THE STATE OF CONCENTRATED SOLAR POWER IN INDIA

A roadmap to developing solar thermal technologies in India

Centre for Science and Environment
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A roadmap to developing solar thermal technologies in India
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JNNSM Phase-I

The launch of Jawaharlal Nehru National Solar Mission (JNNSM) on January 11, 2010 marked a new era of solar-based technologies in India. The Mission aimed to achieve 22,000 megawatts (MW) of solar-based installed capacity by 2022 out of which 20,000 MW was demarked for grid-connected solar power and the remaining 2,000 MW was allocated for off-grid generations. The entire capacity was divided into three phases – the first phase comprising three years, the second phase comprising four years and the third and final phase comprising five years (see Table 1: The three phases of JNNSM).

Table 1: The three phases of JNNSM

<table>
<thead>
<tr>
<th>Application segment</th>
<th>Target for Phase-I (2010-13)</th>
<th>Target for Phase-II (2013-17)</th>
<th>Target for Phase-III (2017-22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility grid power, including roof top</td>
<td>1,000-2,000 MW</td>
<td>4,000-10,000 MW</td>
<td>20,000 MW</td>
</tr>
<tr>
<td>Off-grid solar applications</td>
<td>200 MW</td>
<td>1,000 MW</td>
<td>2000 MW</td>
</tr>
</tbody>
</table>


The idea in Phase-I was to give equal emphasis to both solar photovoltaic (SPV) as well as concentrated solar power (CSP) technologies (also known as concentrated solar thermal [CST] technologies). Therefore, 500 MW each was allocated to SPV as well as CSP technologies in Phase-I. This phase was further divided into Batch-I and Batch-II. The division was designed to take advantage of the learning curve and rectify mistakes of Batch-I so that scaling-up actions could be undertaken in Batch-II. But owing to the longer gestation period for
CSP technologies, most of the target for CSP earmarked for Phase-I was opened for bidding in Batch-I only (470 MW). The Ministry of New and Renewable Energy (MNRE) wanted to ensure that these projects started operations by May 2013. Accordingly, proposals were invited and seven bidders were shortlisted out of 55 in November 2010. The reverse bidding mechanism was used to shortlist bidders; the lowest bid received was Rs 10.49 per kWh. CERC guidelines, which came out in February 2010 – much before JNNSM Phase-I, Batch-I bidding opened – benchmarked Rs 15.31 per kWh as the cost of generation from CSP (irrespective of technologies) based on capital expenditure of Rs 15.30 crore per MW. The lowest bid received through reverse bidding was 31 per cent lower as compared to the benchmark cost decided by CERC. The highest bid amongst the seven shortlisted projects was Rs 12.25 per kWh and average bid was Rs 11.41 per kWh – still 25 per cent lower than the CERC benchmark (see Graph 1: CSP tariff trend during JNNSM Phase-I bidding).

The reverse bidding mechanism helped bring the cost down to such a level that India became one of the lowest in terms of cost per kWh of generation. The average tariff quoted by bidders was 39 per cent lower than the prevailing tariff in Spain, which leads CSP technology in the world (see Graph 2: Comparison of CSP tariffs).

The aggressive biddings can be attributed to the fact that the bidders were not aware of challenges they might encounter while commissioning CSP projects. Lavleen Singal, ACIRA Solar, one of the developers who did not win in the bidding, said in retrospect, “Aggressive reverse bidding brought forth winning bids but not viable bids for sustainable operation.”

NTPC Vidyut Vypar Nigam Limited (NVVN) was appointed as the nodal agency to purchase power from all solar projects during Phase-I of JNNSM. It completed signing the Power Purchase Agreements (PPAs) with all the seven bidders by January 2011. A clause in the bid document said that the projects would be commissioned within 28 months from the date of signing the PPAs and accordingly the commissioning date was decided as May 2013. But because of several challenges faced by the developers in terms of reliable Direct Natural Irradiance (DNI) data, availability of material and manpower, difficulty
in getting finances etc., no bidder could honour the clause. Considering the delays in commissioning, some because of genuine reasons, MNRE granted a 10-month extension in May 2013. But in spite of the extension there was only one project (see Features and Annexures: Overcoming issues – One day at a time) that could be commissioned in the timeline. After the extended deadline also passed, as of January 2015, there were three CSP projects commissioned. The two additional are Reliance Power’s (Rajasthan Sun Technique) 100-MW linear Fresnel plant in Jaisalmer, Rajasthan, and Megha Engineering and Infrastructure’s 50 MW parabolic trough-based plant in Ananthapur district, Andhra Pradesh. The 100-MW CSP plant of Reliance Power had been in the pre-commissioning stage since November 2013 and was officially commissioned in November 2014. MEIL’s plant was commissioned around the same time in November last year.

Aside from these three projects, four remaining projects are far behind schedule. The developers of these projects have again petitioned before CERC for another extension in March 2014 along with revisions of tariffs (see Table 2: CSP plants sanctioned in JNNSM Phase-I, Batch-I).

Apart from these seven projects, there were three more CSP projects at various stages of development at the time of announcing JNNSM. In order to encourage project developers and for the industry to gain confidence in the technology, these three projects were also considered under JNNSM through a migration scheme. The three projects, all of 10-MW capacity, thus migrated to JNNSM to complete the quota of 500 MW of Phase-I (see Table 3: Migration projects under JNNSM Phase-I).

MNRE decided a commissioning date of March 2013 for the migration projects and offered them the full financial support available under JNNSM. However, out of these three projects with capacities of 30 MW, only 2.5 MW have been commissioned so far. ACME built a 2.5-MW solar-power tower in the first phase but because of wrong DNI and other optimisation issues, decided not to

Graph 2: Comparison of CSP tariffs

![Graph 2: Comparison of CSP tariffs](graph.png)

Source: Paving the way for transformational future, ESMAP, World Bank
follow through its expansion plans. The current set-up is also not under operation because of a techno-economic feasibility issue (see Box: First demonstration project after JNNSM Phase-I bidding failed).

In November 2011, Entegra chairman Mukul S. Kasliwal alluded that the company had not even broken ground for the 10-MW CSP parabolic trough plant since they were unable to raise finances for the project. “We haven’t started because we’re not going to do something that doesn’t make sense financially,” Kasliwal said, speaking to Bloomberg.

Dalmia Solar, part of Dalmia Cement, had partnered with Infinia, a USA-based company engaged in the manufacturing of Stirling dishes, for the technology and placed an order of 3,000 units of Infinia’s 3.2 KW Power Dish system. But, Infinia filed for bankruptcy in September 2013. Though the project is said to be still under development, the company website does not talk about the project at all.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Developer</th>
<th>Capacity</th>
<th>CSP technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ACME Solar</td>
<td>10 MW</td>
<td>Solar tower</td>
</tr>
<tr>
<td>2</td>
<td>Entegra</td>
<td>10 MW</td>
<td>Parabolic trough</td>
</tr>
<tr>
<td>3</td>
<td>Dalmia Cement</td>
<td>10 MW</td>
<td>Sterling dish</td>
</tr>
</tbody>
</table>

Source: Guidelines for Migration of Existing Under Development Grid Connected Solar Projects from Existing Arrangements to the Jawaharlal Nehru National Solar Mission (JNNSM), MNRE

Table 2: CSP plants sanctioned in JNNSM Phase-I, Batch-I

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Project</th>
<th>Tariff quoted (Rs/kWh)</th>
<th>Size and technology</th>
<th>Location</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lanco Solar “Diwakar”</td>
<td>10.49</td>
<td>100 MW parabolic trough with 4-hour storage</td>
<td>Askandra, Jaisalmer, Rajasthan</td>
<td>Land levelling done, looking for buyers</td>
</tr>
<tr>
<td>2</td>
<td>KVK Energy Ventures</td>
<td>11.20</td>
<td>100 MW parabolic trough</td>
<td>Askandra, Jaisalmer, Rajasthan</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>Reliance Power (Rajasthan Sun Technique)</td>
<td>11.97</td>
<td>100 MW linear Fresnel</td>
<td>Dhursar, Jaisalmer, Rajasthan</td>
<td>Commissioned in November 2014 after being in precommissioning for a year</td>
</tr>
<tr>
<td>4</td>
<td>Corporate Ispat Alloy/Abhijeet</td>
<td>12.24</td>
<td>50 MW parabolic trough</td>
<td>Nokh, Jaisalmer, Rajasthan</td>
<td>Basic engineering done, looking for buyers</td>
</tr>
<tr>
<td>5</td>
<td>Godawari Green</td>
<td>12.20</td>
<td>50 MW parabolic trough</td>
<td>Nokh, Jaisalmer, Rajasthan</td>
<td>Commissioned in August 2013</td>
</tr>
<tr>
<td>6</td>
<td>Aurum</td>
<td>12.19</td>
<td>20 MW parabolic trough</td>
<td>Mitrala, Porbandar, Gujarat</td>
<td>Land levelling done, orders put for most equipment</td>
</tr>
<tr>
<td>7</td>
<td>MEIL Green Power</td>
<td>11.31</td>
<td>50 MW parabolic trough</td>
<td>Pamidi, Ananthapur, Andhra Pradesh</td>
<td>Commissioned in November 2014</td>
</tr>
</tbody>
</table>

Source: Compiled by CSE from various sources

Table 3: Migration projects under JNNSM Phase-I
First demonstration project after JNNSM Phase-I bidding failed

The lack of demonstration projects always raised the question of the economic and technical viability of CSP projects in India. The 2.5-MW solar tower project in Bikaner, Rajasthan, by ACME Solar can be considered the first demonstration project India had after the JNNSM Phase-I bidding. The 46-metre-high solar tower project began construction in 2009 by ACME Group and became operational in 2011 in Bikaner. The project developer (PD) relied purely on the satellite data provided by NASA and some handbooks that were available at that time for establishing generation pattern for the plant. When the plant started its operation, the PD realised that DNI levels in India were not as high as NASA data showed, which impacted the financial viability of the plant to a great extent.

John M. Jacob, deputy general manager, Solar Thermal Efficiency of ACME said, “At the time of engineering the design, since the DNI was expected to be higher than what has been actually received on the ground, the solar field laid down became insufficient to produce the required power.” As a result, during the inception of the project the plant was drawing more power than it could generate. Though the issue was subsequently resolved and there was positive generation, the problem erupted again. “The plant is not running at the moment and now the issues are being worked on,” added Mr Jacob when a CSE researcher visited the site in July 2013.

On the finance front, the project was built with 100 per cent equity contribution. The idea was to expand the project to the level of 10 MW with financial support from commercial banks once a successful demonstration was in place. However, failure of the demonstration project has prompted ACME to drop all future expansion plans as expansion would require redesigning the entire plant.

JNNSM Phase-I has therefore conceived only three projects amounting to 200 MW in four years. Therefore, bigger questions related to sustainable operations of CSP in India are yet to be answered (see Graph 3: Target versus achievement during JNNSM Phase-I).

JNNSM Phase-II

Because of CSP’s poor performance in JNNSM Phase-I, MNRE has decided to reduce the share of CSP to 30 per cent in Phase-II. In Phase-II, the targets have been divided between the Centre and the states, where states have been
asked to fulfil 60 per cent of the targets. In other words, the 30 per cent target allocated to CSP has been divided further in the ratio of 40 and 60 between the Centre and states respectively. But keeping in mind the performance of CSP in Phase-I (which was a 100 per cent Central target) and lack of experience in states, it is highly doubtful that much of these targets will really be fulfilled (see Table 4: CSP targets at the Central and state levels in JNNSM Phase-II).

