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Concentrated Solar Power: Heating Up India's Solar Thermal Market under the National Solar Mission

Addendum to *Laying the Foundation for a Bright Future: Assessing Progress under Phase 1 of India's National Solar Mission*

Prepared by:
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ABOUT THIS REPORT

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The Natural Resources Defense Council (NRDC) is an international nonprofit environmental organization with more than 1.3 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, Chicago, Livingston, and Beijing. (www.nrdc.org).

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Scope of Report

As an addendum to our previous report on solar photovoltaic projects, *Laying the Foundation for a Bright Future: Assessing Progress under Phase 1 of India's National Solar Mission*, this report focuses on the Jawaharlal Nehru National Solar Mission's objectives, targets, and incentives for grid-connected concentrated solar power (CSP) projects in India. The Mission's goals relating to off-grid solar projects are not covered in this report.

Methodology

This report adopts a whole-of-system approach by focusing on various public and private institutions operating in the solar ecosystem, the record and challenges of commissioning projects, the bankability of projects, the building of a robust manufacturing base, and analysis of the related enabling environment for the industry. The process included initial identification of key solar stakeholders in India and internationally to understand stakeholder perspectives and barriers to effective implementation of the National Solar Mission. Primary research was conducted through extensive discussions during in-person meetings, phone conversations, and written communication, and during conferences and workshops. The organizations also engaged periodically with the Ministry of New and Renewable Energy.

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Cover photo: (Left) Fifty-MW grid-connected CSP project currently being developed under the NSM by Godawari Green Energy Ltd., located in Naukh Village, Jaisalmer District, Rajasthan, © Godawari Green Energy Ltd.
(Top Right) Grid-connected CSP project currently being constructed under the NSM, photo used with permission.

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ADB	Asian Development Bank
CDTI	Centro para el Desarrollo Tecnologico Industrial
CEA	Central Electricity Authority
CEEW	Council on Energy, Environment and Water
CERC	Central Electricity Regulatory Commission
CSI	California Solar Initiative
CSP	Concentrated Solar Power
C-WET	Centre for Wind Energy Technology
DCR	Domestic Content Requirement
DNI	Direct Normal Irradiance
EPC	Engineering, Procurement, and Construction
EX-IM	Export-Import Bank of the United States
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GW	Gigawatt
HTF	Heat Transfer Fluid
IBA	Indian Banks' Association
ICICI	Industrial Credit and Investment Corporation of India
IREDA	Indian Renewable Energy Development Agency
JNNSM	Jawaharlal Nehru National Solar Mission
kWh	Kilowatt hour
MAHAGENCO	Maharashtra State Power Generation Company
MNRE	Ministry of New and Renewable Energy
MW	Megawatt
NAPCC	National Action Plan on Climate Change
NRDC	Natural Resources Defense Council
NSM	National Solar Mission
NTPC	National Thermal Power Corporation
NVVN	NTPC Vidyut Vyapar Nigam
OPIC	Overseas Private Investment Corporation
PPA	Power Purchase Agreement
PV	Photovoltaic
R&D	Research and Development
REC	Renewable Energy Certificate
RPO	Renewable Purchase Obligation
SECI	Solar Energy Corporation of India
WTO	World Trade Organization

EXECUTIVE SUMMARY

Solar power can play a significant role in a secure and diversified energy future for India as the country becomes a hub for solar projects. More specifically, concentrated solar power (CSP) could have a unique role in India's energy mix. Its potential to use hybrid technologies and easily add storage could unlock dispatchable and base-load power, setting the stage for larger renewable energy penetration.

Despite these advantages, much more needs to be done to scale up CSP sustainably. CSP is currently more expensive than photovoltaic (PV) technology, projects take longer to set up, and CSP plants need more water per unit of electricity produced. While these are not necessarily reasons to abandon CSP altogether, particularly since innovation can address some of these barriers, they do highlight challenges that the development of the CSP market could face in India.

In April 2012, the Council for Energy, Environment and Water (CEEW) and the Natural Resources Defense Council (NRDC) published an interim report, *Laying the Foundation for a Bright Future: Assessing Progress under Phase 1 of India's National Solar Mission.*[1] The report, focused on grid-connected solar PV projects, highlighted the importance of a robust solar ecosystem to realize the objectives of the Jawaharlal Nehru National Solar Mission (NSM or Mission).

The purpose of this report is to shine a light on the progress of CSP projects under Phase 1 of the Mission, highlighting challenges arising during Phase 1 implementation, and look ahead at planning for Phase 2. As on-the-ground CSP data is sparse at this stage, this report draws on extensive stakeholder discussions and research on national, state, and international CSP initiatives.

Grid-connected CSP project currently being constructed under the NSM. Photo used with permission.

For a country where access to affordable electricity and the stability of its grid infrastructure are both critical priorities, it would be an error to impose a false choice between PV and CSP technologies. Both are needed to diversify India's electricity sources and make access to electricity more sustainable, affordable, and predictable. The CSP market has to be evaluated on its own merit. Our findings suggest that the Indian government ought to continue to foster CSP development at this stage, even as PV projects progress on the back of rapidly falling PV module prices. As the Mission matures, appreciating the unique roles that both CSP and PV can play in the energy mix is key to ensuring flexible policy emphasis on each solar technology.

We describe key findings from our analysis, as well as recommendations to strengthen the next phase of the Mission.

