specifications to withstand natural weathering outdoors under local climatic conditions, for a minimum period of 15 years. Warranty for a minimum period of 5 years will be provided by the supplier. Necessary spares will also be provided so that the user do not face any problem atleast during the warranty period. • The steel structures provided to support various components of the system will be fabricated in such a way that they are able to take load (both wind load and static dead load) of the whole system. In case the terrace where the system is to be installed is not strong enough to bear the loads, these should be transferred into columns and beams and the proposed load arrangement must be discussed with the concerned civil engineering department and their approval obtained. • The personnel of the buyer/user institution will be trained by the supplier in the operation and maintenance of the system and its back-up system. Proper manuals will be prepared and provided to the user. Log book will also be supplied to the and user so that proper documentation is maintained. • The other important features of system will be i) it will have easy access to the user and proper walkway and platforms will be supplied for easy operation and maintenance of the system wherever necessary ii) safety features such as safety valves etc will be incorporated in the system so that system does not explode under pressure and iii) proper instrumentation as mentioned above will be provided so that user could see the status of system and take precautions corrective steps if the system does not behave as expected.

6.6. Concentrated solar thermal technologies

Although MNRE mandates minimum technical specifications for concentrated thermal technologies, the recent draft lab policy stipulated detailed specifications to be adhered to maintain quality assurance in concentrated thermal technologies. The table below highlights the minimum technical specifications for CST based thermal technologies released by BIS for comments from different stakeholders.

Table 23: Paraboloid Dish Specifications

Scope	This draft standard specifies requirements of paraboloid dish concentrator for process heating and steam generation for temperature range of 60 ^{O}C to 350 ^{O}C. The paraboloid dish shall be useful for steam generation, high pressure hot water and thermic fluid systems in the above mentioned temperature range.
Reflector	**Aluminum reflector** • Specular reflectance shall be minimum 88 percent (The specimen of reflector shall be tested as per ASTM E 903. Measurement of spectral reflectance near normal conical reflectance is made over the spectral range from approximately 300 to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample) • Durability shall be minimum10 years (The mirror specimen shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards)

	• Thickness shall be 0.3 mm minimum in order to get paraboloid shape, if required. **Glass Mirrors** • Specular Reflectance shall be minimum 90 percent. (The specimen of reflector shall be tested as per ASTM E 903. Measurement of spectral near normal conical, hemispherical transmittance (or reflectance) is made over the spectral range from approximately 300 mm to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample.) • Durability shall be minimum 10 years. (The mirror specimen shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards) • Thickness shall be 2 mm to 3 mm. The shape can be paraboloid or flat for fresnel arrangement.
Reflector films	Material shall be polyester, acrylic, epoxy acrylic coated with silver/ aluminum to get reflective coat. Silver reflective film shall be backed by aluminum or any suitable substrate. Edges should to seal using tape or any suitable material. • Specular Reflectance shall be minimum 94 percent. (The specimen of mirror shall be tested as per ASTM E 903. Measurement of spectral near normal conical, hemispherical transmittance (or reflectance) is made over the spectral range from approximately 300 mm to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample.) • Durability shall be minimum 10 years. (The mirror specimen shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards.) • Thickness of substrate shall be 0.38 to 0.5 mm and thickness of reflective film shall be 0.10 to 0.12 mm.
Receiver Assembly	• Absorber coating for absorber surface temperatures less than 200 OC shall be black chrome, paint or selective coating [AS(C2-80)]. Absorptivity shall be minimum 0.9 in optical range of wavelength (300 to 2 500 nm) and emmisivity less than 0.2 in IR range of wavelength. The durability of absorber coating shall be minimum 10 years. The absorber sample shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards. The exposed sample should not have any blisters, degradation of back coating after exposure of 250 hrs. • No coating to be applied for absorber surface temperatures more than 200 ^{O}C for cavity type receivers. The glass cover shall be optional on the receiver mouth. Transmittance of glass shall be minimum 95 percent. • The absorber shall be made of boiler grade alloy steel or stainless steel as per IBR with thickness suitable to stand the design pressure and temperature with corrosion margin as per IBR.
Collector and support structure with civil foundation	The basic framework of the paraboloid dish and support shall be standard structural steel or aluminum. The collector is made of aluminum or steel structure for mounting reflectors. The collector along with mirror is put on support structure along with tracking mechanism. • The structure shall be designed to withstand wind speed of 47 m/s under stow condition and 10 m/s under operating condition. Structure design shall be as per IS 875 (Part 2) and IS 875 • Material of collector structure and support shall be as per IS 2062, and shall be protected from corrosion with suitable process such as galvanization, cathode electrode deposition (CED) or any suitable painting process. The design shall be suitable for life span 20 years.

Tracking system	Enables to remain focused towards the sun so as to capture maximum possible direct radiation during the day. Tracking shall include motors, gearbox or any similar mechanism using relevant IS standards and control system. • Accuracy requirement shall be decided for the specific manufacturer's design which shall be based on Concentration ratio. • Tracking Motor shall be Servo/Stepper/Induction as per IS 9815-1, IS 13079, IS 12615 respectively suitable for the load for taking in stow position at full speed. • Electrical system such as wiring, connections shall be as per IS 732 • Electronic and control system mounted outdoor shall get exposed to all types of weather conditions. In view of the same, the control panel and electronic components shall be protected as per IS/IEC 60529

Acceptance Criteria:

Paraboloid dish should have, η_o = 0.55 (minimum), a1 = 0.8 W/m2K (maximum) and a2= 0.001 W/m2K 4 (maximum), leading to overall thermal efficiency, η = 0.4 (minimum)

Table 24: Scheffler Dish Specifications-

Scope	This standard specifies the requirements for Scheffler dish and various components, for process heating and steam generation, for the temperature range between 100 ^{O}C to 175 ^{O}C.
Reflector	**Aluminum reflector** • Specular reflectance shall be minimum 88 percent (The specimen of reflector shall be tested as per ASTM E 903. Measurement of spectral reflectance near normal conical reflectance is made over the spectral range from approximately 300 to 2500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample) • Durability shall be minimum10 years (The mirror specimen shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards) • Thickness shall be 0.3 mm minimum in order to get paraboloid shape, if required. **Glass Mirrors** • Specular Reflectance shall be minimum 90 percent. (The specimen of reflector shall be tested as per ASTM E 903. Measurement of spectral near normal conical, hemispherical transmittance (or reflectance) is made over the spectral range from approximately 300 mm to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample.) • Durability shall be minimum 10 years. (The mirror specimen shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards) • Thickness shall be 2 mm to 3 mm. The shape can be paraboloid or flat for fresnel arrangement.

Reflector films	Material shall be polyester, acrylic, epoxy acrylic coated with silver/ aluminum to get reflective coat. Silver reflective film shall be backed by aluminum or any suitable substrate. Edges should to seal using tape or any suitable material. • Specular Reflectance shall be minimum 94 percent. (The specimen of mirror shall be tested as per ASTM E 903. Measurement of spectral near normal conical, hemispherical transmittance (or reflectance) is made over the spectral range from approximately 300 mm to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample.) • Durability shall be minimum 10 years. (The mirror specimen shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards.) • Thickness of substrate shall be 0.38 to 0.5 mm and thickness of reflective film shall be 0.10 to 0.12 mm.
Receiver Assembly	• Absorber coating for absorber surface temperatures less than 200 OC shall be black chrome, paint or selective coating [AS(C2-80)]. Absorptivity shall be minimum 0.9 in optical range of wavelength (300 to 2 500 nm) and emissivity less than 0.2 in IR range of wavelength. The durability of absorber coating shall be minimum 10 years. The absorber sample shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards. The exposed sample should not have any blisters, degradation of back coating after exposure of 250 hrs. • No coating to be applied for absorber surface temperatures more than 200 ^{O}C for cavity type receivers. The glass cover shall be optional on the receiver mouth. Transmittance of glass shall be minimum 95 percent. • The absorber shall be made of boiler grade alloy steel or stainless steel as per IBR with thickness suitable to stand the design pressure and temperature with corrosion margin as per IBR.
Collector and support structure with civil foundation	The basic framework of the paraboloid dish and support shall be standard structural steel or aluminum. The collector is made of aluminum or steel structure for mounting reflectors. The collector along with mirror is put on support structure along with tracking mechanism. • The structure shall be designed to withstand wind speed of 47 m/s under stow condition and 10 m/s under operating condition. Structure design shall be as per IS 875 (Part 2) and IS 875 • Material of collector structure and support shall be as per IS 2062, and shall be protected from corrosion with suitable process such as galvanization, cathode electrode deposition (CED) or any suitable painting process. The design shall be suitable for life span 20 years.
Tracking system	Enables to remain focused towards the sun so as to capture maximum possible direct radiation during the day. Tracking shall include motors, gearbox or any similar mechanism using relevant IS standards and control system. • Accuracy requirement shall be decided for the specific manufacturer's design which shall be based on Concentration ratio. • Tracking Motor shall be Servo/Stepper/Induction as per IS 9815-1, IS 13079, IS 12615 respectively suitable for the load for taking in stow position at full speed. • Electrical system such as wiring, connections shall be as per IS 732 • Electronic and control system mounted outdoor shall get exposed to all types of weather conditions. In view of the same, the control panel and electronic components shall be protected as per IS/IEC 60529