The first batch in Phase-II was allocated in February 2014; the 750 MW were all dedicated to PV.16 Guidelines for Batch-II (announced in July 2014) in Phase-II for 1,500 MW have not included CSP either.17 According to MNRE, there is still not enough experience in CSP technology to decide on further course of actions in JNNSM Phase-II. While speaking at the CSP Focus 2014, Tarun Kapoor, Joint Secretary, MNRE, alluded to the fact that Solar Energy Corporation of India (SECI) would soon come out with the proposal for two pilot projects, each of 50 MW capacity before the end of 2014.18 The proposals for the projects are still awaited.

Clearly, CSP technologies have not yet taken off in India.

**Table 4: CSP targets at the Central and state levels in JNNSM Phase-II**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Total</th>
<th>Centre</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ratio</td>
<td>MW</td>
<td>Ratio</td>
</tr>
<tr>
<td>Solar PV</td>
<td>70 %</td>
<td>6,300</td>
<td>40 %</td>
</tr>
<tr>
<td>Solar Thermal</td>
<td>30 %</td>
<td>2,700</td>
<td>40 %</td>
</tr>
</tbody>
</table>

**Source:** Jawaharlal Nehru National Solar Mission Phase-II – Policy Document, MNRE

New targets for renewables

During the budget session of FY 2015-16, Finance Minister Arun Jaitley increased the targets for renewable energy for the country to 175 GW to be achieved by 2022. (see Table 5: Increased targets for renewable energy)

The Ministry of New and Renewable Energy hosted an expo for investment promotion for the renewable energy sector in India, Re-Invest 2015, in February 2015 as well. The event was aimed at setting new targets, new paradigms of growth and demonstrate to the world India’s commitment to a Clean and Green future.1 The event concluded with 14 banks and financial institutions, eight PSUs and private manufacturers, 15 private sector companies giving their green energy commitments of a total of 2,66,000 MW to the ministers.2

In contrast to all the renewed hope in the renewable energy sector, CSP is has been completely ignored. All the solar developments have been focused on solar PV. The 100-GW target set up includes 40 GW of rooftop solar that is entirely solar PV. Apart from this, the government has also announced the Scheme for Development of Solar Parks and Ultra Mega Solar Power Projects in the country in December 2014.3 The Scheme intended to set up at least 25 solar parks each with a capacity of 500 MW and above. The solar parks have not specified whether the focus is on CSP or PV.

**Table 5: Increased targets for renewable power**

<table>
<thead>
<tr>
<th>Sources</th>
<th>Capacity (in MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>1,00,000</td>
</tr>
<tr>
<td>Wind</td>
<td>60,000</td>
</tr>
<tr>
<td>Biomass</td>
<td>10,000</td>
</tr>
<tr>
<td>Small hydro</td>
<td>5,000</td>
</tr>
<tr>
<td>Total</td>
<td>1,75,000</td>
</tr>
</tbody>
</table>

**Source:** Finance Minister’s speech in Parliament on February 28, 2015
1. Why has CSP not taken off in India?

Map 1: India solar resource: direct normal solar resource

To answer the question “Why has CSP not taken off in India?”, we need first to analyse the following two questions: Does CSP make sense for India? If so, what are the challenges it faces?

Does CSP make sense for India?

India’s solar potential

CSP technology concentrates solar radiation to produce heat and convert water into steam. Therefore, the technology requires direct solar radiation to fall on
reflective mirrors to concentrate at a particular point (see Annexure 1). The DNI map of India depicts that several states in India are suitable for solar thermal projects, namely Gujarat, Rajasthan and Maharashtra in the west, Jammu and Kashmir, Himachal Pradesh and Uttarakhand in the north, and Karnataka, Andhra Pradesh and Tamil Nadu in the south of India. Of these nine states, the entire land masses of Gujarat and Rajasthan receive good DNI on yearly average. According to the Trans-Mediterranean Renewable Energy Cooperation (TREC), each square kilometre of hot desert receives solar energy equivalent to 1.5 million barrels of oil.¹ The Thar Desert, in Rajasthan, receives more than 2,000 kWh of DNI per square metre per annum, estimated to be sufficient to generate 700-2100 gigawatts (GW) of energy.² Therefore, theoretically, India has a good potential for CSP technology.

**Capacity utilisation factor (CUF)**

Capacity utilisation factor (CUF) is a critical parameter to evaluate whether a particular technology makes sense in a specific geographic location over a competing technology. CERC tariff order in November 2010 considered a CUF of 23 per cent for CSP technology (without thermal storage) as against 19 per cent for solar PV. Recently commissioned Godawari Green Power in Rajasthan also confirmed achievement of 24 per cent CUF on an average and the maximum has gone up to 29 per cent (see Features and Annexures: Overcoming issues – One day at a time).

MNRE declares the monthly CUF of commissioned solar plants based on actual generation data. The average CUF measured during May-July 2014 for 16 solar PV projects commissioned during JNNSM Phase-I in Rajasthan is 22 per cent whereas average CUF achieved in Godawari Green Power for the same period is 24 per cent (see Table 6: Average CUF achieved in SPV and CSP plants in Rajasthan and Graph 4: Comparison of CUF for SPV and CSP plants in Rajasthan).

Though the actual generation data is influenced by several factors such as solar radiation, technology, temperature, tracking systems and atmospheric conditions (cloud, dust etc.), CUF of CSP (without storage capacity) is comparable to that of solar PV systems with similar operating conditions. It is also worth noting that the rainy season has considerable impact on the CUF in CSP when compared to PV as noticed for the plant.

**Thermal storage**

The biggest advantage of installing a CSP plant is the opportunity of thermal storage capacity addition. Since a CSP plant primarily produces heat, the heat produced can be stored by using various technologies, most prevalent being molten salt technology. The stored heat can be released to produce electricity by running a steam turbine at a later stage. The advantages of thermal storage are manifold:

- **Increase in CUF:** The increase in CUF is possible because the solar power is captured during the day to utilise it at a time when there is no sun or when sunlight is dim. A report published by the National Renewable Energy Laboratory (NREL) in 2011 suggested that CUF of CSP plant can go up to 40 to 50 per cent with 6-7.5 hours of storage while without storage the CUF lies in the 20-28 per cent range.³
Table 6: Average CUF achieved in SPV and CSP plants in Rajasthan

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Company</th>
<th>May 2014 CUF</th>
<th>June 2014 CUF</th>
<th>July 2014 CUF</th>
<th>Average CUF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alex Spectrum Radiation Private Limited</td>
<td>24.34%</td>
<td>24.36%</td>
<td>22.31%</td>
<td>24.00%</td>
</tr>
<tr>
<td>2</td>
<td>Amrit Energy Private Limited</td>
<td>24.96%</td>
<td>24.13%</td>
<td>17.75%</td>
<td>22.00%</td>
</tr>
<tr>
<td>3</td>
<td>Azure Power (Rajasthan) Private Limited</td>
<td>24.09%</td>
<td>23.72%</td>
<td>20.07%</td>
<td>23.00%</td>
</tr>
<tr>
<td>4</td>
<td>CCCL Infrastructure Limited</td>
<td>18.04%</td>
<td>20.42%</td>
<td>20.02%</td>
<td>19.00%</td>
</tr>
<tr>
<td>5</td>
<td>DDE Renewable Energy Private Limited</td>
<td>21.26%</td>
<td>19.73%</td>
<td>18.02%</td>
<td>20.00%</td>
</tr>
<tr>
<td>6</td>
<td>Electromech Maritech Private Limited</td>
<td>21.69%</td>
<td>21.47%</td>
<td>19.13%</td>
<td>21.00%</td>
</tr>
<tr>
<td>7</td>
<td>Finehope Allied Energy Private Limited</td>
<td>25.10%</td>
<td>24.57%</td>
<td>18.77%</td>
<td>23.00%</td>
</tr>
<tr>
<td>8</td>
<td>Greentech Power Private Limited</td>
<td>25.07%</td>
<td>23.23%</td>
<td>22.97%</td>
<td>24.00%</td>
</tr>
<tr>
<td>9</td>
<td>Indian Oil Corporation Limited</td>
<td>19.66%</td>
<td>18.91%</td>
<td>17.06%</td>
<td>19.00%</td>
</tr>
<tr>
<td>10</td>
<td>Khaya Solar Projects Private Limited</td>
<td>26.93%</td>
<td>27.05%</td>
<td>23.13%</td>
<td>26.00%</td>
</tr>
<tr>
<td>11</td>
<td>Mahindra Solar One Private Limited</td>
<td>26.73%</td>
<td>25.55%</td>
<td>23.42%</td>
<td>25.00%</td>
</tr>
<tr>
<td>12</td>
<td>Newton Solar Private Limited</td>
<td>21.25%</td>
<td>20.87%</td>
<td>18.46%</td>
<td>20.00%</td>
</tr>
<tr>
<td>13</td>
<td>Oswal Woollen Mills Limited</td>
<td>23.10%</td>
<td>23.51%</td>
<td>19.13%</td>
<td>22.00%</td>
</tr>
<tr>
<td>14</td>
<td>Saidham Overseas Private Limited</td>
<td>26.84%</td>
<td>27.19%</td>
<td>22.25%</td>
<td>25.00%</td>
</tr>
<tr>
<td>15</td>
<td>Unj Lloyd Solar Power Limited</td>
<td>20.74%</td>
<td>19.89%</td>
<td>16.86%</td>
<td>19.00%</td>
</tr>
<tr>
<td>16</td>
<td>Vasavi Solar Power Private Limited</td>
<td>26.74%</td>
<td>27.32%</td>
<td>22.92%</td>
<td>26.00%</td>
</tr>
<tr>
<td>17</td>
<td>Godawari Green Energy Limited</td>
<td>29.08%</td>
<td>25.38%</td>
<td>16.50%</td>
<td>24.00%</td>
</tr>
</tbody>
</table>

Source: MNRE Net Exported Power Summary

Graph 4: Comparison of CUF for SPV and CSP plants in Rajasthan

Source: MNRE Net Exported Power Summary
Grid-flexibility: CSP with thermal storage enhances the grid flexibility to accommodate infirm or intermittent power. The power which can be produced from the thermal storage capacity can be ramped up and down quickly and on demand. Therefore, depending upon variability of renewable power, CSP plant can minimise grid shocks.

Flexibility in configuration: Given a solar field size and the units of electricity required to be generated, the CSP plant with thermal storage can be configured differently based on the time of day and rate at which power is required.

Vimal Kumar of Cargo Power and Infrastructure said, “The 25-MW CSP plant based on parabolic trough technology in Kutch, Gujarat, will be able to achieve 62 per cent Plant Load Factor (PLF) because of the nine-hour thermal storage capacity.” This makes the plant equivalent to a 66-MW CSP plant without any storage.4

As far as thermal storage is concerned, apart from the 25-MW CSP plant of Cargo Power and Infrastructure in Kutch, Gujarat, which has been under construction for almost three years, there are no case studies. The two pilot projects that MNRE plans to set up will have thermal storage of three hours each.

Hybridisation

In addition to thermal storage, CSP plants can be hybridised with other thermal power plants that run on coal, gas or biomass. Hybridisation can provide two benefits. First, a CSP plant can be coupled with conventional coal- or gas-based thermal power stations to preheat boiler water. This will significantly reduce consumption of coal or gas in thermal power plants and in turn their carbon footprints. Second, CSP can be hybridised with other renewable sources like biomass, wind or solar PV to generate more firm power. This will increase the CUF of the hybrid system significantly.

Today, the cost of power generated from solar thermal power plants is very high (especially when compared to PV). Despite several decades of development, a step change in technology is needed to drive down costs.5 Hybridised CSP plants are a good intermediate step for CSP to gain momentum in the country. Ankit Singhvi, solar expert from NN4 Energy, claims, “There could be a saving of 30-40 per cent in the cost of CSP in case of pure hybridisation. The savings would come from capital investment because there would be no requirement in power block – turbine, boiler and feeder – since those are already exist in the existing plant.” Hybridisation will, therefore, increase capital efficiency.6 Since it would take place with a continuously running thermal power plant, losses accruing during starting of the plant will be avoided. This will result in savings in time and will ensure better efficiency.