START-UP CHALLENGES: PROJECTS ALLOCATED AND WORK IN PROGRESS

Bidding for concentrated solar power projects in Phase 1 of the Mission attracted more than 60 bidders. Seven companies, including Abhijeet, Lanco, and Reliance, were allocated projects at a weighted average price of ₹11.48 ($0.21/kWh) per kilowatt hour (kWh).[2] By August 2012, all seven Phase 1 CSP projects had broken ground. Developers have until May 2013 to commission plants under NSM timelines, but many implementation challenges remain, and several developers are experiencing project delays. All Phase 1 CSP developers have petitioned the Ministry of New and Renewable Energy (MNRE) for a 6 to 12 month extension.[3] Since many of the project developers are large companies with access to significant financial resources, some projects may still be commissioned on time. Looking ahead to Phase 2, concerted stakeholder action is needed on several fronts.

Recommendations

- **MNRE should ensure that Phase 2 policies continue to encourage CSP technologies along with other solar technologies.** CSP offers unique attributes to India's energy mix, including supplementing base-load requirements, supplying peak-load electricity, and ensuring grid stability. MNRE could explore three options for Phase 2: 1) continue fostering both technologies through the Phase 1 50:50 split; 2) divide the technology allocation into three parts, a third each for PV and CSP, with the remaining third unallocated and technology neutral for any solar technology; or 3) allocate 1,500 MW initially in Phase 2—rather than the entire 3,000 megawatt (MW) target—mitigating some of the risk associated with supporting CSP technologies and offering more information for a mid-term review of Phase 2. If insufficient progress is found, then Phase 2's second allocation could be technology neutral. This incremental approach could help establish a clearer roadmap for the development of the solar market, without locking into technologies.
- **The government should enforce commissioning timelines for Phase 1 projects to avoid setting a precedent of leniency on delays.** Looking ahead, MNRE should increase involvement during the project commissioning process to independently analyze the root causes of commissioning delays on a quarterly basis, and determine which unforeseeable delays merit extensions. Such planned interventions can help avoid such delays during Phase 2.
- **The Solar Energy Corporation of India (SECI) should establish a sub-committee** to formulate and implement best practices to overcome commissioning delays, incorporating feedback from all stakeholders.
- **MNRE should ensure that Phase 2 guidelines continue to strike a balance** between encouraging new players to participate and attracting experienced developers by maintaining the requirement that selected developers work with experienced technology providers.

ATTRACTING INVESTMENT: RESOURCE ASSESSMENT AND FINANCE

The burgeoning CSP market in India, like the PV market, depends on access to low-cost domestic financing to continue growing at a healthy rate. The Asian Development Bank estimates that around ₹17,000 crore (approximately $3.2 billion) in debt financing would be needed over the next three years to complete all projects that have been announced already.[4] While domestic financiers have shown reluctance to fund solar projects, projects employing CSP technology are considered even riskier.[5] For the Mission to scale up as quickly as MNRE expects, a concerted effort to reduce these common barriers to solar finance is needed.

Recommendations

- **In order to attract investment, MNRE should coordinate stakeholders to develop strategies to encourage non-recourse project financing**, such as government-backed loan guarantees; work with the Indian Banks' Association (IBA) to share information on the developing CSP market track record; and empanel engineers with CSP technical knowledge as trusted advisors to financiers.
- **The Solar Energy Corporation of India (SECI) should facilitate a set of detailed case studies about key CSP projects** highlighting financial viability and loan syndication. SECI and the IBA should then disseminate such syndication experiences to encourage new players, including additional developers and financiers, and existing players to increase their participation in the solar market.
- **MNRE should continue to facilitate collection of direct normal irradiance (DNI) data, and mandate data sharing by project developers**, as set forth under MNRE guidelines. SECI should independently collect and verify this information on a regular basis to supplement data collected by MNRE's own ground-based weather stations, and build up confidence in the accuracy of DNI data.
- **The Indian government should continue to analyze effective approaches to enforcement of renewable purchase obligations (RPOs) and development of a renewable energy certificates (RECs) market.** A thriving REC market will foster greater investment in solar projects and allow for a variety of technologies and business models to be implemented. The central government should consider requiring states to develop RPO enforcement policies prior to receiving central funds.

HORIZON PLANNING: SUSTAINABLE TECHNOLOGY CHOICES

Drawing on Phase 1 experiences, India can develop a robust domestic CSP industry, but key barriers remain. Discussions with CSP stakeholders focused on five areas for driving sustainable CSP technology choices: 1) domestic manufacturing; 2) storage to create uninterrupted power opportunities; 3) hybridization with base-load capacity; 4) availability of heat-transfer fluid and turbines; and 5) water use and availability.

Recommendations

- **In order to encourage a domestic CSP industry, the Indian government should:** maintain a domestic content requirement or consider other support mechanisms such as non-discriminatory equipment production subsidies for Phase 2; foster R&D collaboration and innovation to encourage domestic production and cost reductions in a growing CSP industry; and consider employing support measures such as production subsidies to encourage CSP manufacturers to establish facilities in India.
- **MNRE should incentivize the adoption of storage technologies in CSP plants and evaluate mechanisms to spur storage-enabled generation**, such as: carving out CSP projects with storage under the NSM; or longer NSM commissioning timelines for projects with storage.
- **MNRE should assess opportunities for hybrid CSP base-load plants** with sustainably-produced biomass and other fuels and develop policy guidelines to encourage such projects.
- **By providing incentives like tariff premiums, MNRE should encourage water-efficient technologies in CSP plants**, including dry-cooled and hybrid systems, and use of treated wastewater.