Table 25: Non-imaging concentrator Specifications-

Scope	This standard specifies requirements of non-imaging concentrator (NIC) for process heating and steam generation for range 60 ^{O}C to 120 ^{O}C. The NIC shall be useful for low to medium process heat application.
Reflector	Material of reflector shall be Aluminum sheet with protective coatings for performance enhancement and durability. • The reflector sheet shall have thickness in the range of 0.3 to 0.8 mm, suitable for forming a parabola. • Reflectivity shall be minimum 90 percent. The specimen of mirror shall be tested as per ASTM E 903. Measurement of spectral near normal cone hemispherical transmittance (or reflectance) are made over the spectral range from approximately 300 to 2 500 nm with an integrating sphere spectrophotometer having a small coal solid angle of incident flux on sample. The solar transmittance, reflectance, or absorptance is obtained by calculating a weighted average over wavelength with a standard solar spectral irradiance as the weighting function by either the weighted or selected ordinate method. • Durability shall be minimum 10 years. The reflector specimen shall be subjected to the neutral salt spray test as per IS 9844 and IS 3438. The specimen shall not have any blisters, degradation of back coating after exposure of 250 hours. •
Receiver Assembly	Receiver assembly shall be made of an evacuated glass tube, U shaped tube to remove absorbed heat & fins to transfer heat to the tube. • Evacuated Tube shall be as per IS 16543 suitable for stagnation temp of 300 ^{O}C minimum. • Absorption of coating shall be minimum 90 percent • Glass transmission of outer glass shall be minimum 92 percent. • Emissivity of absorber coating shall be maximum 10 percent. • The inner absorber tube shall be selectively coated with aluminum nitride based material or any equivalent. • Vacuum durability: 50 percent maximum as per IS 16543. • Vacuum performance test shall be done as per IS 16543 • The U-tube shall be made of copper, stainless steel with thickness suitable for design pressure as per IBR code. The diameter and thickness of tube shall be as per manufacturer's specifications. • The metal fins shall be made of aluminum or copper. The thickness of fins shall be decided by manufacturer with tolerances
Collector and support structure with civil foundation	• The back cover shall be made of aluminum or Galvanized Iron sheet fixed on aluminum or steel frame. One end of receiver tube shall be fixed on to the module with the help of brackets and fasteners. • Design should be as per IS 800/IS 875 (Part 3). • The design strength of the module, stand & foundation shall be in accordance with IS 875 (Part 2) and IS 875 (Part 3). • Strength of civil foundation shall be in accordance with IS 456 and allied/applied codes

Acceptance Criteria:

The optical efficiency should be 60 percent minimum. The system efficiency shall be minimum 45 percent efficient at 90^{O} C.

Table 26: Solar parabolic trough collector (PTC)

Scope	This standard specifies requirements of solar parabolic trough collector (PTC) for process heating and steam generation for range 60 OC to 250 OC. The PTC shall be useful for steam generation, high pressure hot water and thermic fluid systems in the above mentioned temperature range
Reflector	**Aluminum reflector** • Specular reflectance shall be minimum 88 percent (The specimen of reflector shall be tested as per ASTM E 903. Measurement of spectral reflectance near normal conical reflectance is made over the spectral range from approximately 300 to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample) • Durability shall be minimum10 years (The mirror specimen shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards) • Thickness shall be 0.3 mm minimum in order to get paraboloid shape, if required. **Glass Mirrors** • Specular Reflectance shall be minimum 90 percent. (The specimen of reflector shall be tested as per ASTM E 903. Measurement of spectral near normal conical, hemispherical transmittance (or reflectance) is made over the spectral range from approximately 300 mm to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample.) • Durability shall be minimum 10 years. (The mirror specimen shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards) • Thickness shall be 2 mm to 3 mm with parabolic shape
Reflector films	Material shall be polyester, acrylic, epoxy acrylic coated with silver/ aluminum to get reflective coat. Silver reflective film shall be backed by aluminum or any suitable substrate. Edges should to seal using tape or any suitable material. • Specular Reflectance shall be minimum 94 percent. (The specimen of mirror shall be tested as per ASTM E 903. Measurement of spectral near normal conical, hemispherical transmittance (or reflectance) is made over the spectral range from approximately 300 mm to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample.) • Durability shall be minimum 10 years. (The mirror specimen shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards.) • Thickness of substrate shall be 0.38 to 0.5 mm to get parabolic shape
Receiver Assembly	• Receiver assemble shall be of absorber tube generally made from suitable material as per IBR code, with glass cover either with evacuated or air jacket and optionally with secondary reflectors • Absorber coating shall be black chrome, paint or selective coating [AS(C2-80)]. Absorptivity shall be minimum 0.9 and emissivity shall be less than 0.2. Transmittance of glass shall be minimum 95 percent. • The absorber tube shall be made with thickness suitable to stand the design pressure and temperature as per IBR code. • The absorber coating durability shall be minimum 10 years. • The absorber tube and glass cover specimen should be subjected to the neutral salt spray test as per IS 9844 or equivalent standards. The exposed

<table>
<tr><td></td><td>should not have any blisters, degradation of back coating after exposure of 250 hours of the specimen
Glass Cover : The absorber tube shall be covered with glass having transmissivity 95 percent minimum with thickness of minimum 2 mm and diameter suitable for the absorber tube.</td></tr>
<tr><td>Collector and support structure with civil foundation</td><td>The basic framework of the paraboloid dish and support shall be standard structural steel or aluminum. The collector is made of aluminum or steel structure for mounting reflectors. The collector along with mirror is put on support structure along with tracking mechanism.
The structure shall be designed to withstand wind speed of 47 m/s under stow condition and 10 m/s under operating condition. Structure design shall be as per IS 875 (Part 2) and IS 875
Material of collector structure and support shall be as per IS 2062, and shall be protected from corrosion with suitable process such as galvanization, cathode electrode deposition (CED) or any suitable painting process. The design shall be suitable for life span 20 years.</td></tr>
<tr><td>Tracking system</td><td>Enables to remain focused towards the sun so as to capture maximum possible direct radiation during the day. Tracking shall include motors, gearbox or any similar mechanism using relevant IS standards and control system.
Accuracy requirement shall be decided for the specific manufacturer's design which shall be based on Concentration ratio.
Tracking Motor shall be Servo/Stepper/Induction as per IS 9815-1, IS 13079, IS 12615 respectively suitable for the load for taking in stow position at full speed.
Electrical system such as wiring, connections shall be as per IS 732
Electronic and control system mounted outdoor shall get exposed to all types of weather conditions. In view of the same, the control panel and electronic components shall be protected as per IS/IEC 60529</td></tr>
</table>

Acceptance Criteria:

PTC should have efficiency of 0.6 (minimum), a1= 1.5 (maximum) and a2 = 0.07 (maximum)

Table 27: Parabolic Minimum technical specifications for qualification

<table>
<tr><th colspan="2">Reflector</th></tr>
<tr><td>Type</td><td>Specification</td></tr>
<tr><td>Glass mirror</td><td>Material–Tempered and Toughened Solar Grade Glass tested for scratches and durability.

Shape – Parabolic

Thickness-3to4mm

Reflective Coating – Silver Back Coating

Specular Reflectivity– more than 93%

Protective Coating–Edge Sealing coat on all sides of mirrors cut in different sizes after rubbing and cleaning them properly. Special weather protection</td></tr>
</table>

	coat to be made for mirrors to be used in coastal and colder regions. Strength and Durability–Applicable standards ISO 6270-2:2005, ISO9227:2012
Silver Reflective Film backed by Aluminum	Material–Painted Polyester, acrylics / epoxy Polyester paints on Aluminum substrate. Substrate Thickness-0.38 to 0.5mm. Shape: Parabolic. Reflective Coating – Solar Grade Silver Film 0.1 to 0.12mm thickness. Edge Sealing –Use of Edge Tape/Caulk. Specular Reflectivity– more than94%. Strength and Durability–Applicable standards
Support Structure	
Design	Space frame or torque tube structure with Arrangements to fix mirrors so as to have an accurate focus on line receiver
Material	Standard Structural steel as per IS42062
Shape	Parabolic
Protection from corrosion	Cathode Electrode Deposition (CED) painting Process or Galvanization as per relevant code or epoxy coating/PU (polyurethane) paints
Strength & Durability	Designed as per IS800/IS 875 and allied/ applied Codes considering a life span of 25years
Fixing of mirrors	On the base structure with the help of Aluminum channels and standard fasteners
Receiver	
Sub components	Specification
Absorber	Design –Line around tube Material–Stainless Steel 304 grade Thickness–1-2mm Diameter 25-35 mm Durability –Minimum 10 years
Absorber Coating	Material–Black Chrome/ Solar grade absorber paint/ Selective Coating (AS(C2-80)) Absorptivity – 0.90 – 0.95 Emissivity–0.09-0.15
Glass Cover	Design -Linear round tube Material- Borosilicate glass Transmitivity–At least 95% Thickness–2-3mm Diameter–50-80 mm Durability –Minimum 10 years
Absorber-Glass fixing	Glass to Metal sealing methods– Matched thermal expansion seal and unmatched thermal expansion seal
Receiver Fixing	A receiver is fixed on to a mirror support structure with the help of standard steel sections/ angles
Civil Foundation	
Parameter	Specification
Design	Designed to rest on soil of sufficient strength or To suit the prevalent soil condition

Material	Cement and concrete
Coating Protection	Coating of paint on exterior surface
Strength & Durability	Designed as per IS456 and allied/ applied codes considering a life span of 25 years.
Structure Steel Foundation	
Design	Structural steel frame
Material	Standard structural steel as per IS 2062
Protection from Corrosion	Cathode Electrode Deposition(CED) painting Process or Galvanization as per relevant code or epoxy coating/ PU paints
Strength & Durability	Designed as per IS800/ IS 875 and allied / applied codes considering a life span of 25 years.
Tracking system	
Parameter	Specification
Mechanism	Microprocessor/ timer based single axis tracking system i.e. moves East- West
Control-Logic	Sun position sensors based tracking with feedback mechanism or Solar algorithm (preprogramed) based tracking
Accuracy	
Weather Protection of outdoor equipment	Cable channel for electric cables, Aluminum sheet cover on motors, Box casing for micro-processor based electronics
Heat transfer pipe	
Design	Electric Resistance Welded (ERW) pipe or seamless pipe
Material	Galvanized Iron/Mild Steel/Stainless Steel
Size	Diameter of pipe depends on the flowrate of fluid Thickness is based on the pressure required in the system.
Working Fluid	Hot Water /Steam/Pressurized Hot water /ThermicFluid.
Strength & Durability	As per IBR5/ASME6andallied/ applied standards
Insulation	
Type	Thick insulation layer with cladding over the pipe
Material	Insulation Material- Mineral wool or Glass wool or Light Resin Bonded (LRB) mattresses Cladding Material–Aluminum/Stainless Steel/ Galvanized Iron sheets
Support Structure	
Design	Structural Steel Structure fixed on to RCC column
Material	Standard structural steel as per IS 2062, Cement-concrete or civil structure
Coating Protection	Cathode Electrode Deposition (CED) painting processor Galvanization as per relevant code or epoxy coating/ PU paints. Coating of paint on exterior surface of Civil structure
Strength & Durability	Designed as per IS800/IS875/IS456 and allied/ applied codes considering a life span of 25years
Heat Storage Tank	
Type	Cylindrical tank.
Material	Generally MS, other material as per application
Size	Hot water/ Pressurized hot water/Hot oil
Strength and Durability	Designed as per ASME codes and allied/ applied codes