Therefore, hybrid plants, combining solar thermal energy with traditional power generation plants, have several key benefits.7

- Hybrid plants can achieve higher efficiencies than standalone CSP plants
- Incorporating the solar thermal into an existing gas-fired power plant saves on additional costs of a turbine and generator
- Daily start-up and shutdown energy losses can be eliminated
- Additional operational and maintenance (O&M) costs incurred for a solar addition are also lower compared to that of standalone CSP
- There are inherent advantages of reducing carbon dioxide emissions
Hybridisation of solar thermal in existing power plants will also contribute to the objective of capacity building. The workers and engineers working in a conventional power plant would be trained in a new technology.

Despite the advantages, there are currently no hybrid solar thermal plants operational in India.

What are the challenges?

The solar potential along with the attributes of CSP technology discussed above clearly indicate that CSP makes sense for India. However, there are challenges because of which CSP has not taken off in India. These challenges can be broadly divided into three categories – technical, market and environmental.

Technical challenges

No reliable DNI data: Like any other renewable energy plant, knowledge of the quality and future reliability of the resource is essential for an accurate estimation of performance. It, in turn establishes the financial viability of the project. In the first phase of JNNSM, MNRE could not provide accurate DNI data to the project developers at the time of bidding. As a result, all project developers had to rely on satellite modelling data while bidding for 470 MW of allocation. Several literatures suggested that 5 kWh/m²/day (or 1,825 kWh/m²/year) is the minimum DNI required for a CSP project to be viable. The satellite modelling data received from the Spanish Ministry of Science and Innovation (CIEMAT) estimated that 1,847 kWh/m²/year is the DNI available in western Rajasthan where most of the projects under JNNSM Phase-I were to be commissioned. Therefore, CERC recommended a DNI of 1,847 kWh/m²/year to
Case study: 3,780-MW hybrid combined cycle natural gas and parabolic trough concentrating solar power (CSP) generation in Florida, USA

Florida Power and Light’s Martin added 75 MW of parabolic trough CSP to its 3,705–MW combined cycle natural gas, making it the world’s largest such hybrid power plant.1 In 2010, it was also one of the world’s largest parabolic trough solar CSP plants. The project integrates solar thermal into a gas-turbine cycle without the need for heat exchangers.2 To sustain a constant temperature at the entry point of the turbine, the flow of gas is controlled.

The hybridisation of gas turbines with concentrated solar energy has been underdeveloped for many decades. The European Union has funded many projects since the beginning of the 2000s. There have been small-scale hybrid solar gas-turbines, such as the Solgate and Solhyco projects, which have demonstrated solar hybrid gas-turbine projects of 250 kWe capacity.

The advantages of hybrid power plants is that they produce electricity at the most competitive rates, emit the least carbon dioxide and consume the least possible water.

The hybrid plant includes a field of 1,90,000 parabolic mirrors that heat up a synthetic oil thermal fluid as a heat transfer fluid to 398°C. Even before the addition of the solar generation component, the 3,705-MW Martin County power plant was the US’s largest fossil-fuelled power plant. The CSP project is a retrofitted addition to an existing fossil-fuel generation plant in an area of 500 acres because of which the company saved costs on new turbines, transmission lines and other generation infrastructure. Based on experience with this project, Florida Power and Light (FPL) expressed that the retrofit cost them 20 per cent less than if they had to build a new separate solar CSP power plant.

The project developer claims that the solar thermal addition would decrease fossil fuel consumption by approximately 41 billion cubic feet of natural gas and 6,00,000 barrels of oil. According to the US Environment Protection Agency, this is the equivalent of removing more than 18,700 cars from the road every year for the entire life of the project.

The estimated annual generation of the plant is about 155 GWh per year with a capacity factor of 26.3 per cent. The DNI for the location has been 2,026 kWh/m²/yr. The addition of solar thermal cost was about 476.3 million with an estimated levelised cost of US $0.16/kWh over the lifetime of the plant while the US Energy Information Administration’s Annual Energy Outlook estimated that levelised cost of energy for new CSP plant would be US $0.1827/kWh (Rs 11.28/kWh).
calculate the CUF and financial viability of the projects. The NREL satellite map of India showed a DNI of 5.5-6.0 kWh/m²/day in the entire states of Rajasthan and Gujarat. The satellite modelling data released by NASA also showed a DNI figure of 2,044 kWh/m²/year in western Rajasthan. Therefore, most developers considered a higher DNI in the range of 2,000-2,200 kWh/m²/year while quoting for the projects.

But the actual DNI measured on the ground at the time of project execution was quite different than what was estimated at the time of quoting. For example, Godawari Green Project, which considered the DNI of 1,825 kWh/m²/year, actually received 1,753 kWh/m²/year at the site. This affected the project significantly. In order to achieve the desired output of 50 MW, the developer ultimately had to reengineer the entire project – instead of the 80 loops (series of parabolic mirrors arranged in a circular manner) required originally they had to put up 120 loops of mirror (see Features and Annexures: Overcoming issues – one at a time).

No successful demonstration project: Though there are successful demonstration projects based on CSP technology across the globe, India did not have any plant that tested the techno-commercial feasibility of the technology at the time of JNNSM Phase-I bidding. We have had the National Institute of Solar Energy (NISE, erstwhile Solar Energy Centre) since 1982 to develop solar technologies and its related engineering in a 200-acre campus in Gualpahari, Haryana, but there had not been enough R&D on CSP when bidding came out. NISE had commissioned only one 50-KW CSP plant based on parabolic trough technology to enhance research in 1988. Apart from this, Indian Institute of Technology (IIT) Bombay has also had a working grid-connected parabolic trough CSP plant of 1-MW capacity since 1989. But these pilot projects failed to provide enough ground-level experience, investor confidence and policy guidance to take up CSP technology for large-scale implementation.

The 2.5-MW solar tower project in Bikaner by ACME Solar is the first project commissioned in India in 2011 under the JNNSM migration scheme. The idea of the project was to show successful demonstration with a 2.5-MW capacity and gradually expand to 10 MW. However, owing to the fact that the performance of the project has been much lower than expected the company has stalled future expansion plans. ACME blames wrong DNI data as the main culprit for this failure (see Box: First demonstration project under JNNSM Phase-I bidding failed on page 9).

The 50-MW capacity Godawari Green Power with parabolic trough technology is the second project commissioned in 2013 under the JNNSM scheme. The plant also had to go through a difficult phase where the entire project had to be reengineered because of faulty DNI data. The project has been generating power since June 2013 with an average CUF of 24 per cent, but it is too early to conclude on the project sustainability.

A news report in May 2013 had alluded that four CSP projects were planned, one with each technology – central tower, parabolic trough, linear Fresnel and dish Stirling – with an investment of Rs 2,555 crore. The locations for these projects were Gujarat (35 MW), Rajasthan (40 MW), Tamil Nadu (25 MW) and Andhra Pradesh (20 MW). MNRE has clarified that these projects have been shelved.

However, two new pilot projects are under planning currently. Speaking in a conference – CSP Focus India 2014 in New Delhi – Dr Ashvini Kumar, director
(Solar) in the Solar Energy Corporation of India (SECI), said, “The tender for EPC contracts for two pilot projects of 50 MW each, both to be owned by SECI, would be out at the later part of 2014. Both projects would focus on improvements in thermal storage, water requirement, efficiency and cost.” These two projects would be based in Charanka Solar Park, Gujarat and Jaisalmer, Rajasthan. The total cost for both the projects is estimated to be around Rs 2,400 crore out of which Rs 960 crore (40 per cent) would come from government grant. The remaining 60 per cent would be funded by Clean Technology Fund (CTF) and Asian Development Bank (ADB) through soft loans under the sovereign guarantee of government of India. Tarun Kapoor, joint secretary, MNRE, claimed that the levelised cost of energy (LCOE) for these pilot projects is aimed at Rs 6.25 per kWh. These projects have still not been announced.

SECI is also involved in the R&D project for setting up a solar thermal demonstration park at IIT Jodhpur. The plan is to set up three units each of 5-MW capacity – CLFR, solar tower and beam-down CSP.

**Market challenges**

**High capital and operating expenditure:** The cost curve of CSP technology has been unable to compete with that of PV. In India the capital cost for solar PV is Rs 5.87 crore per MW whereas that of CSP is Rs 12 crore per MW as per CERC, 2015-16 guidelines. It is also surprising and noteworthy that when at the beginning of JNNSM in FY 2010-11, the capital costs of solar thermal was deemed lower than that of solar PV, now, in FY 2015-16, it is almost half that of the solar thermal. For solar thermal power plants to compete with PV with these numbers becomes difficult in today’s scenario (see **Graph 5: Capital expenditure of solar thermal and solar PV**).

As a result of the capital-cost disparity, the CERC benchmark cost of generation for solar PV stands at Rs 6.86 per kWh whereas the cost of generation for CSP stands at Rs 12.05 per kWh. At present, the levelised cost of energy (LCOE) in Europe stands at Euro 0.139-0.196 per kWh (Rs 10.92-15.40 per kWh), which is where Indian estimates also stand. Despite the European market having more research and experience with this technology than India’s, power from CSP is not cheaper even in other parts of the world. In terms of operating costs as well, CSP is more expensive than solar PV (see **Graph 6: O&M expenses of solar thermal and solar PV**).

**Graph 5: Capital expenditure of solar thermal and solar PV (in Rs lakh)**

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Solar Thermal</th>
<th>Solar PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY 2010–11</td>
<td>1,530</td>
<td>1,550</td>
</tr>
<tr>
<td>FY 2011–12</td>
<td>1,442</td>
<td></td>
</tr>
<tr>
<td>FY 2012–13</td>
<td>1,300</td>
<td></td>
</tr>
<tr>
<td>FY 2013–14</td>
<td>1,200</td>
<td>800</td>
</tr>
<tr>
<td>FY 2014–15</td>
<td>1,200</td>
<td>691</td>
</tr>
<tr>
<td>FY 2015–16</td>
<td>587</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Compiled from various CERC Renewable Energy Tariff Guidelines*
Given these high costs, solar thermal power plants in India have a questionable future unless prices come down on account of an indigenous manufacturing base and cheaper finances are made available to developers.

**No non-recourse finance**: CSP as a technology has been proven in the world, but it is still in the initial stage of the technology maturity curve. Though there have been significant R&D activities on CSP for several decades now, the technology needs governmental support through subsidies to develop demonstration projects and build an environment that promotes investment. In India, there was not enough R&D done on CSP until JNNSM Phase-I was declared, with a target of 500 MW to be achieved in Phase-I. The government had not spent sufficient money on R&D and set up demonstration projects based on CSP technology prior to JNNSM.

The reverse bidding process in JNNSM for feed-in tariff (FiT) actually skipped two important stages of technology development – R&D and demonstration project. As discussed in the Introduction, the aggressive reverse bidding process brought the FiT to one of the lowest in the world, but lack of prior experience and demonstration in the country posed serious economic challenges to these projects. Investors did not show confidence in the technology despite financial support provided by MNRE during JNNSM Phase-I bidding. As a result, none of the seven projects awarded could obtain non-recourse financing. Rajiv Ranjan Jha, general manager of Power Finance Corporation, said, “Since there was no successful demonstration project on the ground, there had to be a guarantee of performance of various components and sub-components to gain confidence and this was difficult.”