LOOKING AHEAD: THREE POLICY PRIORITIES

The National Solar Mission has catalyzed solar energy growth in India, but much more needs to be done to scale up sustainably. Implementing three key policy priorities will help support the development of the CSP industry, as well as the broader solar industry:

Building a Solar Roadmap: The NSM has kick-started the solar industry in India. To reach the Phase 2 targets, the sector needs long-term signals about the direction of the market, policy priorities, and support measures. As planning for Phase 2 gains momentum, the government should send strong policy signals, such as tying state-level RPO enforcement mechanisms to central funds, to develop confidence in the CSP market. In doing so, the unique characteristics of the available technologies need to be recognized and accommodated. An incremental approach to Phase 2 technology allocation could also provide a roadmap for solar development without locking in technologies that prove unsuccessful.

Strategic Finance: Attracting investment for solar projects, especially CSP, remains a bottleneck to the growth of the industry in India. As noted in our earlier PV report, MNRE should lead in developing a strategy to optimize the potential role of different financial institutions and stakeholders. For the Mission to succeed, significant amounts of financing from a variety of channels need to be unlocked and policymakers need to continue engaging industry stakeholders in dialogue to quickly address issues as they arise. For CSP in particular, more available and credible data on direct normal irradiance, and access to non-recourse financing are key.

Encouraging Innovation: The early stage of the CSP market allows room for innovation in product development, and for a local manufacturing base to develop. The Mission should encourage research, development, and deployment of CSP to allow the technology to fulfill its potential (e.g., through improved storage and more water efficient cooling systems) as an enabling renewable technology.

Continued action by all stakeholders is required to support India's emerging solar energy market. The findings and recommendations in this report are intended to effectively strengthen the development of the CSP ecosystem to help make India's immense solar potential a long-term reality.

[1] Natural Resources Defense Council and Council on Energy, Environment and Water, "Laying the Foundation for a Bright Future: Assessing Progress under Phase 1 of India's National Solar Mission," April 2012, http://ceew.in/pdf/CEEW-NRDC-National_Solar_Mission_Interim_Report_30Apr12.pdf ("NRDC-CEEW Solar PV Report," accessed August 10, 2012).

[2] Vijay Gulati, "JNNSM Phase 1: Journey So Far," NVVN Presentation at World Renewable Energy Forum, Denver, Colorado, 2012, http://www.esmap.org/esmap/sites/esmap.org/files/JNNSM_Journey_so-far_VG_NVVN_16.05.2012.pdf (accessed August 21, 2012).

[3] Noor Mohammed, "Half of solar mission projects to miss commissioning deadline," *Financial Express*, August 16, 2012, http://www.financialexpress.com/news/half-of-solar-mission-projects-to-miss-commissioning-deadline/988909/ (accessed August 20, 2012).

[4] Natalie Obiko Pearson, "India Banks Face Solar Setback As Projects Delay, Fined," *Bloomberg Business Week*, June 12, 2012, www.businessweek.com/news/2012-06-12/india-banks-face-solar-setback-as-projects-delay-fined ("Pearson Solar Setback Article," accessed August 13, 2012)

[5] CEEW-NRDC Stakeholder Discussions, June-July 2012.

CONCENTRATED SOLAR POWER: UNIQUE ROLE IN A ROBUST SOLAR ECOSYSTEM

Exceeding early expectations, the Jawaharlal Nehru National Solar Mission (NSM or Mission) has catalyzed India's small but growing solar energy market. As designed, the NSM is divided into three phases, and aims to meet targets of 20,000 megawatts (MW) of grid-connected solar power and 2,000 MW of off-grid installations by 2022. India recently exceeded 1,000 MW of total installed solar capacity in July 2012.[1] But it remains unclear whether all the projects allocated specifically under the NSM will be operational within the projected timeline.[2] Since Phase 2 targets an ambitious minimum addition of 3,000 MW (potentially reaching 10,000 MW) by 2017, it is important to critically analyze the challenges that remain as well as the positive lessons for projects to draw upon in the future.[3]

The Phase 1 guidelines provided a 50:50 split between projects employing photovoltaic (PV) technologies and concentrated solar power (CSP, also referred to as solar thermal). Given the longer construction period of CSP projects, MNRE allocated all seven selected CSP projects during the first round ("Batch I") of Phase 1 bidding, and set a May 2013 commissioning deadline.[4] PV projects were given a shorter lead time, with commissioning deadlines of January 2012 for Batch I projects and February 2013 for Batch II projects.

Globally, CSP has had a sporadic history.[5] CSP plants were installed in the United States between 1984 and 1991, but little to no CSP capacity was added between 1991 and 2006.[6] Beginning in 2010 through March 2012, more than 700 MW of CSP capacity was added globally. Currently, more than 20,000 MW of solar thermal power are planned worldwide.[7]

Despite this recent resurgence, the CSP market faces intense pressure. Plummeting prices of PV modules and a growing track record of PV project implementation are making the more complex, costly and time-intensive CSP projects less attractive.[8] So far, however, a number of stakeholders across India's solar ecosystem have praised the technology split between PV and CSP and the Ministry of New and Renewable Energy's ("MNRE") commitment to drive CSP innovation in India. Indeed, CSP could have a unique role in India's energy mix, particularly with its potential to use storage and hybrid technologies, and decrease renewable integration risk (see table 1 for CSP's attributes and challenges). Imposing a false choice between CSP and PV, therefore, ignores the fact that both technologies are critical to diversify India's energy sources and increase access to sustainable electricity. Our findings suggest that MNRE ought to continue to foster CSP development, even as PV projects progress on the back of rapidly falling PV module prices. An incremental approach to Phase 2's technology allocation could send the necessary long-term market signals without locking in specific technologies.