Table 28: Concentrated Solar Thermal Test Methods as per BIS test procedures

Scope	Thermal performance of tracking concentrating solar collectors and non-tracking non imaging concentrator
Applicability	This test method applies to one or two-axis tracking reflecting concentrating collectors and non-imaging concentrator (NIC) in which the fluid enters the collector through a single inlet and leaves the collector through a single outlet, multiple collectors in series having single inlet and outlet may also be used.
Test method	Outdoor testing only, under clear sky, quasi-steady state conditions.
Outcome	Focuses on alignment, preconditioning & calculation of efficiency and analysis of data generated to give efficiency equation.
Out of scope	Not applicable for durability or the reliability of any collector or component and safety concerns, if any associated with its use.
Test method procedure	Thermal performance is the rate of heat gain of a collector relative to the incident solar power. This test method contains procedures to measure the thermal performance of a collector for certain well-defined test conditions. The procedures determine the response of the collector for various angles of incidence of solar radiation, and the thermal performance of the collector at various operating temperatures. The test method requires quasi-steady state conditions, measurement of environmental parameters, and determination of the fluid mass flow rate-specific heat product and temperature difference, Δt, of the heat transfer fluid between the inlet and outlet of the collector. These quantities determine the rate of heat gain, for the solar irradiance condition encountered. The solar power incident on the collector is determined by the collector area, its angle relative to the sun, and the irradiance measured during the test.
Measuring instruments required	• Solar radiation: Class I Pyranometer, equipped with shading rings • Temperature measurement: Three temperature sensors for solar collector testing • Flow rate: Flow sensors (Volumetric flow)(standard uncertainty of the liquid flow rate measurement shall be within ± 1 percent of the measured value, in mass per unit time) • Pressure sensors • Wind speed sensors
Measurements	• Collector aperture area • Global solar irradiance • Diffused solar irradiance at the collector aperture • Direct Normal Irradiance (DNI) • Surrounding wind speed • Surrounding air temperature • Temperature of heat transfer fluid at the receiver inlet

- Temperature of heat transfer fluid at the receiver outlet
- Mass flow rate of the heat transfer fluid
- Pressure of fluid in receiver

6.7. Evacuated glass tube and flat plate collectors

Evacuated glass in glass tube and flat plate based collector solar water heating systems are predominantly used for domestic water heating applications in India. The standards are mandated by MNRE for all the empaneled partners and applicable to only non-concentrating, direct, vented solar collector systems that convert solar radiation to thermal energy based on thermos symphonic principle. All the auxiliary water heater integrated systems will be switched off during the testing procedure. Components of Evacuated glass tube collector solar thermal system and standards.

Evacuated glass tubes	•Material conforming to ISO 3585 •The absorptivity of solar selective coating shall be minimum 0.92 at AM 1.5
Flat plate collector	•Solar flat plate collector shall conform to IS 12933
Storage water tank	•inner tank- IS 6911 or ASTM grade 304,304L,316, Mild steel sheet conforming to IS 1079 with anti-corrosive coating. •Cladding- pre-painted galvanized steel conforming to IS 14246 •Insulation- Pre-injected PUF of minimum thickness 50mm. The free rise density of PUF shall be minimum 26 kg/m3 and moulded density shall be minimum 36 kg/m3 •inner seal and dust cover for tubes- Silicon rubber to withstand 175 C and shall be of EPDM rubber/ UV stabilized PVC
Diffuse flat plate reflector	•Diffuse flat plate reflector if provided shall be bright aluminium/stainless steel sheet of suitable thickness.
Tube resting caps	•UV stabilized ABS/Nylon/PP plastic material
Supporting frame stand	•Mild steel conforming to IS 2062 with hot dip galvanized or powder coated •Galvanized steel sheet conforming to IS 277 with/without powder coating •Stainless steel. •Aluminium with anodized coating
Pipe and fittings	•IS 6392:1971 Steel pipe flanges • IS 6911: 1992 Stainless steel plate, sheet and strip

Apart from the components adhering to different IS standards, the solar thermal products which are formed by integrating different components has to qualify the following outdoor and indoor tests and equipment's required to meet the performance standards:

Idle heating test	Leakage Test	Integral Test	External thermal shock test	Frost Resistance test
Anemometer, Pyranometer, Data logger	Hydraulic pressure source, Pressure guage	Anemometer, pyranometer, data logger	Flow sensors	Cold storage

The above all individual component standards are the sub section of the IS standards tabulated in the table below

Evacuated Tube Collectors Type	Indian Standards
All Glass Evacuated Solar Collector Tubes-Specification	IS 16543 : 2016
All Glass Evacuated Tubes Solar Water Heating System.	IS 16544 : 2016
Direct Insertion Type Storage Water Tank for All Glass Evacuated Tubes Solar Collector Specification	IS 16542:2016

The pioneer work in developing standards for solar thermal was done by the International Organization for Standardization that developed ISO-IEC standards and European Standardization Organization that developed European Standards (ENs) for this sector.

ISO Standards

- ISO 9806:2013 - Solar energy -- Solar thermal collectors -- Test methods
- ISO/DIS 9806-Solar energy -- Solar thermal collectors -- Test methods
- ISO 9808:1990 - Solar water heaters -- Elastomeric materials for absorbers, connecting pipes and fittings -- Method of assessment
- ISO 22975-1:2016-Solar energy -- Collector components and materials -- Part 1: Evacuated tubes -- Durability and performance

European Standards

- EN 12975-1. Thermal solar systems and components - Solar collectors - Part 1: General Requirements.
- EN ISO 9806. Solar Energy - Solar thermal collectors - Test methods.
- EN 12976-1. Thermal solar systems and components - Factory made systems - Part 1: General requirements.
- EN 12976-2. Thermal solar systems and components - Factory made systems - Part 2: Test methods.
- EN 12977-1 Thermal solar systems and components - Custom built systems - Part 1: General requirements for solar water heaters and combi systems
- EN 12977-2 Thermal solar systems and components - Custom built systems - Test methods for solar water heaters and combi systems
- EN 12977-3 Thermal solar systems and components - Custom built systems - Part 3: Performance test methods for solar water heater stores

Standards and Testing guidelines

- Standards and Tests to be carried out for glass tubes:

IS/ISO 9488:1999 Solar Energy – Vocabulary

ISO 3585:1998 Borosilicate glass 3.3

The following tests shall be performed on sample of all glass evacuated solar collector tube:

1. Dimensions - Shall conform to the requirements
2. Visual Appearance– Shall conform to the requirements
3. Stagnation performance parameter test
4. Stagnation solar irradiance test

6.8. Solar Thermal Cookers testing and certification

Solar cookers performance is evaluated by different parameters such as efficiency, cooking power, figures of merit etc. In the absence of an interrelation between the different performance parameters it is very difficult to compare the cookers' performance reported by different manufacturers and establish the criteria required for selection of a cooker which can accomplish cooking successfully and satisfactorily. The table below reviews some of the performance parameters and related test procedures.

Box type solar cooker	IS 13429 (Part 1 to Part3) : 2000

Table 29: Specifications for box and dish type type solar cooker

Parabolic dish made of single/ multiple reflectors fixed firmly to a rigid frame. The size and shape of the reflectors is such when joined/fixed they automatically form non parabolic dish	
Dish area	1 sq. m minimum
Reflecting mirrors	
i) Material	Bright anodized aluminum sheets/glass mirrors/ polymer film/any other better and durable material with protective layers of coating on back surface and sides to protect from exterior weathering effect. For coastal and colder regions, special protections to be made.
ii) Reflectivity	90%minimum with a maximum degradation of10%over its life span. Warranty/guaranty to be provided fora period of five years. To be replaced immediately if found deteriorating during this period.
iii) Mirror fixing	With positive locking or sticking by good quality adhesives. Due protection of mirror coatings to be taken while fixing the mirrors. Tying of mirrors with wires not acceptable. For high wind areas special protection to be made.

Concentration ratio	Over 80
Bowl Supporting frame	The supporting frame for the reflecting bowl will be made of MS rings supported by MS Strips or FRP material/thick MS wire-mesh structure. It will be rigid enough to avoid any deformation of the bowl shape during manual/handling or under wind pressure. The MS structure will have epoxy/ ant-rust coating.
Bowl stand	• Of mild steel epoxy/ powder coated. • With arrangement to hold cooking vessels of different sizes. • With suitable provision for securing the cooker to the ground.
Tracking Mechanism	• Manual or automatic • Designed to enable unrestricted 3600 rotation to parabolic dish around its horizontal axis passing through its focal point and center of gravity and also around its vertical axis, for adjustment of the cooker in the direction of the sun. With simple locking arrangement to hold/ fix the bowl at a particular position • With pointer/ other arrangement to facilitate users positioning of the bowl exactly in the direction of the sun
Cooking Vessel	• ISI mark pressure cooker of suitable capacity. Resistant black powder coated bottom.

7. Gap Analysis

Indian renewable energy market is still in its nascent stages having realized just a miniscule percentage of the vast available potential of renewables (especially solar) in the country. A lot of solar plants have been installed in the recent years and majority of these solar plants have only completed about 4-5 years or just about 20% of their life cycle and a lot of development is still expected in the sector. The solar plants installed till now have been compromised on quality as there were very limited norms of quality control for the infrastructure and the norms that were available lagged execution and weren't followed diligently. The effect of this leniency in the quality infrastructure of renewable equipment will be seen in the long run, when the efficiency of the plants will be bargained ultimately marginalizing their life cycle. Hence, it is essential to identify the gaps in the quality of the infrastructure installed and rectify them.

7.1. Quality concerns and safety gaps in a PV plant

Quality infrastructure is a basic fundamental in ensuring that the power plant works effectively, efficiently, is devoid of repetitive faults and has a high utilization factor throughout its entire life cycle. A lot of quality and safety issues can arise along the entire solar PV value chain upon installation of unreliable equipment that are not standardized as per the designated standards. This will degrade the quality of the PV plant, efficiency will be reduced and ultimately the plant will get shut down before completing its entire life.