Aggressive bidding was another reason for doubting the financial viability of the projects in the long run. During Batch-I bidding, the lowest bid received was Rs 10.49 per kWh against the CERC benchmark of Rs 15.31 per kWh. The average tariff received from the seven winning bidders was Rs 11.41/kWh, which was 25 per cent lower than the benchmark. According to the investors, the reverse bidding process was not a good option for CSP as investment risks have not been assessed for India. A report commissioned by the Australian government on CSP in India has expressed that the reverse auction approach for tariff determination carries with it considerable risk of “adventurous” bidders getting allocation who may ultimately be unable to deliver. Although
there is a built-in check and balance system of increased bid bonds for higher discounts, it might be difficult to discourage aggressive biddings if bid bonds are not considerably high for larger discounts. Reverse bidding also discourages the adoption of innovative and comparatively expensive technologies. For lowest costs, developers usually adopt safe, existing technological solutions for winning bids for the projects. On the other hand, investors fear that low tariff bids would not be able to make their projects financially viable.

No local manufacturing: According to a World Bank report, the lack of local manufacturing facilities for some critical components, such as reflective mirrors, tracking devices, molten salt and heat transfer fluids were a major hindrance for the growth of CSP technology. Since all the projects in JNNSM Phase-I relied on import for these components, it made a huge impact on the cost and delivery of the project. Therefore, the report concludes, developing domestic manufacturing facilities for some of these critical components would help improve project delivery at a reduced cost, which in turn will help large-scale deployment of CSP.

This argument can be corroborated by the fact that the 25-MW CSP plant based on parabolic trough technology with nine hours of thermal storage and commissioned in the third quarter of 2013 under the Gujarat Solar Scheme could reduce the capital cost to Rs 12 crore/MW due to backward integration of manufacturing reflective mirrors, said Dhruv Batra, Director, Cargo Power & Infrastructure, the developer of the project. Developers argue that the CERC estimates are far below the actual capital costs. The actual cost for the Godawari Green plant, according to the company’s executives, is around Rs 16-18 crore per MW. So Cargo Power managed to reduce the capital cost by around 30 per cent.

However, John Jacobs, deputy manager, Solar Thermal Engineering of ACME Solar, is of the opinion that the manufacture of reflective mirrors is a matured technology. There is hardly any scope for cost reduction through manufacturing process improvement. Given that CSP components are exempt from import duty, low-cost labour is the only possible option for cost reduction. But this will require economies of scale.
No skilled manpower: Lack of skilled manpower is another reason why CSP faced several challenges during JNNSM Phase-I, which in turn caused delays. Achieving this target was not difficult as there are several components which could be manufactured locally. But making these components locally without prior experience and a lack of in-house skills was a challenge which hindered CSP take off. For example, the Godawari Green project required the manufacture of components with high precision to fabricate the mounting structure. Jyoti Structures, that took up the major portion of fabrication of the mounting structure, required more time than anticipated to complete its work. The reasons for this delay were lack of experience and in-house skills. Human resource development (HRD), which has a pivotal role in promoting local manufacturing, has to be given due importance. Unfortunately, NISE has not produced enough skills in this regard since 1988 though it had an in-house CSP plant specifically meant for research and education.

Competition from PV technology: The SPV technology is very mature as compared to that of CSP. This can be validated by the fact that cumulative SPV installation crossed the 100-GW mark worldwide in 2013 whereas CSP is still under the 5-GW level as on December 2014. In India, too, the growth of SPV is phenomenal as compared to CSP’s – about 3,300 MW of SPV installations as against 200 MW of CSP as on February 28, 2015. This establishes the fact that project developers as well as investors are more comfortable with SPV than CSP. The reasons for this inclination are following:

- SPV is cheaper than CSP in terms of capital costs and installations
- Technological knowhow and skill availability is more in the case of SPV
- Investors have experience in working with the technology globally and are aware of associated financial risk. Therefore, non-recourse project finance is available for SPV
- SPV works on global irradiance whereas CSP works only on direct irradiance.
Therefore, impacts of aerosol, water vapour, etc. are less in the case of SPV. This makes PV more reliable in terms of power generation than CSP.

- Water requirement per unit of electricity generated from SPV is less than that from CSP.
- SPV has a lower gestation period than CSP.

Project-developer and investor-sentiment bias towards SPV adds an additional hurdle in the development of CSP.

Environmental challenges

Water requirement versus allocation: Water is a crucial resource required for the successful operation of solar thermal plants. It is required mainly for the regular cleaning of mirrors and production of steam to run the turbine. Needless to say, water used for producing steam needs to be cooled before recirculation. CSP plants also use cooling towers to condense water like any other thermal power plant does. The International Energy Agency (IEA) estimated that parabolic trough and Fresnel technologies need water up to 3 cubic metre/MWh whereas solar tower uses less only 2 cubic metre/MWh of electricity generation. Comparing these estimates with actual figures achieved on the ground, we find that ACME Solar produced 7 MWh by utilising 20,000 litres of water per day, which means 2.85 cubic metres of water per MWh. According to the Central Electricity Authority (CEA), a typical 2 x 500 MW coal-based power plant uses 4,000 cubic metres of water per hour, mainly for ash disposal and cooling, which translates into 3.5-4.0 cubic metres of water per MWh. This means that water consumption of a CSP plant is less than that of coal-based thermal power plants.

Wasting water

In the case of Rajasthan, project developers were assured of water availability through the Indira Gandhi Nahar Project (IGNP) canal – 11.92 cubic feet of water per second for 400 MW of CSP installations. If we consider a 24 per cent capacity utilisation factor, we find that 12.67 cubic metre of water has been allocated per MWh of electricity generation. This means actual water allocation is 4.2 times more than IEA estimation! Though the rationale behind such huge allocation is not clear, there is the possibility of criminal wastage of water in the deserts of Jaisalmer.

Table 7: Water allocation of CSP plants in Rajasthan in JNNSM Phase-I

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Project</th>
<th>Capacity (MW)</th>
<th>Water allocation</th>
<th>Water allocation Cusec</th>
<th>Cubic metre/MWh at 24 per cent CUF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lanco Solar, Divakar</td>
<td>100</td>
<td>2.9</td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>KVK Energy</td>
<td>100</td>
<td>2.9</td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Godawari Green</td>
<td>50</td>
<td>1.6</td>
<td>10.27</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Corporate Ispat</td>
<td>50</td>
<td>2.02</td>
<td>12.9</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Reliance Power, Rajasthan Sun Technique</td>
<td>100</td>
<td>2.5</td>
<td>8.0</td>
<td></td>
</tr>
</tbody>
</table>

But areas with high DNI, such as Rajasthan and Gujarat, the ideal locations for CSP in India, suffer from acute water shortage. Five out of seven projects under JNNSM Phase-I came in Jaisalmer, Rajasthan, and one came in Porbandar, Gujarat (see Box: Groundwater levels in Rajasthan and Gujarat).

As a result of water scarcity, CSP has the option of dry cooling but it comes with a trade-off. A CEA study in 2009-10 to evaluate the potential of dry cooling found that it is less efficient. Dry cooling can lower performance by 7 per cent and increase cost of generation by 10 per cent.37

However, considering the importance of water in Rajasthan and Gujarat, this trade-off can be an acceptable norm in the future. Dry-cooling technology has...
already been adopted as the future for cooling across the world to reduce water consumption. The trend is gradually emerging in India too.

Land requirement versus allocation: Land in India is scarce and heavily contested. Hence, there are three important concerns to keep in mind with respect to land for CSP:
- land is used optimally based on technology adopted
- ensuring that the land used is not forest or agricultural land
- ensuring that local communities are benefitted from the CSP plant in terms of adequate compensation for land purchase/land lease, employment and energy access.

The land requirement for CSP varies widely with technology. According to NREL, total land requirement for different CSP technologies in USA varies from 4.7 acre/MW to 10 acre/MW. However, CUF of different technologies are different and accordingly the land requirement per giga-watt hour (MWh) of generation per year will give a different picture altogether. For example, a solar tower has the highest requirement of land per MW (10 acres/MW), but in terms of power generation it consumes the least land (3.2 acres/GWh/year) as shown.38 (see Graph 7: Land required for CSP plants in the US)

Though land is one of the scarcest resources in India, the country has not developed any benchmark for land uses for CSP. CERC benchmarked 5 acres per MW for solar PV technology in 2010, but no such benchmark has been decided for CSP so far.39 However, state government undertaking Rajasthan Renewable Energy Corporation Limited (RRECL) had set a benchmark of 6.17 acres per MW for CSP with a CUF of 23 per cent both for parabolic trough as well as solar tower technology. The rule further said that an additional 0.25 acre per MW will be allotted per 1 per cent increment of CUF if the project comes up with thermal storage.40 Similarly, the government of Gujarat’s Department of Energy and Petrochemicals also set a benchmark of 6 acres per MW for CSP with a provision of extra allowances in case of thermal storage.41 Clearly there is a huge difference between the benchmark land requirement set in Rajasthan and Gujarat with that of USA. This requires proper due diligence on the part of the government.
2. Solar thermal applications

Development of solar thermal applications

Solar thermal applications have been used in India since the 1980s. Solar water heaters (the most prominent of the solar thermal applications) are available in the market for consumers to buy and use. They can be installed on any rooftop.

In December 2014, there were 8.63 million square metres of solar water-heating collector areas. The target set out by MNRE for FY 2014-15 has already been achieved for the water-heater sector.¹

The scheme “Accelerated Development and Deployment of Solar Water Heating System in Domestic, Industrial and Commercial Sectors” started in 2008. A target of 1.4 million sq. m of collector area was proposed for 2008-10 with a set-aside expenditure of Rs 49.50 crore under the programme. Most of the achievements in the sector during this period were attributed to this scheme. As per the annual report of MNRE, there were 2.15 million sq. m of collector area of solar water heaters in the country and it rose to 3.5 million square metres till the start of JNNSM in 2010.² There was also an interest subsidy; the discounted rate at 6.5 per cent was to be released by IREDA to banks/FIs/intermediaries. This programme has been put on hold and no new projects are being taken up by IREDA because, according to MNRE officials, the priority at this moment is to clear the large backlog that has piled up.³

JNNSM introduced the “Off-Grid Solar Thermal Scheme” to improve the market reach of solar thermal applications. The programme thus far has been implemented through approved channel partners of the categories of Renewable Energy Service Providing Companies (RESCOs) and financial institutions, including microfinance institutions acting as aggregators, financial integrators, system integrators and programme administrators. JNNSM set out the goals for solar collectors in 2010 (see Table 8: Targets for JNNSM for solar collectors).

Graph 8: Solar water heating collector areas (in million square metres)

Source: MNRE Annual Report 2013-14
According to MNRE, the maximum potential of solar water heating is in the residential sector. As per their estimates, more than 80 per cent of the installation in the sector has been attributed to the residential sector (see Graph 9: Solar water heater market, 2013). They also look at the same sector that has the maximum potential for development in the future. The estimated potential for solar water heating systems in the country has been 140 million sq. m in collector areas, out of which only 40 million sq. m are potentially techno-economically feasible (see Table 9: Solar water heating potential in India).

Solar water heating in the residential sector

Two types of solar water heaters are available in the market: one with flat plate collectors (FPC) and the other with evacuated tube collectors (ETC) (see Table 10: Costs and area required for solar water heating systems in residential areas).

The biggest savings of using a solar water heater is the electricity saved from using it. According to some estimates you can save 1,000-1,500 units in a year, depending on which region of India the system is located in. Ideally, a solar water heating system with a capacity of 100 litres is suitable for a family of four. Assuming that a unit of power costs Rs 5, on an average a household can save Rs 6,250 a year and recover the cost of investment in 2.5-3.5 years, depending on the system they install.