A DEVELOPING CONCENTRATED SOLAR POWER ECOSYSTEM

In April 2012, the Council for Energy, Environment and Water (CEEW) and the Natural Resources Defense Council (NRDC) published an interim report, *Laying the Foundation for a Bright Future: Assessing Progress under Phase 1 of India's National Solar Mission*.[9] The report, which focused on grid-connected PV projects, highlighted the importance of a robust solar ecosystem to realize the objectives of the National Solar Mission. This ecosystem depends on successful coordination among many diverse enablers and stakeholders operating at various levels: strategic policy; project implementation; and the supporting environment. For grid-connected CSP to succeed, the same three components of the ecosystem will need to operate in concert (see figure 1, which highlights some key developers, contractors, financiers, and other stakeholders).

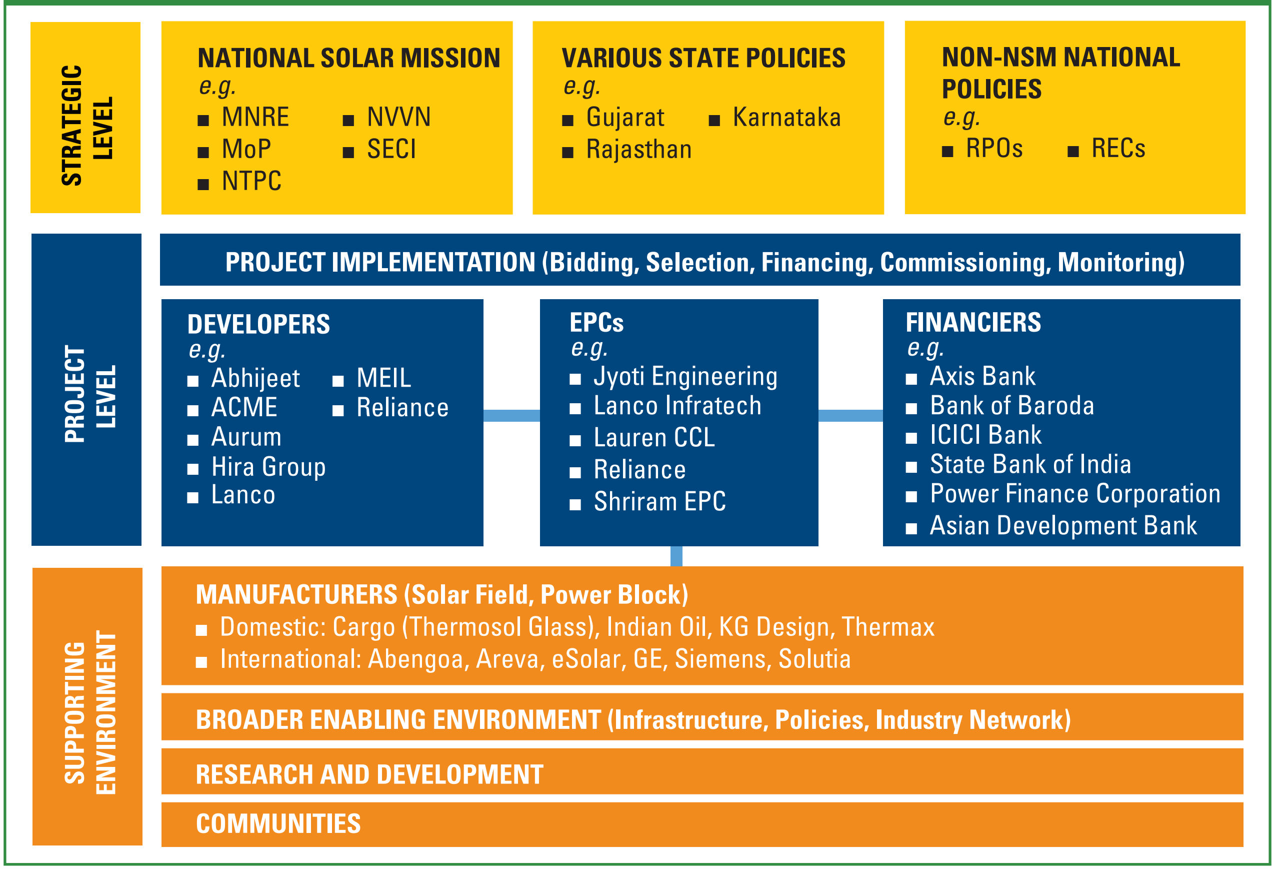
The report also discussed a range of interventions that help to create an enabling environment and advance project