These issues range from the uncertainty in the quality of the components installed in the power plants to non-availability of reliable site data. The equipment must have suitable IS or IEC standards (as applicable) obtained from the designated bodies. Errors can also get generated due to inadequate wiring or cabling during the installation process and hence a proper monitoring is required. Operation and maintenance needs to be timely and consistent once the power plant has been commissioned leaving no scope for prolonged and unnecessary downtime for the plant. The grid connected solar PV plants can become unstable and get shut down in case of under drawl or over drawl of power from the plant. Hence, it is mandatory to keep a regular check on the consumption pattern from a specific plant and maintain the Grid stability.

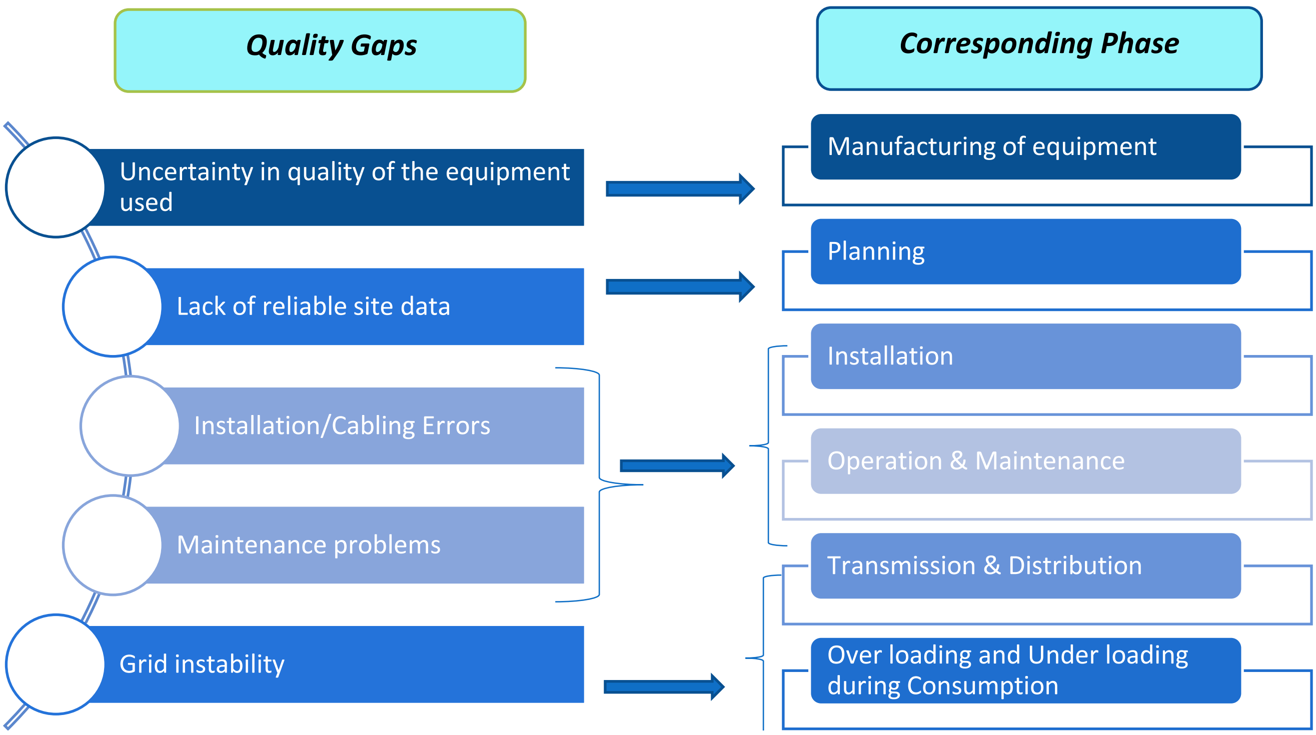


Figure 38: Quality gaps along the phases of a Solar PV

India has an ambitious target of taking the renewable energy capacity to 175 GW by 2022. Renewable energy capacity addition saw a significant growth worldwide in the recent years and India did not lag behind, adding a record 5.5 GW of solar power itself in the last financial year owing to the support from the government by creating a favorable policy environment for the renewables as well as a sharp drop in the prices of modules, inverters and BoS. However, among all this, the quality assurance of the power plants got neglected and substandard equipment were installed in a haste.

Recently, TUV Rheinland (a testing, certification and auditing company) claimed that 30% of all the Solar PV plants installed worldwide have serious installation defects.

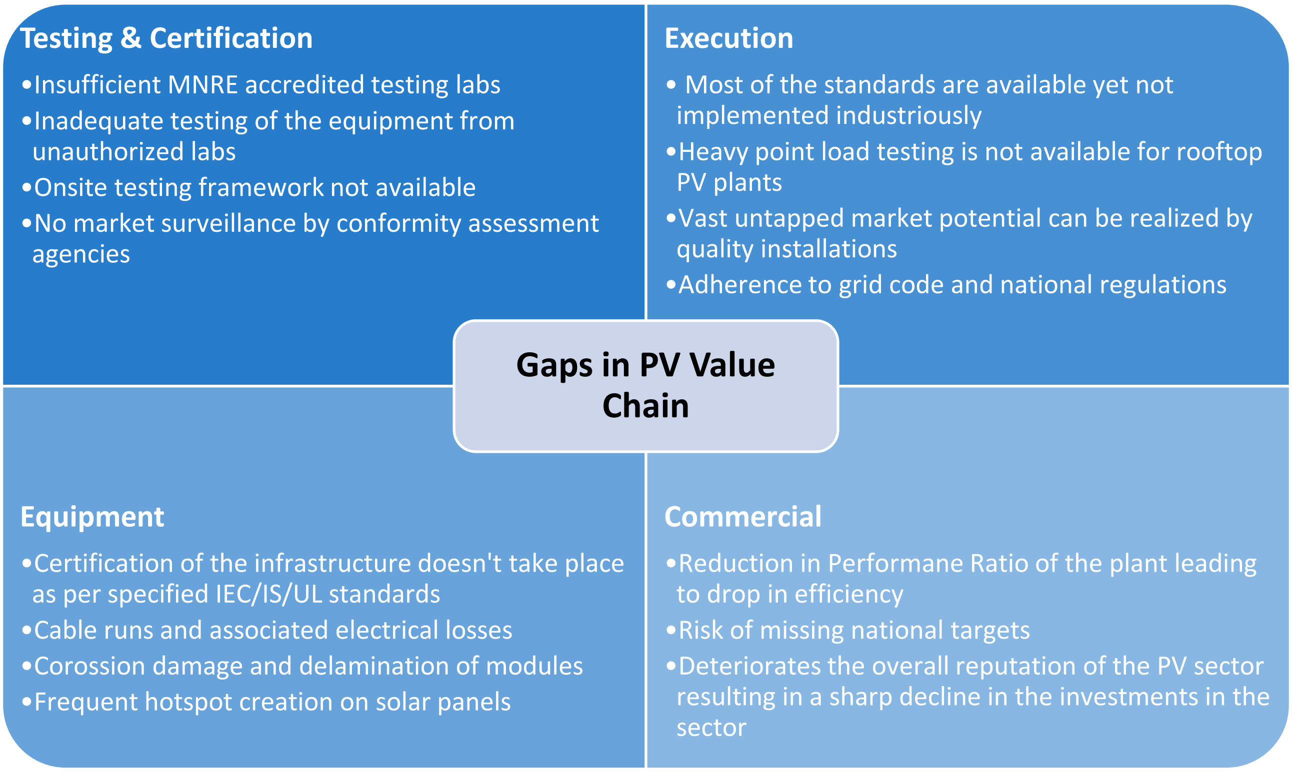
With the policy support in the renewable sector from the government, the installation of solar power plants has shot up abruptly without a proper focus on the quality assurance of the infrastructure that is being installed. Several requirements regarding quality control are being circumvented which need to be curbed or else this will lead to the decline in the life of these plants.

According to TUV Rheinland, 30% of all the Solar PV plants worldwide have serious installation defects

7.2. Gaps in Quality Infrastructure in the PV Value chain

In the last decade India's Renewable energy segment has grown from strength to strength in terms of technology adoption but the maturity of Quality infrastructure is still far-fetched. Developers and EPC companies in India are more focused on high Performance Ratios (PR's) rather than adopting the best practices for quality installations and design of the components used. India vastly lags in accelerated reliability testing and hence the PV installations are unable to withstand stress conditions as they are subjected to extreme environmental conditions and deteriorating effects occur to the elements over their lifetime.

India needs to have a stipulated framework for onsite testing since many systems are not satisfactorily evaluated prior to being placed into service and once installed it is necessary that they be tested to verify performance and to evaluate the condition of the wiring systems and equipment in order to maintain their efficiency and safeguard them from long term defects. This makes it quite significant to have a safety check for the sites in order to create more focus on reliability and performance of the project sites along with that on the components.



7.3. Gaps in Solar Thermal Value Chain

7.3.1. Lack of performance standards and testing protocols

CST in India is majorly attributed to commercial and industrial applications and limited to hybrid applications, where fossil fuel and CST are used in tandem to deliver the required heat and steam at specific temperature and pressure. The performance of CST are purely relied upon efficiency and the reliability of operation honored by EPC players and manufacturers.

Since most of the applications are tailor made by the manufacturers as per the user demand, the quality assurance on overall system are not followed, rather there are globally acceptable standards available component wise. Performance of CST is dependent on ambient conditions- the losses like convection (top losses from the receiver tube), conduction losses and radiation losses are purely dependent on the ambient temperature and micro climate surrounding the overall system. In India, there are only two mobile testing facilities available to test the components and their performance at project locations.

CSP technologies incorporating thermal storage solution will make solar power dispatchable and thus more cost effective to meet all segments of power demand. There is a realistic potential for solar thermal technologies to make an important contribution to meeting India’s capacity and energy demand and diversify the country generation profile. Albeit, there are few technologies to scale-up to large scale to operate under non-sunshine hours to stabilize the power output. Small scale testing facilities has to be set-up to understand the operational parameters of energy storage.

7.3.2. Performance Monitoring

It is important to track the operational parameters of CST to understand the performance of technology under intermittent and stable conditions. The key parameters under consideration to evaluate the performance of CST are DNI (Direct Normal Irradiance), diffused radiation, wind speed and ambient temperature. These four key parameters will play a significant role on the heat delivered by the system. Having the backdrop of performance and parameters on hourly basis for a year will fine-tune the testing protocols and schedule the operation and maintenance in advance to reduce the overall downtime of the system.