![Graph 9: Solar water heater market, 2013](source: MNRE Annual Report 2013-14)

### Table 8: Targets for JNNSM for solar collectors

<table>
<thead>
<tr>
<th>Applications</th>
<th>Target for Phase-I (2010-13)</th>
<th>Target for Phase-II (2013-17)</th>
<th>Target for Phase-III (2017-22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar collectors (million square metres)</td>
<td>7</td>
<td>15</td>
<td>20</td>
</tr>
</tbody>
</table>


### Table 9: Solar water heating potential (in million square metres)

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>7.68</td>
<td>15.74</td>
</tr>
<tr>
<td>Hotels</td>
<td>0.61</td>
<td>0.97</td>
</tr>
<tr>
<td>Hospitals</td>
<td>0.27</td>
<td>0.43</td>
</tr>
<tr>
<td>Other commercial/institutional</td>
<td>0.39</td>
<td>0.52</td>
</tr>
<tr>
<td>Industry</td>
<td>0.57</td>
<td>1.57</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9.52</strong></td>
<td><strong>19.23</strong></td>
</tr>
</tbody>
</table>

Source: MNRE Annual Report 2013-14

### Table 10: Costs and area required for solar water heating systems in residential areas

<table>
<thead>
<tr>
<th>Capacity (litres per day)</th>
<th>ETC system</th>
<th>FPC system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost (Rs)</td>
<td>Area (sq. m)</td>
</tr>
<tr>
<td>100</td>
<td>15,000</td>
<td>1.50</td>
</tr>
<tr>
<td>200</td>
<td>28,000</td>
<td>3.00</td>
</tr>
<tr>
<td>250</td>
<td>34,000</td>
<td>3.75</td>
</tr>
<tr>
<td>300</td>
<td>40,000</td>
<td>4.50</td>
</tr>
<tr>
<td>350</td>
<td>62,000</td>
<td>7.50</td>
</tr>
</tbody>
</table>

Source: Abhishek Jain, Solar Water Heater System – how it can help save on electricity bills, March 2014
(without any subsidy).\textsuperscript{6} This is an important point, since the future of any such subsidy is in question at the moment.

In India, more than 4,39,500 systems have been installed during 2008-14 with a cost of almost Rs 2,250 crores.\textsuperscript{7} Although this achievement is with the subsidy that is available – 30 per cent of the cost as subsidy to users in “General” category states and 60 per cent in “Special” category states, e.g. the hilly states, north-eastern states and islands limited to benchmarks Rs 3,000 per sq. m for ETC-based systems and Rs 3,300 per sq. m for FPC-based systems.\textsuperscript{8}

However, the analysis shows that solar water-heating systems are proved to be economically viable and the focus should be on more awareness and widespread installation of these systems.

**Solar thermal applications in the industrial sector**

There are a few examples of industrial applications of solar thermal in the iron and steel, paper and pulp, textile, ceramic and tile, food processing and dairy (for pasteurisation) industries. It has the potential to replace the fuel these industries are currently using. As per Shirish Garud, TERI, speaking at the Global Renewable Energy Forum, Brazil, 2008, “There is a potential of fuel replacement up to 100 per cent in case of pulping, paper drying and pulp bleaching in the textile industry.”\textsuperscript{9}

It was proposed that 20 R&D installations would be started in different industries in the 11th Five-Year Plan (2007-12). Each would have a thermal capacity of about 50 kW for the development of solar-heat collection (up to 250°C). The projects would focus on increasing efficiency and reducing heat losses, which would be apart from low-heat applications, such as cooking,
cooling, drying and food processing. The National Institute of Solar Energy currently is working on:
- a high-efficiency solar thermal air-conditioning system of 100 kW cooling capacity implemented by Thermax Limited
- a project in partnership with TERI, Thermax Limited, SEC and CSIRO Australia with an objective to develop cold storage, particularly in rural areas, utilising exhaust heat of biomass gasifier engine/solar Scheffler dish

The ministry has allotted funds from the National Clean Energy Fund (NCEF) for the implementation of CST-based systems in institutional and commercial establishments for process heat, community cooking and cooling applications under the Off-Grid Solar Thermal Programme for the years. However, the share of money allocated for MNRE from these funds has been slashed from 80 per cent in 2013-14 to 34 per cent in 2014-15.

There is tremendous scope for CST applications in industries. It is estimated that over 15 million tonnes of fuel oil is consumed annually in industries for process heat applications below 250°C. Likewise, over 35 million tonnes of fuel oil is consumed annually for industrial applications above 250°C. In JNNSM

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**Case study: Solar cooling systems at Mahindra and Mahindra, Pune**

Mahindra and Mahindra has a facility in Chakan, on the outskirts of Pune, spread over 700 acres and built with an investment of Rs 5,000 crore. The facility tested solar and renewable solutions that would be suitable for its industrial process heat and cooling requirements. The Paint Shop Process in the facility requires cold water, at 7°C, which was maintained with the system of electrical chillers (160 TR chillers with another standby). Constant operation of the Paint Shop led to high electricity cost for the facility. The plant also uses LPG in electrical heaters. Over time, the electricity bill along with the emissions of the plant skyrocketed.

The facility installed an 1,120 sq. m integrated solar and heat recovery system for cooling and heating requirements. The system has 70 solar dishes and a collection of equipment – waste-heat recovery units, vapour-absorption machines, heat pump, heat exchanger and a hot-water generator. The system is capable of meeting the needs of the facility (see Table 11: System performance, 2013).

The project helps Mahindra save 1,476 tonnes of LPG and 184 MWh of electricity every year at its paint shop. However, like solar thermal power generation, the monsoon months do not yield good results for the plant. The project was set up with a total cost of Rs 1.24 crore with a grant from MNRE of Rs 39.2 lakh. The rate of return with subsidy for the project is about 23.63 per cent, but without it would only be 12.92 per cent. The investment was recovered in less than three and a half years with the subsidy; without it, the payback period would be six years and four months.

“We have installed solar dishes supplied by M/s Thermax India Limited, Pune, for steam generation to be used for boiling food. We are happy to say that the system is performing satisfactorily and is leading to considerable savings of LPG consumption of the hostel. The services of the solar division of M/s Thermax India Limited have been prompt and they have proved to be a dedicated team. The system supplied by them meets our requirements,” says K.N.K.S.K. Chockalingam, director, National Engineering College, Kovilpatti.

<table>
<thead>
<tr>
<th>Table 11: System performance, 2013</th>
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<tr>
<td>Months</td>
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<td>October</td>
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<td>November</td>
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<tr>
<td>December</td>
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Source: Sun Focus magazine, April-June 2014
Phase-II, at least 400 systems of 250 sq. m each on an average (total 1,00,000 sq. m collector area) will be installed.

A pharma company in Baddi, Himachal Pradesh, uses six Combined Solar Heat and Power (CHP) Systems (solar collectors which include two parabolic dishes) for HVAC – heating, ventilation and air-conditioning application. The plant generates around 1,00,000 kcal per day of average DNI location of 5 kWh per sq. m every day. Siddharth Surgicals at Valsad, Gujarat, have commissioned 263 sq. m accumulated area of concentrated solar at an estimated investment of Rs 45 lakh. The solar field will produce 4.02 lakh kcal per day of energy, displacing an average 40 kg of LPG on a normal day.

Solar cooling/refrigeration is the most pertinent application for India in the industrial space. It is estimated that cooling consumes about 35,000 MW of electricity for various end-uses. It has a few demonstration systems, including:

The China example

China has been developing and investing in solar thermal application since the 1970s. The development of solar thermal technology has been phenomenal and China is considered by far the biggest solar thermal market worldwide. In terms of collector area, it represents over 80 per cent of the global residential market.

China established a commercial solar thermal industry, with over 1,000 factories manufacturing and selling solar systems. Most of these collectors are used to heat water and are sold without subsidies. It began with supporting the needs of the rural population who did not have access to electricity for water heating needs. Werner Koldehoff, a member of the advisory board European Solar Industry Federation (ESTIF), claims, “Chinese markets developed out of necessity. Lack of energy and access to infrastructure pushed the population in remote areas to pursue alternative forms of solutions for water heating.”

The market has been now taken over by the urban sector. One of the primary reasons is that in mid-2007 the National Development and Reform Commission (NDRC) issued the “Plan on Enforcement of Utilization of Solar Energy Heating Nationwide” that mandated solar hot-water heating in every new construction. This was done keeping hospitals, schools, and hotels in mind. It gave the country a unique advantage of having an enormous domestic market, especially for residential and commercial/institutional uses.

“As a builder, one does not receive building permission from the municipality unless one has demonstrated the plan for integrating solar hot water into the building,” says Fude Li, a project engineer for Linuo Paradigma. The solar thermal industry in China is moving from retrofitted systems for individual households towards large-scale systems that serve entire buildings from their rooftop.

Today, the country has taken the export market by storm due in part to technological development making it more competitive.

In terms of policy, there are currently no subsidies or assistance available for solar water heating in China. In most Chinese provinces, the solar option of domestic hot water supply is viewed as the most economical. So costs are not an impediment associated with this sector. Government support is offered in the context of finance for administration and research. Research on solar thermal utilisation has been part of the national priorities for the country. The government also allocated special funds to establish an advanced laboratory and testing facility for solar thermal.

China saw the demand for solar water heating, assessed the need to create a manufacturing base to supply the product for low prices and developed products to meet the demand. After catering to many of their population, they are exploring markets abroad with investment in research to enhance the quality of their products. India can learn the correct way of developing a technology and the right way of supporting them.
- a 100-tonne refrigeration (TR) system at Muni Sewa Ashram, near Vadodara, for their cancer hospital
- a 92-TR plant functioning at TVS Suzuki factory near Chennai for their office premises
- a 212-TR system based on vapour absorption and desiccant cooling at a hospital run by MC, Thane
- a 1,120 sq. m integrated solar and heat recovery system for cooling at Mahindra and Mahindra, Pune

However, solar cooling/refrigeration is an emerging technology and faces many growth barriers that are different from other heating and cooling technologies.

**Challenges**

One of the most significant challenges for the installer is that the technology is still evolving and there are frequent upgrades and improvements available in the systems installed. This is an issue since the installer needs to decide what the right time to invest in a technology would be and/or whether he should wait for an improved version.

Finance is another issue not addressed. Although there are few subsidies available for installation, there are very few scattered projects on the ground, particularly for the industrial sector. Given the limited uptake, the technology costs are high for these applications. There is also delay in the disbursal of the subsidy on the part of MNRE/IREDA. Also, there are very few manufacturers of these systems in India and some components need to be imported, adding to the cost of the project.

Awareness and knowledge of these applications are limited. The industry depends mostly on conventional fossil fuel for these uses. They are not aware of the cost savings of solar thermal and the variants of its uses. This is one of the major hindrances in the development of solar thermal applications as the industry views.

The government is not doing enough to promote the solar thermal applications in the country, especially in industrial sector. It is clearly visible from the fact that they have no plans of developing any new policies for the promotion of the same. The existing policies and subsidies themselves have been stopped expanding. The new Modi government especially is of the opinion that these technologies should be financially competitive and should not require any kind of support, particularly in the form of subsidies.
3. The way forward

The attributes and challenges of CSP discussed so far have set the ground for a possible way forward. Globally, CSP has a bright future. Countries such as USA, Spain and Israel are shaping the future. India too is optimistic about CSP and has set very aggressive targets in JNNSM.

But the actual status is that the future of CSP in India is in the doldrums on account of the lack of a long-term vision. Therefore, we will have to set the ground right in the first place in the following ways:

Map 2: Solar monitoring stations commissioned under JNNSM

Source: Dr Gomathinayagam, 2013, SRRA component of Sol–Map project
Build data, capacity and confidence

Measure DNI data on the ground

One of the important learnings from JNNSM Phase-I is that we cannot depend solely on satellite data to measure DNI and prepare project details based on that. Actual measurements at the project locations are crucial. Ideally, the India Meteorological Department (IMD) should have commissioned sufficient monitoring stations to collect and monitor solar irradiance data for the entire country. But till the recent past, IMD had only 45 ground stations across the country to monitor solar radiation data and only a few of them had instruments to measure DNI.1

Realising the limitation of IMD, MNRE authorised the National Institute of Wind Energy (NIWE), Chennai, to commission monitoring stations all over the country under the “Solar Radiation Resource Assessment” (SRRA) projects. Accordingly, 51 stations were commissioned in 2011 as part of JNNSM Phase-I and an additional 60 have been commissioned in 2013-14 as a part of JNNSM Phase-II programme2 (see Table 12: State-wise DNI stations commissioned by NIWE during JNNSM Phase-I and II and Map 2: Solar monitoring stations commissioned under JNNSM).