Table 1: Concentrated Solar Power's (CSP) Attributes and Challenges	
Concentrated Solar Power's Attributes	
Key Components	Solar Field: Concentrates solar energy and converts it into heat stored in a medium such as oil or steam. Key components include mirrors, absorber tubes or receiver towers, structures, heat transfer fluid, tracking equipment, pumps, piping, medium such as molten salts, and storage tanks. Power Block: Uses the medium heated in the solar field to run a turbine and produce electricity. Key components include heat exchanger(s), steam turbine, generator, control systems, and cabling.
Thermal Energy Storage	When used with storage (usually through molten salt technology), CSP can be configured to generate electricity after the sun sets. Storage allows CSP to address both peaking and off-peak power.
Hybridization	When used in conjunction with a conventional coal or gas plant, thermal industrial systems, or with renewable sources such as biomass, CSP can be configured to use the existing plant's turbines to cost-effectively increase its efficiency and reduce the carbon footprint.
Dispatchability	Thermal energy storage and hybridization allow energy from CSP to be decoupled from immediate solar resource availability. This allows electricity to be dispatched on demand, when it is needed the most. Because India's electrical demand peaks after sunset, CSP with storage can play an important role in the country's energy mix.
Grid Flexibility	CSP with storage also builds grid flexibility and enhances the grid's capacity to accept a larger fraction of energy from variable output renewable energy sources, such as wind and PV, whose output varies with wind intensity and solar irradiation, respectively. For example, a project in Spain demonstrated that connecting CSP plants to grid sub-stations allows for a greater share of wind energy.
Concentrated Solar Power's Challenges	
Capital Cost Premium	The cost of a parabolic trough CSP plant in India ranges from ₹10.5 crore to ₹13 crore per MW (approximately $1.9 million to $2.3 million per MW) in capital cost, according to Indian developers consulted. Storage increases the capital cost further but also increases electricity generation. Energy cost optimization over the lifetime of a CSP plant depends on power tariffs, solar resource, cost of storage, and system configuration.
Limited Implementation Record	Parabolic trough is the most mature CSP technology, and more than 80 percent of CSP plants in operation or under construction globally use this technology. Most plants under the NSM also use parabolic trough technology. In contrast, linear fresnel and power tower plants are relatively less mature, with less than 100 MW each of global installed capacity. Indian developers have very limited CSP experience and only 8.5 MW of installed CSP capacity existed in the country as of February 2012.
Environmental Concerns	CSP plants require water predominately for cooling, and also for cleaning. A CSP plant's cooling water requirement is similar to a coal-based power plant. Locations suitable for CSP are usually arid regions with a short supply of water. Technology choices to reduce CSP's water demand are available, but affect the levelized cost of electricity. An Indian electricity regulator study found that the most water efficient technologies reduce consumption by 90 percent, but result in an 8 percent to 9 percent increase of electricity tariff.

See IRENA CSP Cost Report; Paul Denholm and Mark Mehos, "Enabling Greater Penetration of Solar Power via the Use of CSP with Thermal Energy Storage," *National Renewable Energy Laboratory*, November 2011, http://www.nrel.gov/csp/pdfs/52978.pdf ("NREL CSP Report," accessed Aug. 10, 2012); International Energy Agency, "Technology Roadmap Concentrating Solar Power" (Paris, 2010), http://www.iea.org/papers/2010/csp_roadmap.pdf (accessed August 21, 2012); International Energy Agency, "Electricity in India – Providing Power for the Millions," (Paris, 2002), http://www.oecdbookshop.org/oecd/display.asp?K=5LMQCR2KF5WC&DS=

Electricity-in-India-Providing-Power-for-the-Millions ("IEA India Electricity Report," accessed August 21, 2012); "Report On Minimisation Of Water Requirement In Coal Based Thermal Power Stations," *Central Electricity Authority* (January 2012), http://www.cea.nic.in/reports/articles/thermal/min_of%20water_coal_power.pdf ("CEA Coal Water Requirement Report", accessed August 22, 2012); "Concentrating solar power in India: CSP plants and equipment to be fully exempt from import duty", *Solar Server*, http://www.solarserver.com/solar-magazine/solar-news/current/2012/kw11/concentrating-solar-power-in-india-csp-plants-and-equipment-to-be-fully-exempt-from-import-duty.html (accessed August 22, 2012). See also, Sami Yassa, "Massachusetts Biomass Regulations: The Model for Getting Biomass Policy Right," NRDC Switchboard, April 27, 2012, http://switchboard.nrdc.org/blogs/syassa/massachusetts_biomass_regulati.html (accessed August 21, 2012).

FIGURE 1: Enablers and Stakeholders in a Successful Concentrated Solar Power Ecosystem



implementation for PV projects. These interventions and associated challenges are common to CSP and PV technologies, and include land acquisition, community involvement, and the need to augment grid infrastructure to transmit power from the typically remote locations of solar plants. Providing a long-term roadmap through clear market signals is also key.

Compared to the developing PV market, the CSP ecosystem is at an earlier stage of maturity, presenting both a challenge and an opportunity. On one hand, stakeholders have experienced difficulty raising finance for projects and finding skilled resources such as engineers and welders. On the other hand, market participants are optimistic that as more projects are commissioned in India, a local manufacturing base for CSP components could develop to cater to both domestic and international markets.[10] As MNRE plans for the future, both complementary and distinct aspects of the entire solar market, including PV and CSP, must be incorporated in shaping Phase 2 policies and guidelines.

[1] This total capacity includes installations under both State and Central initiatives. MNRE, "Progress under Jawaharlal Nehru National Solar Mission," May 11, 2012, http://pib.nic.in/newsite/erelease.aspx (accessed July 19, 2012).