Key benefits of performance monitoring are highlighted in the figure below:

Policy makers

- Information to darft various policies and fine tune the testing standards
- Database for resource assessment
- Benchmarking the technology performance

Manufacturers

- Validation of new designs
- Optimal sizing of new installations
- fine-tuning the design to optimise the location specifc performance

End user

- Continious track of data to improve the thermal output
- Operation and maintenance management

Developers

- Design confirmation
- Operation and Maintenance
- Performance assessment
- Financial modelling

Figure 39: Benefits of performance monitoring for CST projects

7.3.3. Lack of skilled manpower

Due to increase in awareness of solar PV and global price drop due to technology advancements, solar PV overshadowed solar CST technologies in the recent times. With this backdrop, skill development programs in India were inclined towards solar PV and the pan India program Suryamitra launched by MNRE was more focused towards PV. India has strong and established related industries in manufacturing in most of the components of the value chain and have the experience of in developing skilled manpower and resources through a large number of established technical and engineering institutes.

7.3.4. Lack of domestic manufacturing

The market and ecosystem for solar flat plate and evacuated tube based collector system is matured and have standards and quality assurance in place in India. For concentrated technologies like Parabolic and central tower there are no standards and quality assurance practices that are being followed in India. During our discussions with CST EPCs and technology providers the following challenges are identified with recommendations highlighted in the table below.

Table 30: Domestic manufacturing and recommendations

Component	Manufacturing Infrastructure	Applications and Challenges	Recommended actions
Receivers for Parabolic Trough type	Low	Critical component for the performance of the solar collectors with most of the thermal and optical losses originate. The receivers are made of selective coating which are highly absorbent and having low emissivity at the operating temperature. Technical know-how for selective coating and anti-reflective coating Lack of expertise for metal glass seal	1. Promote research and development for sealing the metal glass and selective coatings on receiver tubes 2. Impetus to collaboration with global players 3. Application specific selective coatings need to be standardized
Receivers for Central tower type	Low		1. Promote R&D for receivers able to work under high solar flux, for volumetric receivers using atmospheric air as HTF, and for durable pressurized air receivers
Mirrors for Parabolic Trough	Medium	Mirrors used in CSP plants are different from traditional mirrors in reflectivity, durability, and strength. The fabrication of the needed extra clear glass requires low-ferrous sand that is not easily available in India. Furthermore, this glass has no other application in India and therefore must be made specifically for solar CSPs. High quality low-iron sand availably in India Technology gap for some of the players (bending and mirroring)	1. In India majority of the manufacturers of CST import solar grade mirrors, due to lack of availability of raw material and competitive prices offered by global players. 2. The country has to explore for sources of iron sand, which is the key component for in manufacturing solar grade mirrors 3. Should encourage local manufacturing by providing incentives like zero customs to import iron sand.

		Testing facility and Industry standards are not available in India	4. Installation of mirrors and their placement has to be standardized to reduce the degradation rate,, due to ambient conditions. 5. The minimum reflectivity of mirrors has to be capped at 95 percent from the current 90 percent.
Tracking technologies	Low	The purpose of the tracker is to ensure that the reflectors are optimally positioned to track the sun's position. The key components include hydraulic power pack, cylinder, sensors and electronic controllers, expect the hydraulic power pack the other components are imported by tracker manufacturers Know-how of sensors and controllers	Currently the accuracy level of trackers are in the range of 98-99%. Although, there are no specific standards available in the market expect for the torque and power consumption standards In CST, the selection of tracker depends differs from application to application. The power consumption and torque guidelines are not in place as of now- which are highly recommended to improve the overall system efficiency. The tracker and the electronics are exposed to high temperature conditions, the imported components should be reliable enough to operate under such conditions
Heat Transferring Fluid and molten salts	Medium	The main concern of HTF manufacturing in India is over the dull demand for the HTF and the availability of raw materials (ethylene and propylene crude) that are used to produce HTFs. There are many NABL accredited laboratories to test and certify the oil properties in India. Lack of quality and specification standards	Should promote R&D in HTFs to increase high heat density, stability, thermal conductivity, and latent heat Scope of developments in thermochemical and electrochemical storage. Currently synthetic oil with flashing point in the range of 120-220 Celsius is used for most of the applications in India, which is again application specific Few manufacturers globally trying to test the fluids with Nano particles with different ratio of mixtures to improve conductivity to achieve higher efficiency at optimal fluid rates.

Turbines and cooling systems	Medium/high	Solar thermal heat based turbines have slightly different operational requirements than conventional steam turbines due to frequent change in operational cycles and numerous start-up and shut down procedures. They relatively has low capacity Less efficient compared to fossil fuel based turbines	Development of technical and quality standards for solar thermal based turbines Local manufacturers need to develop the expertise to make turbines more efficient The other factor is the lead time to manufacture for supplying customized applications

The figure below represents the SWOT analysis of solar thermal manufacturing value chain from the discussions with all the stakeholders across the value chain.

Strengths

1. Strong and established related industries in manufacturing in most of the components of the value chain—glass, precision equipment and Thermal energy storage

2. Prior experience in developing skilled manpower and resources through a large number of established technical and engineering institutes.

3. History of established models of success in other technology intensive industries, such as public private partnerships (PPPs) and technology transfer through joint ventures (JVs).

4. Lower cost of unskilled labor resulting in lower costs of components manufacturing and EPC.

Weakness

1.Relative weaknesses in technologies for CST and CSP plant development and component manufacturing.

2.Gaps in infrastructure and uncertain government support for performing local R&D for new and emerging technologies.

3. High financial cost of capital ranging from 11% to 11.5% from local sources of finance, leading to higher tariff rates, supplier financing and finance from overseas sources.

SWOT

Opportunities

1. Strong indications by central and certain state governments of readiness to promote solar thermal power technologies, such as many incentives in the form of customs duty, solar energy enterprises zones (SEEZs), exemption from electricity duty, establishment of solar PV parks in SEEZs, and tax holdiay

2. Expectation of increasing costs of other technologies as there is more demand for fossil fuels.

Threats

1.Lack of long term visibility and commitment from government CST installations, in terms of pricing and policy framework.

2. Lack of clarity on long-term market penetration of any one technology

3. Core technology available only from two countries and only a select few global players.

4. Lack of knowledge of CST technology among banks and financial Institutions

5. Bureaucratic slow response in the provision of essentials such as water, power lines, roads, approvals and facilities.

6. Very tight project completion time lines (24 months) for such new technologies, with long lead time for supply of materials (for turbines, it is 18 months).

Figure 40: SWOT Analysis of Solar Thermal

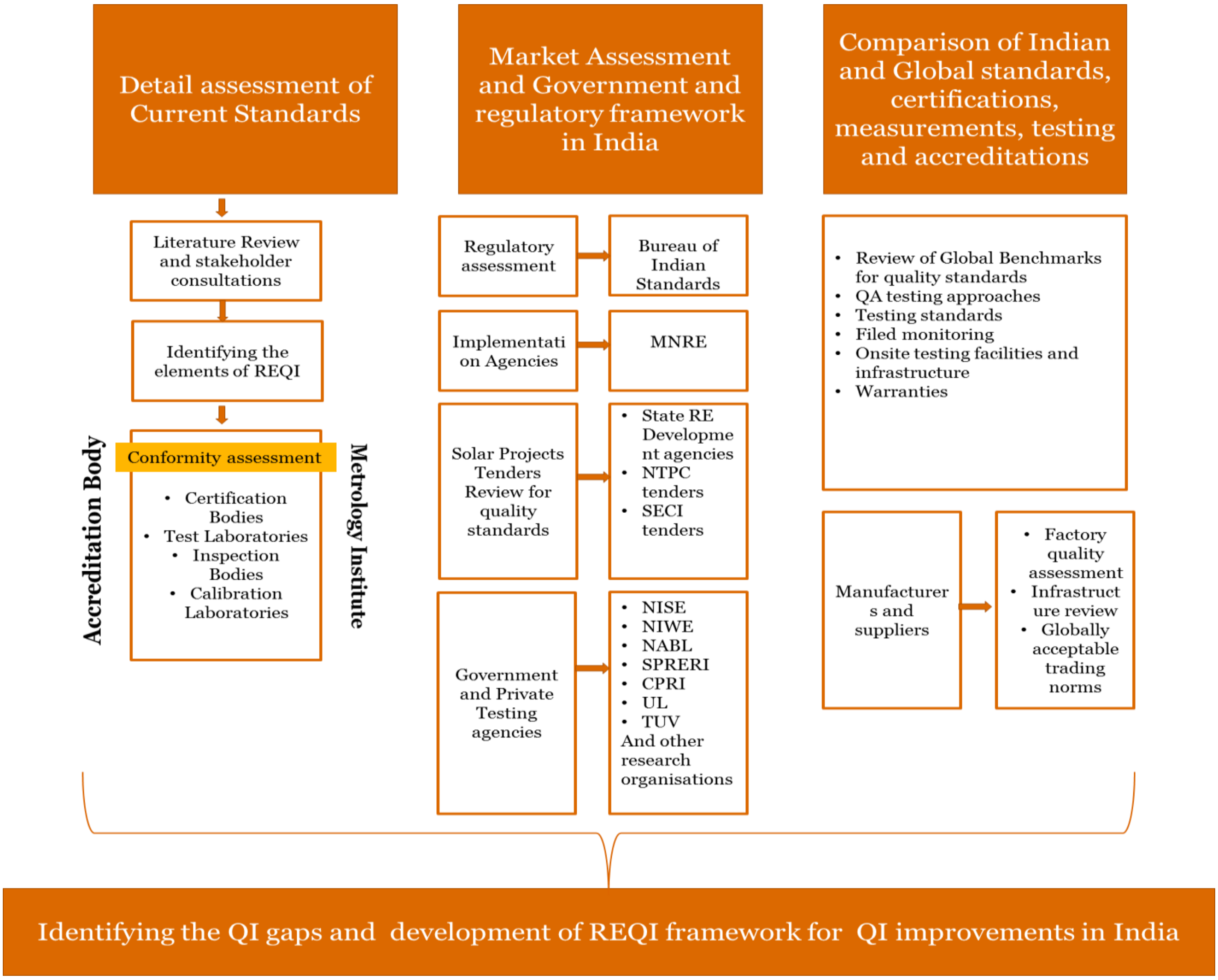


Figure 41: Improving QI Elements of REQI

7.4. Addressing issues in Solar Thermal

The solar thermal sector in India is still in its nascent stages and is actually evolving, with the industrial sector anticipated to latch on this sector. For major advancements to take place in India, it is essential to move from an 'only collector driven' approach to an actual performance driven outlook. This involves improving the quality aspect of the equipment such as glass tubes, collectors, reflectors, receiver assembly etc. involved in the projects. It will not only promote a healthy competitive landscape for domestic players, but also ensure that more impetus is being provided to R&D efforts, which are currently lacking. Some of the prominent issues that needs to be addressed with regards to implementation of solar thermal projects include the following:

- **Addressing infrastructural gaps**: Testing Infrastructure is the biggest roadblock in this context, with not enough research facilities in the countries. Only 2 research centers, at present, perform validation of the CST systems in terms of output, efficiency, heat delivery and other related parameters: Pune University and NISE.