DNI is influenced by several parameters, such as clouds, aerosols and water vapour, but the effect of aerosol is the highest on DNI.3, 4 Aerosols can be natural or man-made. Vegetation, ground dust, sandstorms, smoke, industrial pollutants and volcanic eruptions all comprise these minute particles that are

### Table 12: State-wise DNI stations commissioned by NIWE during JNNSM Phases I & II

<table>
<thead>
<tr>
<th>S. no.</th>
<th>No. of SRRA station</th>
<th>Phase-I Commissioned</th>
<th>Phase-II Commissioned</th>
<th>S. no.</th>
<th>No. of SRRA station</th>
<th>Phase-I Commissioned</th>
<th>Phase-II Commissioned</th>
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<tbody>
<tr>
<td>1</td>
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<tr>
<td>3</td>
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<td>1</td>
<td>19</td>
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<td>4</td>
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<td>6</td>
<td>3</td>
<td>21</td>
<td>Andaman and Nicobar</td>
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<td>5</td>
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<td>Assam</td>
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<td>6</td>
<td>24</td>
<td>Dadra and Nager Haveli</td>
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<td>Madhya Pradesh</td>
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<td>1</td>
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<td>Uttarakhand</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>Haryana</td>
<td>1</td>
<td>1</td>
<td></td>
<td>Total</td>
<td>51</td>
<td>60</td>
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</tbody>
</table>

Source: NIWE website
suspended in the atmosphere. Since the particles vary daily, monthly and seasonally, measuring DNI for short periods will not give a reliable conclusion. According to a report by the International Solar Energy Society (ISES), DNI should be measured over five to 15 years to obtain reliable data. However, this is not practical in the Indian context since the solar monitoring stations have been commissioned very recently. The best possible solution is to measure the DNI data for at least one to two years and compare the data with satellite-based model data to arrive at a correlation.

**CSE recommendation 1**

*CSE recommends that NIWE measures the DNI for two years for each SRRA stations and compares it with five years of satellite data to evaluate DNI for a particular location. NIWE should declare these evaluated DNI data for each location where the SRRA stations were commissioned which becomes the basis for project design and financial-viability calculations. Based on these timeline, NIWE should be in a position to declare reliable DNI data for Rajasthan, Gujarat, Tamil Nadu, Andhra Pradesh and Karnataka by end of 2015. For all other states, this should be done by the end of 2016.*

**Build in stages**

**Development of solar thermal applications**

There are several industrial applications of solar thermal systems. It can be used in the iron and steel, paper and pulp, textile, ceramic and tile, food processing and dairy (for pasteurisation) industries. Solar thermal energy has the potential to replace the fuel these industries currently use. However, this also has to be dealt with in a sustained manner. Tarun Kapoor, joint secretary, MNRE, speaking in a conference on solar process heat systems said, “Solar thermal applications have not gained acceptance in India because they are not trusted by the industry, even though they have been working since 1983. There is no reliability or confidence on the technology as far as perception goes.” Dr Indu Keoti, EcoAxis, which has been monitoring 15 solar thermal applications projects across India both in the industrial and community context, said that only industries can maximise the utilisation of the system and ensure that their investments are recovered.

**CSE recommendation 2**

*CSE recommends that in the interim, where solar thermal power generation is not financially feasible, solar thermal applications for industries should be promoted by MNRE. This will encourage the manufacturing sector to develop since there would be a constant demand for them to supply and thereby costs reduce over time as a result of economies of scale. In addition, these installations would help reduce the carbon footprint of these industries. This would act as a perfect transitional phase for the technology – it would reduce cost and develop skills and expertise in this technology rather than remain theoretical knowledge at the research level.*

**Promote local manufacturing**

India not only has a geographical advantage for the development of CSP, but the increasing cost of coal and concerns about climate change also make it...
logical to look into CSP as a future replacement of coal-based thermal power stations. Owing to the fact that India has a huge potential for CSP, the country can be the hub for CSP manufacturing in the world. Some critical CSP components, such as reflective mirrors, molten salt etc., can be produced locally. The manufacturing processes for them have a high degree of maturity in the world and there is no requirement of high-level R&D to produce these components locally.

**CSE recommendation 3**

*CSE recommends that the government encourage local manufacturing of CSP components in India through a domestic content requirement clause and a host of incentives to set up manufacturing facilities. This will not only reduce the price of these components significantly, but will also transform India into a manufacturing hub for CSP with ample job opportunities. It also buys into the government’s idea of “Make in India”.*

**Implement demonstration project before scaling up**

Internationally, a lot of research is being conducted to understand the optimum size for CSP with different technologies. With a single turbine and single condenser, there is potential for saving on costs of equipments and heat loss. The effectiveness of dry-cooling technology and its impact on CSP’s performance is another critical area of research. Therefore, successful CSP demonstration projects are vital not only for building the experience curve but also for developing skilled manpower in the country. This requires special focus on R&D and human resources together. The proposed demonstration projects promoted by SECI are positive moves in that direction. Though the request for selection (RFS) are not out yet, CSE estimates that they are likely to be commissioned by end of 2018, provided projects are awarded in the beginning of 2015 and are commissioned within 36 months from the date of issuance of the letter of intent (LOI). Moreover, 50 MW of Godawari Green Power, 100 MW Rajasthan Sun Technique promoted by Reliance Power and 50 MW MIEL Green Power all have been commissioned by the end of 2014. These projects put together make a good ground for successful demonstration as well as developing a skill base.

**CSE recommendation 4**

*CSE believes that MNRE announcing pilot projects with technological innovations, especially with thermal storage, is a step in the right direction. It is important that there are projects on the ground which would illustrate that the technology is performing as per expectations. These projects are also important for testing components and sub-components of the solar thermal. CSE believes that this is the first step in the development of any technology.*

**Use advantages of hybridisation**

Hybridisation helps CSP integrate with other thermal-power-generating sources very easily and allows availability of solar power on demand even when there is no sunlight. It helps accommodate infirm powers like wind or solar PV into the grid. In that sense, hybrid CSP plants enhance grid flexibility and have positive consequences on CSP’s cost and performance. It will contribute to reduction in capital expenditure as well as increase in overall efficiency of any power plant.
CSE recommendation 5
CSE recommends that hybridisation be given first preference wherever possible. Hybridisation is possible where coal-, gas- or biomass-based power plants already exist with sufficient land for commissioning CSP plants. Therefore, such possibilities should be identified, particularly in Rajasthan and Gujarat, so that the full benefit of CSP can be tested and harnessed. CERC should allow the use of mixed fuel in the case of hybridised CSP plants and must decide a minimum percentage for solar fuel mix in order to qualify for the hybridised tariff. CERC also should work out a levelised cost of energy (LCOE) analysis for such plants.

Reworking existing projects
CSP projects not on the ground

The projects commissioned under JNNSM Phase-I along with the proposed demonstration projects of SECI will be helpful to gain investors’ confidence in CSP technology. Even after the demonstration projects get commissioned, the sector will be in the phase of development that requires government support. There are four projects that have not even started construction under the programme. These projects can be better utilised by the government.

CSE recommendation 6

CSE recommends that existing projects that have not yet been commissioned be cancelled and penalties be levied. Even after deadlines have been extended twice, the bank guarantees of these projects have not been encashed. The guarantees should be encashed and used for development of these projects as demonstration projects. Since the plants would not be coming up in the near future, they should be divided and re-auctioned.

Resource efficiency is critical
Optimal utilisation of land and water

CSP is land- and water-intensive. Places where DNI is good are dry and water tables are much below the ground level. Moreover, as CSP works on DNI, solar rays have to fall perpendicularly on the reflective mirror in order to concentrate sunrays at the focal point. Therefore land has to be horizontal. The requirement for both the availability of water and horizontal land limit the land available for CSP.

Places in Rajasthan and Gujarat where most of the CSP plants are likely to be commissioned are sandy and not suitable for habitations (example, Thar Desert). However, because land is scarce in India, it has to be utilised optimally.

CSE recommendation 8

Government should declare available lands for CSP projects well in advance in the public domain based on DNI data actually measured on the ground, land slope, and groundwater availability for such projects. Since land requirement for CSP is a function of CUF, which is dependent upon thermal-storage
capacity, it is always better to measure land requirement per gigawatt hour of generation per year rather than measure in terms of installation capacity. This will make allocation of land technology agnostic within CSP (CSP has four different technologies) and ultimately push the most efficient technology suitable for a particular location. The developer would be responsible for procuring the required land from respective state governments along with water linkage and for obtaining all necessary clearances before construction of the project.
Features and annexures
On August 13, 2013, Godawari Green Energy Limited (GGEL), a flagship company of the HIRA group, received the commissioning certificate for a 50-MW CSP plant in Nokh Village in Rajasthan’s Jaisalmer district, 156 km from the city of Bikaner. The CSP plant, featuring parabolic troughs, began supplying electricity to the grid on June 5, 2013.

Unlike many other CSP projects, GGEL faced no financial issues. The Bank of Baroda conducted extensive evaluation of the project before disbursing a loan. The lenders did have some apprehension since CSP technology in India is fairly new and there is little experience in setting up plants. The bank appointed energy consultants Mott MacDonald to scrutinise the project and based on their evaluation the project was allocated funds.

GGEL managed to address a major problem faced by CSP projects. Developers of such projects usually complain that lack of reliable DNI data hinders completion of projects. Information provided by the Ministry of New and Renewable Energy does not reflect the ground reality. NASA analysis showed that in 2009, when the plant was allotted to the company, the DNI was 1,950 kWh/m²/day. After the company set up its own station at the site, it was measured to actually be 1,753 kWh/m²/day. DNI is the amount of solar radiation received per unit area by a surface perpendicular to the sun’s rays.
To compensate for the uncertainty of DNI data, the 50-MW plant increased the mirror area to harvest more heat energy. An official reports that rather than the 80 loops required (theoretically) for 50 MW of power, the plant put up 120 loops of mirror.

Barely a month’s delay

Actual commissioning of all CSP projects is required 28 months after the power purchasing agreement (PA) is signed. But there was a month’s delay in commissioning the Jaisalmer plant. This was because the structures had to be changed to be in tune with the plant’s location. The parabolic trough structures required high precision fabrication. Engineering procurement and construction contractors, Jyoti Structures, took up a major portion of fabrication. This work took a little more time than anticipated. Developers complain that a commissioning period of 28 months is overambitious, given the lack of experience.

Performance so far

The plant has been operating for a year with a Siemens turbine of a rated capacity of 55 MW. During April 8-10, 2014, the plant was using 47 per cent of its capacity after 10-12 hours of operation. In May 2014, the plant achieved a CUF of 29 per cent, the highest recorded so far for the plant. The minimum generation has been zero in July 1-4, 2014, mostly on account of cloudy days. “The significance of CSP plants is that the generation depends on the clarity of skies and not on how hot the day is or what the temperature during the day is,” said J.S. Solanki, general manager, GGEL, at the plant site. From January onwards, the CUF of the plant has been 24 per cent.
Given that the plant does not operate for more than 12 hours every day, the plant heads are planning to add thermal storage to the plant. Sudeep Chakraborty, director, GGEL, went as far as to say at a recent conference, CSP Focus India 2014 in July 10-11, 2014, “It is a crime to operate a CSP plant without thermal storage.”