[2] Natalie Obiko Pearson, "India Misses Solar Target With 20-Fold Jump in Capacity in Year," *Bloomberg*, January 20, 2012, http://www.bloomberg.com/news/2012-01-20/india-misses-solar-target-with-20-fold-jump-in-capacity-in-year.html (accessed August 13, 2012).

[3] MNRE, "Jawaharlal Nehru Solar Mission: Towards Building a Solar India," January 2010, http://india.gov.in/allimpfrms/alldocs/15657.pdf ("Mission Document," accessed August 10, 2012).

[4] The first batch of PV projects was due to be commissioned in January 2012, with the second batch of PV projects expected to be commissioned in January 2013.

[5] International Renewable Energy Agency, "Concentrating Solar Power, Renewable Energy Technologies: Cost Analysis Series, Vol. 1: Power Sector, Iss: 2/5," June 2012, http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-CSP.pdf ("IRENA CSP Cost Report," accessed August 16, 2012).

[6] See id. Nevada Solar One commissioned 64MW parabolic trough plant outside Las Vegas in June 2007, reigniting interest in the U.S. See Acconia Energy Website, Activity Areas: Nevada Solar One, http://www.acciona-energia.com/activity_areas/csp/installations/nevadasolarone/nevada-solar-one.aspx (accessed August 20, 2012).

[7] Note that some of these planned CSP projects are under construction. See IRENA CSP Cost Report.

[8] Ucilia Wong, "Report: Solar Panel Supply Will Far Exceed Demand Beyond 2012," *Forbes*, June 27, 2012, http://www.forbes.com/sites/uciliawang/2012/06/27/report-solar-panel-production-will-far-exceed-demand-beyond-2012/ (accessed August 20, 2012).

[9] See NRDC-CEEW Solar PV Report.

[10] CEEW-NRDC Stakeholder Discussions, June-July 2012.

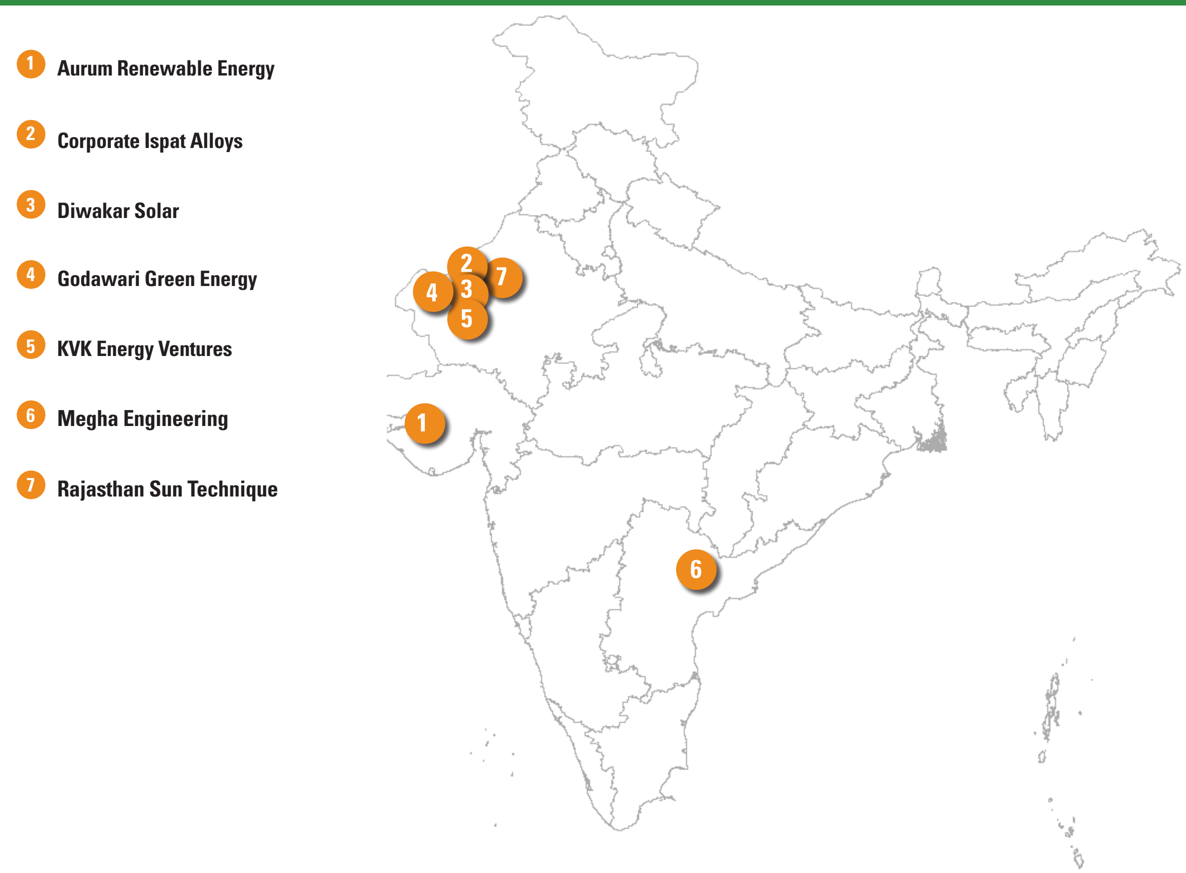
WORK IN PROGRESS:
PHASE 1 CONCENTRATED SOLAR POWER PROJECTS

> *"Different technologies and storage need to be encouraged, but that is currently lost in the race to the bottom structure. If we just let the [current NSM reverse auction] decide, then only cheapest prices will prevail and a huge percentage of power will come from technologies that don't address base-load. Good planning now is important because these are long-term decisions that we will live with later."*
>
> — CEEW and NRDC stakeholder discussion, July 2012[1]