- **Improving quality of materials**: Solar grade mirrors should be made compulsory. All other mirrors including aluminium based should be stopped. If not, there must be higher subsidy for CSTs with solar grade mirrors and lower subsidy for other options. Technology and vendor neutral tender needs to be finalized for installation of various types of CST based systems for different applications and provided to nodal agencies & other bodies for seeking bids from suppliers.

- **Improving data collection**: Moreover, on the data collection front, things need to improve with every beneficiary providing regular updates on data points regarding performance of the system through 'online remote monitoring' feature. Such performance monitoring will come a long way in developing improved dedicated standards for CST systems/equipment in terms of quality.

- **Capacity building for performance testing:** Best practice guidelines/ training manuals for installation and integration of various CST based systems along with conventional systems should be developed on priority basis and followed by all suppliers. Training programmes for installers of various manufacturers should be organized by NISE/ other designated centers with training certificates provided to them based on the test conducted for them at the end of each programme. Only certified trained installers should be allowed to install the systems of various suppliers. Even developers don't have a proper understanding about diverse solar thermal technologies and which technology must be preferred for different temperature requirements. It becomes obligatory to conduct training and educational programmes to impart technical knowledge regarding the same.

- **Promoting domestic manufacturing**: Introducing special provisions for domestic manufacturing through subsidy mechanism will definitely provide the required essence to upscale quality and stimulate indigenous manufacturing. It is a well-known fact that Indian manufacturers of dish collectors have been highly dependent on mirror imports for high temperature applications. (ARS Glass Tech Pvt Ltd. is the sole company which produces a broad range of glass types/solar grade mirrors including light transmission, solar control, weather resistance, safety, security and year-round energy efficiency). Hence, special incentives can be provided for domestically manufactured equipment.

As discussed with NISE officials, the testing for solar thermal equipment takes a minimum of 15 days. The output is a thermal report which provides collector efficiency at varying temperatures. The break-up of 15 days is as follows: DNI Radiation requirement of 5 days, 5 days are required for analysis of the collected data and further 5 days for generation of the thermal report.

NISE yet does not provide NABL accreditation as all the sensors need to be calibrated and also BIS standards have been released recently. As per the discussions, it is planning to start providing NABL accreditation in the near future. All the sensors will be calibrated by IMD (Indian Metrological Institute) or any NABL accredited labs and will then be installed.

There are various issues with designing of thermal plants and requires meticulous planning and industrious calculations to find out optimal design and appropriate technology for a specific site having a particular solar radiation. The 1 MW solar thermal plant installed at NISE campus was designed for higher radiation but it has never run on rated capacity and has never achieved performance efficiency equivalent of a 1 MW plant. Hence, it is mandatory to develop a Performance and Financial simulation tool for solar thermal concentrators which can perform backhand calculation and can determine the selection of appropriate technology for a specific site.

7.5. Key findings

Renewable energy quality infrastructure should be in line with the government's policies and market development. India is striding to new heights in terms of renewable energy capacity addition and ensuring quality and adoption of quality management practices play a vital role for sustainable development of the overall renewable energy ecosystem. India has domestic experience of manufacturing various renewable technologies and has the expertise to leap frog globally in terms of capacity additions and manufacturing indigenous products and component for various renewable energy based power plants.

By the end of July 2018, India's solar Installed capacity of solar PV and thermal has reached more than 23 GW, solar PV catering to electricity production and solar thermal catering to domestic and commercial heating applications. The upward trend of this growth will surely continue in the future, with the backdrop of government's ambitious plan to reach 175GW renewable addition by 2022.

The decrease in solar LCOE over the past decade has been driven substantially by component cost reduction and the costs are expected to plunge posing a substantial risk to quality assurance, performance and durability of the components.

In the last decade, investments in renewable energy surpassed $ 240 billion in 2016. India alone accounting for $ 9.7 billion investments in renewable energy and this trend is expected to continue as the markets expand. The Solar PV and thermal systems are becoming more competitive for electricity production and heating options, with billions of Indian rupees at stake. The need of the hour is to ensure concrete policy and infrastructure for quality to ensure robust reliability and deliver as per the expected outcomes throughout their lifetime. Thus, in order to lay the foundation for sustainable market growth, credibility on the technology must be enhanced, and the risk for investors, policy makers and consumers alike must be reduced through ensuring quality assurance across the solar value chain.

Solar Projects and products observe a failure rate with a 'bath-tub' curve pattern. Failure rates are higher at the early stages due to technology infancy failures, as are end-of-life stages due to wear and tear. At the construction or early stages of product lifecycle, the high risk of product failure is borne by EPCs and project developers. EPC contracts are only liable to few years post commissioning of the projects and the focus will be on short term quality technology failures.

Quality assurance plays a crucial role in order to reduce the delivered price of energy (Electricity and heat) and further contribute to ensure stability for the investors and other stakeholders and it is an essential instrument to protect and accelerate future investments in solar PV and thermal technologies deployment. Quality assurance helps to reduce the risk by providing the confidence that a product or service will meet the expectations, which in turn lower capital costs, raises performance, increases lifespan of the products and also lowers LCOE.

7.5.1. Focus is on short-term performance

Due to lack of enforcement from the government agencies (MNRE, BIS etc.) in terms of quality assurance, manufacturers are focused on short term performance rather than long term reliable performance which depends on adopting testing protocols and adhering to quality management practices. Looking at the tenders released by various organizations, it is evident that the design is based on the performance or output energy from the system for which the EPCs are designed and installed. The operational parameters indicates that there is significant degradation in the performance during the course of the plant life cycle. This is due to lack of quality management practices adopted during the operation and maintenance stage and also during the installation period. Although there are quality standards for components and partial testing protocols for CST performance parameters, but the focus is on short term performance rather than the long term reliability.

7.5.2. Performance monitoring is requisite to develop robust quality standards

To understand the performance of the CST and CSP systems on long term basis and the factors impeding the output it is imperative to have performance monitoring systems to design a robust framework ensuring quality standards in place during installation and operation and maintenance period. Developers often complained about the performance of the overall system in the long run post performance guarantee period on the availability of skilled manpower and maintenance scheduling.

7.5.3. Lack of standards for logistics and sampling

Our discussions with stakeholders from testing laboratories, manufacturers and installers of solar PV and thermal components it has been found that there are no relevant standards for sampling and safe transportation of the products from factory to site. In case of PV modules and solar grade mirrors, due to conventional and unsafe transportation and handling leading to micro cracks which are invisible to human eyes. These micro cracks are leading to hotspots in solar PV modules and impacting the optical efficiency of solar grade mirrors. It is recommended to adopt international standards for logistics handling, sampling and transportation.

7.5.4. Lack of domestic manufacturing and testing infrastructure

Although the country has moved from experimental phase to matured market in terms of technology adoption, installation, manufacturing and skill development. Testing infrastructure and in country certification plays an important role in level playing field with in the country and also exporting the clean energy generating equipment and systems to other countries. It is evident that the testing infrastructure in the country is focused on solar PV modules and its BOS and domestic water heating based solar thermal products and their components.

Solar grade mirror are the crux of the concentrated solar thermal systems and local manufacturers are not able to certify their performance and optical properties of indigenous solar grade mirrors and relied upon other countries for testing and certifications. The main concerns for mirror manufacturing in India revolve around the certainty of demand, availability of low-iron sand, and incremental capex costs of investments. Mirror manufacturers need to start some production operations locally first by importing low-iron float glass and then bending and tempering it locally to produce curved glass. This can then be further processed in terms of mirroring. Global players who have the technology can then upgrade their facilities to produce float glass. Investment will be required in bending and tempering equipment and line upgrades.

For local players, the cost of licensing will also need to be factored in. Government support of an action plan is required for the waiving off of import duties and customs on low-iron float glass and bending equipment in the short term. In the long term, a waiver on the import of low-iron sand and customs is required.

The current infrastructure for solar PV testing is sufficient to meet the yearly targets installations envisaged by ministry. Government should rollout a policy for onsite testing facilities or mobile testing labs to scan the faulty components during the installation stage.

The recent draft on renewable energy lab policy released by MNRE highlights the framework to be adopted to establish lab infrastructure and the methodology to test new products followed by certification. The draft policy also encourages entrepreneurs to implement testing infrastructure mobile and immobile to reap the benefits of rising demand for compulsory testing of solar PV and thermal components mandated by the government of India. (4.5.3.)

There is also potential for the subcomponents of solar thermal systems to be manufactured in India in the short, medium, and long terms if the testing infrastructure adhering to global standards is in place. India has inherent competitive advantages that will facilitate the transition to becoming a major provider of solar thermal technologies. The factors that could contribute to this include highly trained engineering staff, low labor costs, and a large domestic market. These are only a few aspects that can be leveraged by the Indian industry to lower the capital costs for CST plants, subsequently decreasing the LCOE and driving the market penetration of solar thermal technologies.