The auxiliary consumption of the plant is 11 per cent. “The operations team plans to reduce it to 10.5 per cent in the next quarter,” commented Prakash Marapan, senior manager, Operations, GGEL. This consumption is higher during winter. During peak winters, the heat transfer fluid (HTF) freezes in the tubes and anti-freezing pumps have to be used to keep the HTF flowing. Since the temperature during peak winters goes below zero on some nights, the start-up time of the plant is affected and lowered the CUF (CUF in December 2014-January 2015 was below 12 per cent).

One major issue in Jaisalmer is sandstorms because of which the frequency at which mirrors are cleaned increases. Workers clean 30 loops of mirrors every day. The plant has hired 50 local workers dedicated to cleaning them. Also, as recommended by the manufacturers, the mirrors are cleaned with only demineralised water; 2-2.5 m³ of water is used to clean one loop. The plant has 65 employees, 30 contract workers and 50 people to clean the mirrors. Essentially, the plant generated employment for 80 local people.
The brightly lit kitchen in the headquarters of the Brahma Kumaris World Spiritual University (BKWSU), in Shantivan, 18 km from Mount Abu in Rajasthan, is filled with aroma of dal and rice boiling in steam cookers. Lunchtime is an hour away. Chefs in spotless white work in tandem to ensure that the food is cooked to perfection.

Built in 1998 and spread over 7,000 sq. m, this solar kitchen has over 15 steam cookers with capacities of 500-1,000 litres and several deep pans for cooking vegetables. Food is to be served to an impressive 15,000 diners. There are bigger kitchens but none that runs on solar energy.

Vegetarian meals for 38,000 people can be cooked together in the BKWSU kitchen, with solar energy generated in the form of steam on the roof of a building next to the kitchen. The roof, which one reaches after four flights of stairs, is emblazoned with, “Welcome to solar world”. It has 84 shining parabolic concentrators, each a huge dish made of reflecting concave mirrors. Every dish is 9.6 sq. m and has 520 pieces of special white glass imported from Germany. They are arranged in pairs, one higher than the other. A rotating support adjusts them automatically according to the sun’s position so that the dishes can reflect and focus maximum sunlight on receivers.

Made of high-grade steel, these receivers are 3 m from the centre of the concentrators. A strong beam of reflected sunlight from the concentrators heats up the receiver. The temperature reaches up to 500°C at its focal point. The receivers are attached to pipes running along the row of concentrators. Receivers heat the water inside the pipes and steam is generated.
The steam travels through insulated pipes to the kitchen. The cooking vessels have perforations at their base to allow the entry of the steam. The entire solar installation generates 3.6 tonnes of steam every day which is used for preparing food and drink. About 50 kg of rice can be cooked within 12 minutes.

“The kitchen saves around 200 litres of diesel and 1.2 tonnes of carbon dioxide emissions in a day. It also saves 184 kg of LPG every day,” says Aneta Loj, research and development coordinator, India One Solar Thermal power project at BKWSU. The kitchen and the roof have been designed by Switzerland-based Wolfgang Scheffler, regarded as the father of solar community kitchens, with BKWSU’s renewable energy department.

BKWSU is also planning to fulfil its electricity needs through solar energy. It is building a 1-MW solar thermal plant on 22 hectares, using the technology used in the kitchen. Construction of the project, India One, is underway.

Pieces of mirror fitted on large parabolic metal structures, each 60 sq. m, constitute a concentrator. About 260 concentrators will be required to generate enough steam to power 1 MW of turbine to generate electricity. At the centre of each concentrator a camera will be fitted to monitor whether the focus of the sunrays on the receiver is accurate. The receiver, in this case, can heat up to 1,200°C and is integrated inside a heavy iron drum. The hollow of the drum has a spiral of heat-exchanger pipes in which water will flow. On heating, the water will turn into steam, which will be compressed to run the turbine.

A big advantage of this project is that the heat produced can be stored for as long as 16 hours so that it can be used after sunset to generate electricity. The stored heat can be 250-450°C. “We use cast iron to store the heat,” informs Loj, adding, “If we combine the storage system, the actual capacity of the plant becomes 3.2 MW.”

According to Loj, the project cost is 25 crore, 60 per cent of which is funded by corporates. The rest is jointly borne by the Union Ministry of New and Renewable Energy and the German government, which provided the technology. Loj says the project’s objective was to develop technology suitable for India. BKWSU’s solar thermal power project can be replicated elsewhere in the country.
The working principle of CSP technology

Concentrated solar power (CSP) is basically a solar thermal technology. Here the light energy of the sun is concentrated by using reflective mirrors to generate heat, which in turn produces steam to run a turbine. The generator coupled with the turbine rotates and produces electricity.

The basic difference between CSP and conventional thermal power station is that CSP uses sunlight as fuel instead of coal or gas to produce steam (see Diagram 1: Function of a CSP project). Unlike a solar PV system, which can work on direct as well as diffused radiation, CSP can work only with direct radiation. Therefore, the ideal locations for CSP are the Sun Belt regions, i.e., regions between 40 degrees north and south of the equator. The area includes areas of the Middle East, North Africa, South Africa, India, southwest United States, Mexico, Peru, Chile, Western China, Australia, southern Europe and Turkey.

Parabolic trough

Parabolic trough technology uses a curved, mirrored trough which reflects the direct solar radiation onto a glass tube containing a fluid (also called a receiver, absorber or collector) running the length of the trough, positioned at the focal point of the reflectors. The collectors track the sun so that its radiation is continuously focused on the receiver. The temperature can rise up to 400 °C. Hot liquid is passed through a series of heat exchangers to generate steam and drive a turbine.

Parabolic trough is the most prevalent and proven technology amongst CSP technologies. Dr Yehuda Harats of EnerT International Ltd, involved in the first CSP project based in California, opines, “Parabolic trough is less sensitive to variations and fluctuations in DNI than any other CSP technology” (see Diagram 2: Parabolic trough technology).
Vimal Kumar, President (Projects), Cargo Power & Infrastructure, in charge of a 25-MW parabolic trough with nine-hour storage, says, “Fresnel and power tower technologies are not appropriate for Indian conditions with a lot of dust and frequent sandstorms to deal with. Parabolic trough has minimum exposure in such cases and is best suited for India.”

**Central tower receiver**

The solar power tower is a type of solar furnace using a tower to receive focused sunlight. A solar furnace uses concentrated solar heat to produce high...
temperatures. The focused rays heat water and the plant uses the steam produced to power through a turbine.

Power towers also reportedly have higher conversion efficiencies than parabolic trough systems.\(^8\) There is considerably less experience in this technology the world over, which is inferred to be an incomplete comprehension of many developers of the technical and financial risks involved with the technology. Technologically, power tower has the maximum efficiency because it has the ability to achieve higher temperatures at the collection point when compared to other CSP technologies\(^9\) (see Diagram 3: Solar tower technology).

**Linear Fresnel reflector**

This technology uses long flat mirrors at different angles to have the effect of sunlight focusing on one or more pipes. These pipes have heat-collecting fluid mounted above these angled mirrors. The relative simplicity of this type of system makes it comparatively cheap to manufacture.\(^10\) When compared to other CSP technologies, Fresnel uses lesser equipment. There is higher equipment reliability in the system for the same reason. It is also said that the system yields higher power cycle efficiency and less pumping losses because of the simplistic nature of the plant. The biggest advantage for Fresnel plants is that it requires lesser area to operate in comparison to other technologies for the same power output. Thermal storage in linear Fresnel technology is still in development stage across the globe\(^11\) (see Diagram 4: Linear Fresnel technology).

**Diagram 4: Linear Fresnel technology**

Source: CSP World [www.csp.world.com](http://www.csp.world.com)

**Dish Stirling engine**

Dish Stirling technology, dating back to the 1800s, is the oldest solar technology.\(^12\) Solar dish systems comprise a dish-shaped concentrator (like a satellite dish) that reflects solar radiation onto a receiver mounted at the focal point. The receiver can be a Stirling engine and generator (dish/engine systems) or it may be a type of PV panel that has been designed to withstand high temperatures (CPV systems).\(^13\) Dish systems are said to be more suitable for standalone, small power systems due to their modularity. However, there is no
reason why the dish systems cannot be mounted in vast numbers in DNI-rich regions where they could generate large amounts of electricity (see Diagram 5: Dish Stirling technology).

CSP technologies use combinations of mirrored concentrators to focus the solar radiation to receivers that convert the energy into high temperature for power generation. As seen in Diagram 1: Function of a CSP project, thermal energy of the sun is converted into mechanical energy of turbine to generate power.
The world of CSP

CSP is still in a nascent stage of development in the world. There is over 4.6 GW of installed capacity of CSP as on December 2014 the world over.¹

CSP technologies are of four types – parabolic trough, linear Fresnel reflector, solar tower and dish Stirling.

Parabolic trough is the technology that leads, with around 56 per cent of the projects opting for it. Parabolic trough, linear Fresnel reflector and solar tower are used mostly for power plants in centralised electricity generation whereas solar dishes are more appropriate for distributed generation.² IRENA’s

Graph 1: CSP technologies

Graph 2: CSP projects

Note: *As on December 2014
Source: CSP Today
document on CSP costs assesses that solar towers might become the top choice for CSP technology in the coming future because solar towers can achieve very high temperatures with manageable losses using molten salt as a heat transfer fluid. This permits higher efficiency.³

The leaders in the sector are Spain and USA because of a combination of availability of resources in the country and the policy support provided by their respective governments. In December 2014, Spain took the leading position with respect to installed capacity of solar thermal power plants.⁴

The first commercial CSP plant began operating in 1986 – a 354-MW plant in California,⁵ although the CSP sector developed and arguably gained considerable momentum in other parts of the world only post-2005. This growth is seen mainly in Spain and in southwestern USA predominantly as a result of favourable policies like Feed-in Tariffs (FiT) and Renewable Portfolio Obligations (RPOs). The International Energy Agency’s CSP Technology Roadmap details scenarios where the global installed capacity of CSP can reach up to 1,500 GW, providing 11.3 per cent of global electricity in hybridised mode (in a combination of solar and backup fuels – fossil fuels and biomass) by 2050.⁶

The following is a country-specific state of CSP in the world.

Spain

Spain is one of the first countries in the world to introduce FiT for CSP development. The FiT was fixed at such a level that it made projects bankable and within two years over 1,000 MW was under various stages of development in the country.⁷ As on March 2014, Spain had an installed capacity of 2,285 MW of solar thermal power plants.⁸ The surge in the CSP market in the world can be attributed to the strides made in this sector in Spain.

India can learn from Spain about what long-term support for research and development in CSP technology can do to fully exploit the potential for improvements in the sector and subsequently reduce the levelised cost of power. CSP plants in Spain are allowed to generate 10-15 per cent of their power with natural gas or fuel oil as back up. The fuels maintain the temperature of the heat storage fluid when solar thermal electricity production is interrupted. This allows the plant to perform at a higher capacity-utilisation factor, thus in turn increasing the financial viability of these projects.