Of the more than 60 CSP bids received during the Mission's inaugural auction, MNRE selected seven projects, totaling 470 MW.[2] MNRE also "migrated" three existing CSP projects of 10 MW each into the NSM with a combined total of 500 MW. The CSP projects' weighted average bid price was ₹11.48/kWh ($0.21/kWh) as compared to the average electricity price of ₹4.70 /kWh ($.09/kWh).[3]

Most stakeholders viewed the 50:50 split allocation between CSP and PV technologies, on a megawatt-capacity, as favorable, deeming the Phase 1 reverse auction process a success. They particularly praised the transparency of the bidding process. Some stakeholders expressed that in addition to the 50:50 technology ratio, additional policy measures could spur innovation in CSP storage technologies.

Figure 2. National Solar Mission Projects Under Development in India



Project timelines and commissioning deadlines remain a challenge for developers. Developers with power plant experience seem to have an advantage in working toward CSP project timelines. By August 2012, all seven Phase 1 CSP projects had broken ground. However, as the projects move toward the May 2013 final commissioning deadline, several developers are experiencing project delays and have requested deadline extensions. Since many of the project developers are large companies with access to significant financial resources, some stakeholders are optimistic that the CSP projects may still be commissioned on time. Yet, attention is needed on multiple fronts. Looking ahead to Phase 2, stakeholders expressed that strong government policies supporting CSP and other solar technologies are critical to grow India's solar energy market.

Based on research and stakeholder discussions, the following key findings on Phase 1 CSP projects have been formulated:

The Mission's Phase 1 technology split supported CSP market growth: Equal project allocation between the two solar technologies played an important part in kick-starting the CSP market. The seven CSP projects include one 20 MW project, three 50 MW projects, and three 100 MW projects. Some stakeholders emphasized that, in order to encourage CSP project growth in the midst of falling PV module prices, both Central and State governments must continue to strongly support CSP technologies. Stakeholders highlighted the long-term benefits of CSP: building base-load sized 100 MW (or larger) clean energy plants, supplying peak load electricity, and developing storable, dispatchable energy infrastructure. One option for Phase 2 polices is to continue with the 50:50 split as has been the case in Phase 1. Alternatively, one stakeholder suggested that Phase 2 could divide the technology allocation into three parts, a third each for PV and CSP, with the remaining third left unallocated to

Table 2: National Solar Mission's Concentrated Solar Power Projects at a Glance

	Project	Promoter	Technology	Size (MW)	Bid (₹/kWh)	Supplier(s)	EPC Contractor	Location	Financing (Lead)
1	**Aurum Renewable Energy**	Aurum	Linear Fresnel	20	12.19	Sumitomo Shin Nippon	Indure	Mitrala, Porbandar, Gujarat	SBI
2	**Corporate Ispat Alloys**	Abhijeet	Parabolic Trough	50	12.24	Siemens turbine & receivers	Shriram EPC	Nokh, Pokaran, Rajasthan	BOI and IOB
3	**Diwakar Solar**	Lanco	Parabolic Trough	100	10.49	Siemens	Lanco Solar & Initec Energía	Askandra, Nachna, Rajasthan	Axis
4	**Godawari Green Energy**	Hira Group	Parabolic Trough	50	12.20	Siemens, Schott Glass, Flabeg, Aalborg	Lauren, Jyoti Structures	Nokh, Pokaran, Rajasthan	Bank of Baroda led consortium
5	**KVK Energy Ventures**	Lanco	Parabolic Trough	100	11.20	Siemens	Lanco Infratech	Askandra, Nachna, Rajasthan	ICICI
6	**Megha Engineering**	Megha Engineering Limited	Parabolic Trough	50	11.31	GE	MEIL Green Power Limited	Anantapur, Andhra Pradesh	IDBI led consortium
7	**Rajasthan Sun Technique**	Reliance	Compact Linear Fresnel	100	11.97	Areva	Reliance Infrastructure	Dahanu, Pokaran, Rajasthan	ADB, US Ex-Im, FMO

See CSP Today, India Map 2012, http://www.csptoday.com/india/pdf/CSP_IndiaMap_V2.pdf (accessed August 21, 2012); Powerbase: Renewable Energy News, "India to scrap duties on solar parts," *Powerbase.in*, http://powerbase.in/india-scrap-duties-solar-parts/ (accessed August 21, 2012); HeliosCSP, "Siemens wins 50mw Concentrating Solar Power Order in India," March 26, 2012, http://www.helioscsp.com/noticia.php?id_not=993 (accessed August 21, 2012); HeliosCSP, "GE, Siemens Win India CSP Orders," January 18, 2012, http://www.helioscsp.com/noticia.php? id_not=888 (accessed August 21, 2012); Natalie Obiko Pearson, "GE, Siemens Win India Solar Turbine Orders to Offset U.S. Slump," *Bloomberg*, January 5, 2012, http://www.bloomberg.com/news/2012-01-06/ge-siemens-win-india-solar-turbine-orders-to-offset-u-s-slump.html (accessed August 21, 2012); Emergent Ventures International, "Summary of Tariff Bidding Process for Solar Projects under NSM," January 2011, http://www.emergent-ventures.com/docs/Summary%20of%20Tariff%20Bidding%20Process%20For%20Solar%20Projects%20under%20NSM.pdf (accessed August 21, 2012); CEEW-NRDC Stakeholder Discussions, June-July 2012.

either technology. A third option is for Phase 2 to adopt an incremental approach to project allocation, which would avoid locking in specific technologies at this early stage. Stakeholders were also keen to see future project allocations at a size that helped to realize economies of scale.