Cost reductions are also expected from local manufacturing of tracking devices, receiver tubes, parabolic mirrors, turbines, and structures considering there is adequate testing infrastructure and transparent market pricing. Developers would find local manufacturing very attractive also because of value-added services, such as the local presence of many O&M options, better procurement lead time, and trained local workforce. The rapid reduction of solar PV price has made it mandatory for solar thermal technologies to accelerate the cost reduction process for their survival. Having achieved significant cost reductions in the recent times, India has the potential to make the solar thermal technology competitive to solar PV. For this, however, there must be a critical mass of investment, dedicated human resources, and educational efforts, and criticality will be achieved when there is alignment of convergent forces with national and regional policy and the right financial environment.

7.5.5. Lack of awareness on quality infrastructure

The ministry is working hard on the harmonization of quality infrastructure which requires the development of testing laboratories and certification bodies, along with support organization and agencies for certification, surveillance, skill development and comprehensive standards development. To meet international and national standards it is a pre-requisite to develop awareness among all the stakeholders across the value chain and highlight the tangible and intangible benefits of quality assurance during the project lifetime. Emerging markets like India need to implement quality assurance mechanisms to prevent unsafe, underperforming and failure prone products from ruining the image of solar thermal value chain and its investments.

UNDP-GEF-CSH, publication of sun focus magazine is one of such initiatives to promote CST technologies all over the country. These efforts have culminated into installation of approximately 42,000 m2 of aperture area of CST systems into community cooking, process heating and cooling applications.

7.5.6. Limited skilled manpower

An effective renewable energy infrastructure and the quality of testing and certification is directly dependent on the quality of human capital. In the recent times solar PV has overshadowed solar thermal due to economics of cost and technology availability and the focus on skill development was shifted towards solar PV. In more technical areas of solar thermal, such as metrology, specialized human capital is needed to increase capacity in the country and guarantee precise measurements and a supply of reliable services. Accurate measurement depends on well-equipped laboratories which can precisely measure and record solar PV and thermal performance characteristics which are relied upon ambience parameters (Temperature, AMI and macro climate) as well as on the presence of competent staff to conduct.

Similarly, the objectivity of the accreditation and conformity assessment processes largely depends on the quality of the technical staff. Assessment teams must have sufficient collective scientific and technical skills to understand the testing and calibration activities of laboratories and the management systems of certification bodies relevant to solar PV and thermal technologies. In the area of laboratory accreditation, technical expertise requires assessors with knowledge of the latest technologies and scientific practices. Training personnel who will manage the system's quality services must develop adequate human capital. In order to achieve the 100 GW solar energy target by 2022, India requires 6.5 lakh trained professionals in the sector. Skill development and trainings in the solar sector have been provided by schemes such as the Suryamitra scheme, jointly designed by Ministry of New and Renewable Energy (MNRE) and National Institute of Solar Energy (NISE) to develop skills in the solar sector to enhance employment opportunities in the sector.

A single project requires the contribution of people from a range of backgrounds and skillsets, from planners and project managers to engineers, business development professionals to equipment operators etc. Large-scale deployment of solar energy projects would require lakhs of technically trained work force. It is also necessary to make sure that the trainings imparted must be qualitative in nature and adequate skills, both technical and commercial are imparted to the concerned workforce. Specific skill requirement across solar energy value chain is shown in the figure below.

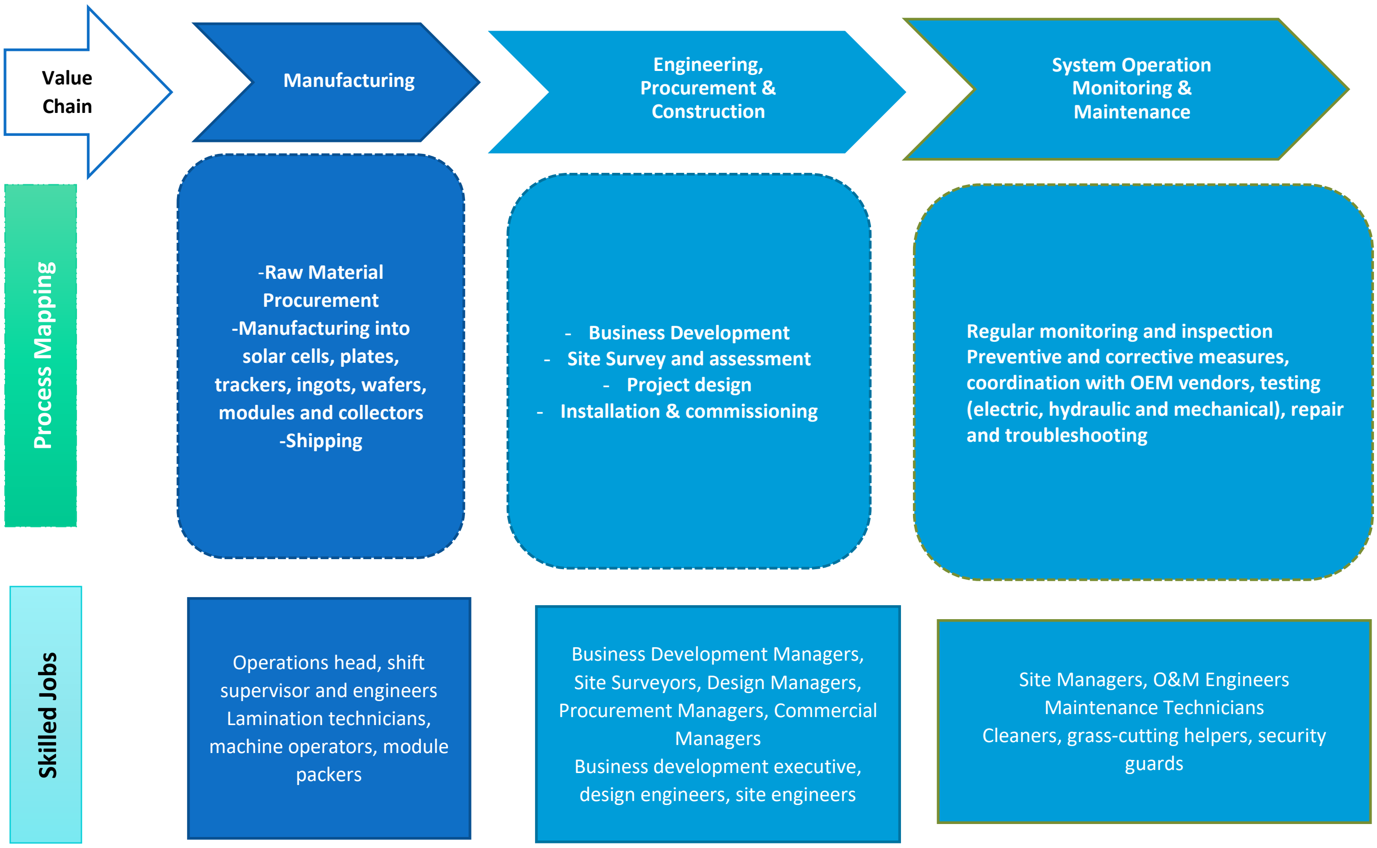


Figure 42: Skill requirements across solar energy value chain

7.5.7. Traceability and Surveillance

Traceability is the capacity to identify and track the type of certification, certifying agency, date of testing, tests conducted and test results of the product. It should also cover the whole supply chain tests of product has gone through before installing at the site. Traceability is a solution for the consumer protection, but also an instrument of control and delineation of responsibility. It is requisite to have a central monitoring portal to cross check the testing certificates provided by the manufactures to ensure quality standards and also improve consumer confidence.

Surveillance tests should be organised by BIS or MNRE or their authorised representative. Under this the samples can be picked up from the manufacturing site or field supply site and the sample is tested as per bench mark test or qualification tests.

7.5.8. Absence of NABL accreditation for CST

The testing facilities in India are private as well as government and are guided by the regulations as per Bureau of Indian Standards (BIS). These testing facilities are accredited by the National Accreditation Board for Testing & Calibration Laboratories (NABL), Government of India. The Solar PV plant components conform to the IEC / equivalent BIS standards for design qualification and performance testing at standard test conditions and need to be approved by one of the MNRE/ NABL accredited testing laboratories.

But, when it comes to Solar Thermal, India does not have NABL accredited testing laboratories to certify the components and make them qualitatively exhaustive. Hence, it is imperative to put in place NABL accredited labs for testing and certification of Solar Thermal components to check their adherence to the specified standards. In discussion with NISE officials, they stated that their labs are yet not NABL accredited but will apply for NABL Accreditation approval in the near future. Moreover, it must be made mandatory that only the NABL accredited components are being installed.

7.5.9. Requirement of guidelines for transportation of equipment

A renewable energy project will only perform effectively and efficiently over its life cycle if the design, installation and maintenance are of the highest quality. The quality of a solar project is directly proportional to the quality of installation and materials used. With an upsurge in solar installations in recent times in order to achieve the ambitious target of 100 GW by 2022, it is imperative that only superior equipment (devoid of any defects) are installed having quality standards. It is necessary to make sure that not only the installed equipment are appropriately standardized but proper care is also warranted during the transportation of these materials.

The glass of solar panels and concentrators is highly sensitive and can develop hotspots and minute cracks (not visible to the naked eye), if suitable handling is not done during their transportation. This will significantly reduce their efficiency and hamper overall performance of the plants over their life cycle, making the project unviable for the investors. But, India does not have any such guidelines or standards to certify efficient transportation of the equipment to be installed. Hence, it is necessary to provide specific guidelines by MNRE or BIS to the developers and EPC contractors regarding the handling and transportation of equipment and it must be made sure that these guidelines are strictly adhered to.

7.5.10. Lack of guidelines for proper cabling

Cabling is one of the most significant activity for implementation of any solar energy project. It is necessary to provide comprehensive cable management for solar projects. Cables must be routed through the solar plants in a robust and efficient way. Effective and proper cabling ensures reliable and effective performance and high efficiency over the life cycle of the plant. This in turn will considerably save the operations and maintenance costs improving the monetary benefits for investors.

It is imperative to choose the right cables depending upon the loading of power plants. The workforce must be skilled enough to distinguish between the string cabling and DC/AC connection cabling. Correct sizing of solar cables ensures no overheating and very little loss of energy. Using an undersized cable poses a potential for causing a fire due to overheating and using and oversized cable amounts to unwarranted loss of energy. Even with such critical importance in installation of a power plant, there are no specific guidelines to guarantee accurate cabling. Hence, it is recommended to adopt best practices and provide suitable standards for cabling in the solar projects.