Spain has depicted what effective policy is capable of achieving and will help policymakers understand the importance of CSP development in the country. Studies indicate that optimal CSP plants have capacities of 150-250 MW. When combined with thermal storage, CSP has the ability to serve as a base-load supplier. For instance, Gemasolar in Spain produces electricity continuously just like “base load” nuclear power plants.⁹ A 19.9-MW plant based on solar tower technology, it has a molten salt heat storage system.¹⁰ Commissioned in May 2011,¹¹ its annual generation is around 110 GWh of power, enough to supply electricity to 25,000 homes.¹² In Spain, a 50-MW plant with thermal storage installed provides 2,250 jobs per year from the design phase till completion of construction. Once in operation, the plant still requires around 50 permanent qualified professionals for proper functioning.¹³ A study was
conducted in the southern region of Spain, which indicated that CSP plants required less water per hectare than agricultural activities.14

The development of CSP in Spain is attributable to the constant support from both the public and private sectors for R&D and educational programmes. It is supported by an effective and supporting regulatory mechanism and commitment for development on the part of the industry.15

However, issues have arisen in Spain discouraging the CSP market, especially after recession hit the EU. Since January 2012, Spain has discontinued feed-in tariffs (FiT) for any new CSP projects. In September 2013, the Energy Minister also announced a 6 per cent tax on electricity prices received by the producers, thereby effectively reducing the amount of FiT received.

**United States of America**

The United States boasts of 38,000 GW of potential concentrating solar power. If these CSP plants operated at a 20 per cent capacity factor, it would generate 60.19 million kWh annually, equivalent to more than 15 times the total power generation of 3.90 million kWh in 2013.16 The Sun Belt region of the United States is one of the largest areas for CSP exploitation; its copious solar radiation in states like California, Arizona, Nevada, New Mexico, Colorado, some of Utah, and Texas could be tapped for CSP-generation plants.17 Eight of the 13 biggest planned CSP projects in the world will be located in California and Arizona.18

USA has spent 50 years experimenting with the solar thermal power generation techniques and how to bring the cost of generation down. In April 2008, the Department of Energy committed US $60 million in funding over the next five years to support the development of low-cost CSP technology.19 Government support plays a vital role in the development of new solar technologies. The National Renewable Energy Laboratory (NREL) in Golden, Colorado, receives federal funding to collaborate with private developers to improve cost-competitiveness of many renewable energy products, including CSP, and to perform high-risk research on systems for CSP plants.20

Nine Solar Energy Generating System (SEGS) plants in southern California were built by the Luz Company. Construction began in 1984 and operation in 1990. These parabolic trough CSP plants are supported by natural gas and have a total capacity of 354 MW. They have been generating effectively for over 20 years, with O&M costs declining and annual output increasing over time. This truly proves trough technology and is a primary reason that most of the new, large projects are variations of the SEGS technology approach.21

The NREL estimates that approximately 455 construction jobs are created for every 100 megawatt (MW) of installed CSP.22 According to an analysis by Black & Veatch, a 100-MW CSP plant would produce 4,000 direct and indirect job-years in construction compared to approximately 500 and 330 job-years for combined cycle and simple cycle fossil fuel plants of the same production capacity, respectively.23

However, there are glitches on the road to development of CSP as well. The recent boom in cheap exploration of shale gas in the US has become an impediment for the growth of solar power, particularly CSP. Power producers have shifted focus to the inexpensive abundant fuel available questioning the competitiveness of CSP plants.24
Middle East – new initiatives

According to CSP Today analysis, CSP capacity in the coming five to 10 years will be about 6 GW. After notable contributions from Clean Technology Fund (CTF), North African countries plan to add 1,120 MW of CSP in the region and are considered to have one of the most ambitious CSP plans worldwide. The region received US $660 million from CTF. One of the Climate Investment Funds (CIF), CTF provides middle-income countries with resources to scale up low carbon technologies in the fields of renewable energy, energy efficiency and sustainable transport.

Morocco aims to have 2 GW of CSP by the end of 2020. A parabolic trough plant with a capacity of 160 MW is being constructed by EPC contractor Saudi ACWA and is planned to be operational by the end of 2015. The country also estimates that there is an opportunity to create 35,000 jobs with CSP. The creation of the Moroccan Agency for Solar Energy or MASEN and the government support is one of the reasons why uptake of solar has increased in a short span of time in Morocco. United Arab Emirates (UAE) announced a 1-GW solar park Mohammed bin Rashid Al Maktoum worth 12 billion dirham (US $3.2 billion) which they hope to complete by 2030. Waleed Salman, chairman of Dubai Supreme Council of Energy, told CSP Today, “Out of the 1,000 MW planned, 200 MW would be generated through PV and 800 MW through CSP.” However, the bifurcation has not been officially announced, and the actual installation might vary. In July 2013, Kuwait started the bidding process for a 50-MW CSP plant with thermal storage of 10 hours in Shagaya Multi Technology Renewable Energy Power Park.

China – starting the right way

Dr Ashwini Kumar, managing director, Solar Energy Corporation of India (SECI), believes, “There is cost reduction in any industry when the manufacturing components and sub-components move to the East – India and China primarily.”

China is committed to developing a capacity of 3 GW by 2015 and 10 GW by 2020. Chinese players completely took over the PV market, and drastic reductions in the cost of solar power resulted. This has led to many anti-dumping allegations and notifications announced against Chinese manufacturers in Europe, USA and India. The allegations have made China shift focus to the CSP sector. Sunny Sun, director (Solar) at CSP Focus said, “China is going slow in deploying CSP. They are currently working on background research. The emphasis is on resource survey, site selection, developing a roadmap based on pilot and demonstration scale development/commercial deployment route.”

Before formulating the feed-in tariff for CSP, the Chinese government’s priority was to develop support for the manufacturing industry – mirrors, heliostat, receiver, storage and transfer medium, receiver tubes and many other components and sub-components. Many private companies have set up pilot projects with government support. Another advantage that China has is cheaper loans available – interest rates are around 5-8 per cent as compared to India’s rate at 13 per cent.

The Chinese are going in the right direction. They have adopted the strategy of expanding the field of investment while simultaneously focusing attention on...
the development of markets as well as the absorption of technology from around the world.\textsuperscript{38}

The first commercial CSP plant – a 354-MW plant in California – started operation in 1986.\textsuperscript{39} But the CSP sector developed and arguably gained momentum in other parts of the world only post-2005. Growth has been mainly in Spain and increasingly in south-western USA and is predominantly due to Feed-in Tariffs (FiT) and Renewable Portfolio Obligations in these countries. The International Energy Agency’s CSP Technology Roadmap details scenarios where the global installed capacity of CSP can reach up to 1,500 GW, providing 11.3 per cent of global electricity (in a combination of solar and back-up fuels – fossil fuels and biomass) by 2050.\textsuperscript{40}

A lot of the development in this sector was expected to be done by industrial alliance Desertec Industrial Initiative. The Initiative was intended to harness primarily the potential of solar and wind in the Middle Eastern and North African (MENA) deserts. Now, after the global recession, there is uncertainty of how soon Desertec Foundation can achieve the project detailed out.

CSP technology can prove to be very beneficial in fulfilling the base load requirements and helping stabilise the grid with influx of various renewable-based power generations.\textsuperscript{41} This means that CSP can provide power that is dispatchable and dependable and can meet both the peak and base load.\textsuperscript{42} AT Kearney predicted that a best-case scenario of up to 100 GW of global installed capacity by 2025 would result in the creation of 1,00,000 to 1,30,000 new jobs potentially, out of which almost 50 per cent would be permanent jobs in operation and maintenance.\textsuperscript{43} IPCC 2010’s “Special report on renewable energy” mentions that CSP emits fewer greenhouse gases over its lifecycle as compared to PV and wind. Even if we include emissions of thermal storage, CSP has the advantage since it displaces the emissions from the back-up plants that would otherwise be needed to balance intermittency.
INTRODUCTION

11. Interview with John Jacob, ACME Solar.
18. Tarun Kapoor, Joint Secretary, MNRE speaking at CSP Focus India 2014, New Delhi at July 10-11, 2014.

Box: First demonstration project after JNNSM Phase-I bidding failed

2. Interview with John Jacob, ACME Solar.

Box: New targets for renewables

1. **WHY HAS CSP NOT TAKEN OFF IN INDIA?**

4. Interview with Vimal Kumar, Cargo Infrastructure and Power.
6. Interview of Ankit Singhvi, NN4Energy.
10. Interview with official from Infrastructure Leasing & Financial Services for the report.
13. Shirish Garud, Making solar thermal power generation in India a reality – Overview of technologies, opportunities and challenges, The Energy and Resources Institute (TERI), India.
16. Dr Ashvini Kumar, Director (Solar), Solar Energy Corporation of India speaking at CSP Focus India 2014, New Delhi at July 10-11, 2014.
17. Tarun Kapoor, Joint Secretary, MNRE speaking at CSP Focus India 2014, New Delhi at July 10-11, 2014.
20. Interview with Jasmeet Khurana, Head of Market Intelligence, Bridge to India.
22. Non-recourse project finance means finance where repayment is done only through the revenue generated by the project itself and not from the assets of the borrower.
29. Interview with John Jacob, ACME Solar.
30. Interview with official from Infrastructure Leasing & Financial Services.
31. Sharada Balasubramanian (2013), CSP on-ground Update, Energetica India, January-February 2013 Issue
35. Site visits to Diwakar, KVK, Godawari and Corporate Ispat Alloy and interviews with site managers showed
that some projects were considering air-cooling. Later presentations at the 3rd Concentrated Solar Thermal Power Summit in Gurgaon on March 14-15, 2012 gave no indication of if air-cooling would be used. At SolarCon Hyderabad November 10th Lanco representative stated that water-cooling would be used.


38. Sean Ong et al. (June 2013), Land-Use Requirements for Solar Power Plants in the United States, National Renewable Energy Laboratory (NREL), Denver, Colorado.


**Box: Case study: 3780-MW hybrid combined cycle natural gas and parabolic trough concentrating solar power (CSP) generation in Florida, USA**


**Box: Wasting water**

1. 11.92 cubic feet/sec (cusec) = 10,651,606.65 cubic metre/year; 400 MW at 24% CUF without thermal storage = 840,960 MWh. Hence water allocation is 12.67 cubic metre/MWh.

**Box: Groundwater levels in Rajasthan and Gujarat**


2. SOLAR THERMAL APPLICATIONS


3. Interview with MNRE officials


6. Rs 15,000 can be recovered in 2.5 years if the annual savings in Rs 6,250. Similarly, Rs 22,000 can be recovered in 3.5 years with the same annual savings of energy costs

7. SOLARWHIN Online Application, Consolidated Statement Statewise Installed By: ALL From 01-08-2007 To 09-01-2015, MNRE, New Delhi


**Box: Case study: Solar cooling systems at Mahindra and Mahindra, Pune**


**Box: Chinese example of solar thermal**


**3. THE WAY FORWARD**


4. An aerosol is defined as a colloidal system of solid or liquid particles in a gas. An aerosol includes both the particles and the suspending gas.


**ANNEXURE 1**


6. Dr Yehuda Harats, EnerT International Ltd speaking at CSP Focus India 2014, New Delhi at July 10-11, 2014.
7. Vimal Kumar, President (Projects), Cargo Power & Infrastructure speaking at CSP Focus India 2014, New Delhi at July 10-11, 2014.
9. Interview with John M. Jacob, Deputy General Manager, Solar Thermal Efficiency, ACME.
11. Interview with Hem Raj Sharma, Project Director, Reliance 100 MW Linear Fresnel Plant in Dhursar, Jaisalmer, Rajasthan.

ANNEXURE 2

17. CSP concentrates the mind, Desertec, January/February 2008.
18. Gary Gereffi and Kristen Dubay (2009), Center on Globalization Governance & Competitiveness, Clean Energy for the Electric Grid, Chapter 4 - Concentrating Solar Power.
33. Dr Ashvini Kumar, Director (Solar), Solar Energy Corporation of India speaking at CSP Focus India 2014, New Delhi at July 10-11, 2014.
36. Sunny Sun, Director (Solar), CSP Focus speaking at CSP Focus India 2014, New Delhi at July 10-11, 2014.
43. AT Kearney (June 2010), Solar Thermal Electricity 2025 - Clean electricity on demand: Attractive STE cost stabilize energy production, Duesseldorf, Germany.