7.5.11. Lack of installation and commissioning benchmarks

Reliability and performance of any power plant depends on the installation and commissioning of instrumentation, control and electrical equipment. The installation and commissioning is generally performed by a contractor specifically appointed to perform this task. The responsibility of the installers also includes specified field engineering activities, procurement of materials for installation, control of materials and equipment during the installation process, first line inspection and after-installation testing of equipment. After completion of the installation process and specified after-installation testing, the equipment is turned over to the commissioning group for pre-operation and startup testing. One of the major issues that arise during installation phase is alignment of modules. It is imperative that all modules are aligned at the same tilt angle. This can be ensured by providing adequate certification to design of the project.

Most of the developers specified their concerns to MNRE and emphasized on the requirement of having some installation and commissioning benchmarks to be provided by BIS or MNRE to ensure quality performance of the projects over their life cycle. Under this, the authorized representatives from MNRE and BIS can visit the solar site and can authenticate that the plant is being installed as per the specified guidelines The same representative can visit post installation for verification of the site and during commissioning phase to confirm that all the specified benchmarks are being followed by the installer.

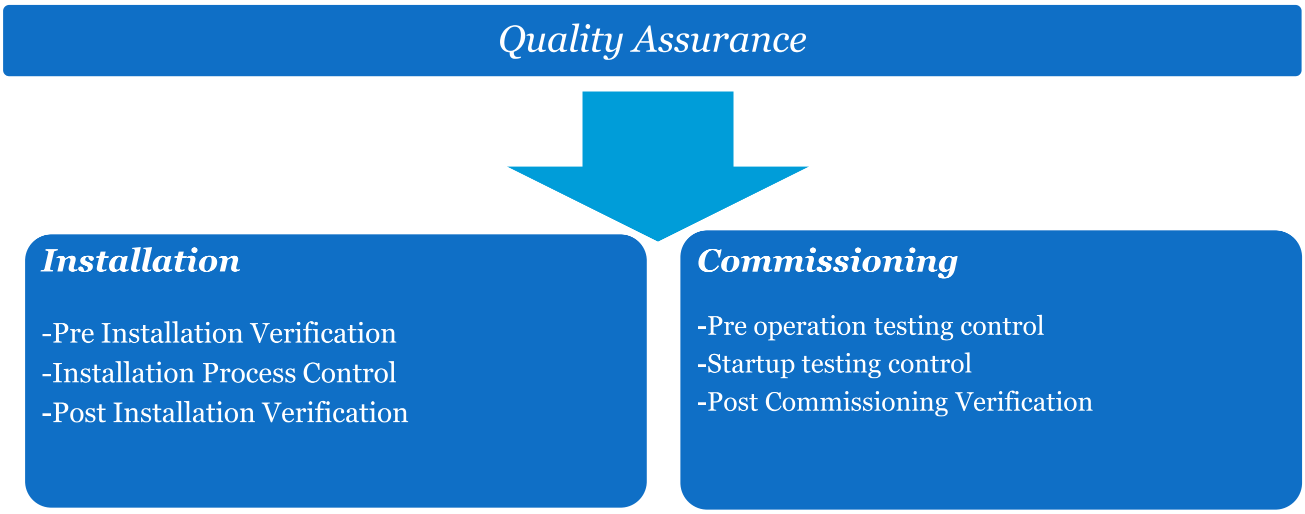


Figure 43: Quality Assurance during Installation and Commissioning phases

7.5.12. Requirement of Insurance for solar

Financial risk affects not only renewable energy producers, but also an ever increasing number of stakeholders throughout the value chain. Insurance for Solar Resource Volatility offers a tailor-made innovative mechanism to manage earnings unpredictability and associated financial distress. In general, large PV systems require liability and property insurance and many developers may also opt to add policies such as environmental risk insurance. These insurance schemes are broadly defined below:

1. General Liability Insurance: This scheme covers the damage to property such as solar system installers, since the risk is high during the installation stage
2. Property Risk Insurance: The property risk insurance often includes theft and catastrophic risks
3. Environmental Risk Insurance: the risk of either environmental damage imposed by their development or pre-existing damage on the development site
4. Business Interruption Insurance: To protect the cash flow of the solar project

To tackle the risks associated, there is a need to insure the solar projects. All risks will be covered associated with a solar project both pre commissioning and post commissioning of the project.

Pre-commissioning

- Transit Insurance
- Theft
- Third Party Liability Insurance
- Automobile Liability Insurance (to be taken by contractors)
- Employer's/Director's & Officers' Liability Insurance
- Performance Warranty Insurances of modules/overall plant as well
- Fire & Allied Peril Insurance
- Comprehensive General Liability Insurance
- Workmen's compensation insurance

Post commissioning (Generation shortfall)

- Generation shortfall from anticipated
- Solar module degradation
- Potential defect during installation/maintenance

Degradation in solar projects is system phenomenon and is accounted for while estimating generation, however projects have been witnessed to have degradation beyond anticipated numbers. For example, several projects on thin film projects in Rajasthan have seen severe degradation and a few are on the verge of shutting down. While the upside is limited as the tenders and the power purchase agreements allow only a maximum CUF to be quoted. For example, in case of SECI tenders, the developers declare annual CUF at the time of commissioning and allowed to revise it in 1 year, provided the declared CUF is more than 17%. For the first 10 years, the CUF has to be maintained within +10% and -15% and has to be maintained within +10% and -20% from 11th to 25th year of the life of the project. If the developer is unable to generate minimum energy corresponding to the lower limit of CUF, the shortfall is liable for compensation under the power sale agreement.

Key benefits with this product are:

Stakeholders	Impact without cover	Benefits with cover
Solar Plant operator	• Hit on operating performance, cash flow fluctuates • Potential payment difficulties to cover operating costs and investors' compensation	• Stabilization of future cash flows, impact of adverse weather conditions on revenue is minimized • Good rating can be maintained

	• Declining investors' interest, downgrade of rating	• Improves investment planning, secures profits • Enables new project financing through increased investment security
Developers/ Installers	Less demand for solar technology if generation becomes volatile	Can help secure demand for solar energy-related products

B. Annexures

List of stakeholders interacted

S.No	Name of the organization	Type of Business
1	Megawatt Solutions Pvt. Ltd.	Double axis tracked paraboloid dishes
2	Unisun Technologies Pvt. Ltd.	Single axis tracked Scheffler dishes
3	Clique Solar	Double axis tracked Fresnel Reflector based dishes
4	Taylormade Solar Solutions Pvt. Ltd	Single axis tracked Scheffler dishes
5	Oorja Energy Engg. Services Hyd Pvt. Ltd	Single axis parabolic trough collectors
6	ARS Glasstech Pvt. Ltd.	Solar grade mirrors
7	Enersun Power Tech Pvt. Ltd.	Curved Linear Fresnel Reflector
8	M/s Vcare Engineering Pvt. Ltd.	Compound Parabolic Collector (CPC)
9	NISE Gurgaon	Testing Lab
10	UL India Pvt. Ltd.	Testing Lab

List of referred Indian Standards for CST (as specified by BIS)

IS No.	Title
732 : 1989	Code of practice for electrical wiring installations (third revision)
800 : 2007	General construction in steel — Code of practice (third revision)
875 (Part 3) : 2015	Design loads (other than earthquake) for buildings and structures — Code of practice (Part 3) : Wind loads (third revision)
2062 : 2011	Hot rolled medium and high tensile structural steel — Specification (seventh revision)
9815-1 : 1994	Servo-motor operated automatic line voltage correctors (Part 1) : Correctors for single-phase applications — Specification (second revision)
9844 : 1961	Methods of testing corrosion resistance of electroplated and anodized aluminum coatings by neutral salt spray test
12615:2011	Energy efficient induction motors — Three phase squirrel cage (second revision)
12933-5 : 2003	Solar flat plate collector — Specification (Part 5) : Test methods (second revision)
13079 : 1991	Stepping motors — Specification
IS/IEC 60529 : 2001	Degrees of protection provided by enclosures (IP Code)
Doc: MED 04 (11238)	Concentrated Solar Thermal (Part 2) : Scheffler concentrator — Specification
Doc: MED 04 (11241)	Concentrated Solar Thermal (Part 5) : Test methods
ASTM E903-12	Standard test method for solar absorptance, reflectance and transmittance of materials using integrating spheres

Types of Testing for PV Modules in Germany

Type	Details of tests involved
Electrical Tests of PV-Modules	• Power Determination at Standard Test Conditions • Determination of Temperature coefficients • Electric Insulation Test (dry and wet) • Impulse Voltage Test • Bypass Diode Test • Accessibility Test • Measurement of Spectral Response • Measurement of Angle-of-incidence effect • Weak Light Measurements • Reverse Current Overload Test • Robustness of Terminations • Ground Continuity Test • Partial Discharge Test • Leakage Current Test
Mechanical Tests of PV-Modules	• Mechanical and Dynamic Load Test • Hail Impact Test (even Swiss Standard up to 75mm) • Module Breakage Test • Peel Test • Cut Test • Wiring Compartment Test and Terminal Knock-Out Test • Strain Relief Test • Terminal Torque Test • Push Test • Transport Test

Environmental Simulation Tests on PV-Modules	• Temperature Test • Humidity-Freeze-Climate Chamber Test • Damp-Heat-Climate Chamber Test • Thermal-Cycles-Climate Chamber Test • Fire Test • Hot-Spot Test and Risk Analysis • Light Soaking Test • UV – Test (Ultraviolet) • TCO-Layer Corrosion Test (PID) • PID – Test; Determination of sensitivity of Potential Induced Degradation • LID – Test; Determination of sensitivity of Light Induced Degradation • Determination of NOCT (NMOT) • Water Spray Test • Corrosive Gas Test (e.g. Ammonia)
Other Tests	• Thermographic Analysis • Electroluminescence Analysis • Visual Inspection • EVA Gel Content Determination / Cross linking • Accelerated Aging Test • Aging Tests at Real Conditions in Field • Prototyping with own Laminator

SGS Germany has added three new types of independent qualification tests to support PV modules' product bankability.

- **Long Term Durability Tested** – covering the investigation of the long term reliability of PV modules with the help of various types of weathering tests and extreme climate simulations
- **Sand Resistant** – PV modules qualification for various types of deserts and other extreme climates.
- **PID Resistant** – testing of PV modules for potential-induced degradation.