Stronger policy measures are needed to spur transformative CSP technologies: The reverse auction rewarded projects to the lowest bidders, which indirectly discouraged innovative, but potentially more expensive, CSP technologies. Two technologies that give CSP transformative potential are thermal energy storage and dry-cooling (also known as air-cooling). Even though stakeholders expressed keen interest in storage and dry-cooling innovations, none of the Phase 1 CSP plants includes dry-cooling, and only one plant will employ storage technology. Since Phase 1 policies are technology-neutral, developers sought to both maintain low bid prices by excluding higher upfront costs, and avoid jeopardizing commissioning deadlines by adding technological complexity. For further discussion on how to spur innovative CSP technologies, see the Horizon Planning section.

Developers expressed challenges in meeting milestones: The Mission guidelines set out a 28-month timeframe for commissioning CSP projects. A number of project implementation challenges were common to many developers, including land acquisition and a lack of ground-measured direct normal irradiance (DNI) data. Developers also noted commercial risks such as the depreciating rupee, which raised imported equipment costs, and the availability of some components. Apart from these India-specific delays, some international stakeholders found this timeline ambitious to bring CSP projects online even in countries with more experience and available financing.[4]

Several developers have also requested extensions to the project commissioning deadline set by the NTPC Vidyut Vyapar Nigam (NVVN), the agency that signs the power purchase agreements with the developers. However, in order to build market confidence, meeting deadlines is crucial to demonstrate that companies are able to deliver on commitments. Several stakeholders commented that to maintain the Mission's integrity, any exceptions granted by the government must be based on transparent criteria to account for unforeseen disruptions in project commissioning outside of the developer's control. More involvement and planned interventions by the government as delays arise can help keep projects on time and avoid such delays in future phases. Alternatively, some stakeholders proposed that the government could provide incentives to well-performing developers to continue meeting deadlines and reward a positive track record. According to stakeholders, preserving accountability to the government is critical to building investor confidence and the solar energy market.

CONCENTRATED SOLAR POWER'S GLOBAL VIEW

By the end of March 2012, the global installed capacity of CSP plants totaled about 1.9 gigawatts (GW). The majority of operational solar thermal plants are located within just two countries: Spain and the United States.

SPAIN

Spain dominates the total installed CSP capacity, with about 1,330 MW of installed capacity. The Spanish government hopes to obtain 20.8 percent of final energy consumption from renewable sources by 2020, of which 8 GW to 9 GW will be produced by solar power facilities. In January 2012, however, Spain halted all subsidies to newly commissioned plants within the renewable energy sector, which may have a devastating effect on the domestic CSP market.

UNITED STATES

The United States has the second-largest installed CSP capacity, with more than 518 MW of CSP power installed and an additional 1,300 MW planned as of March 2012. Although the federal government has not set any national solar targets, the state of California launched the California Solar Initiative (CSI) in 2007, aiming to install 1,940 MW of new solar power and create a sustainable solar industry by 2016. In January 2010, California also established a specific CSI-Thermal Program that attempts to facilitate market transformation through declining incentive rates, focusing on solar water heaters.

CHINA

A more recent entrant to the CSP field, China is rapidly expanding its CSP installations. China is projected to install 1,000 MW of CSP capacity by 2015, and 3 GW by 2020. Additionally, the country is planning to construct at least two mega-CSP plants—a 1,000 MW project in Qinghai by Lion International Investment Ltd., and a 2,000 MW project in Shaanxi by Shandong Penglai Dianli and eSolar.

See IRENA CSP Cost Report at 11; Renewable Energy Policy Network for the 21st Century, *Renewables 2011: Global Status Report*, (2011), http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf; *Who's Winning the Clean Energy Race*, The Pew Charitable Trusts (2011), http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Clean_Energy/Clean%20Energy%20Race%20Report%202012.pdf; CA Public Utilities Code § 2851, enacted by Senate Bill (SB) 1 (Murray), Chapter 132, Statutes of 2006; CA Public Utilities Comm., D.10-01-022 (2010); PG&E, *California Solar Initiative Thermal Program Quarterly Progress Report: April 1 – June 30, 2012*, August 15, 2012. See also, Zachary Shahan, "Concentrating Solar Power Alliance Launched," CleanTechnica.com, March 12, 2012, http://cleantechnica.com/2012/03/12/concentrating-solar-power-alliance-launched/; Zachary Shahan, "China to Have 3 GW of Concentrated Solar Thermal Power (CSP) by 2020," CleanTechnica.com, March 30, 2012, http://cleantechnica.com/2012/03/30/china-to-have-3-gw-of-concentrated-solar-thermal-power-csp-by-2020/; Steve Johnson, "Investors may walk after Spain's solar cut," *Financial Times*, January 9, 2012, http://www.ft.com/intl/cms/s/0/a2982e50-1a95-11e0-b100 00144feab49a.html#axzz1wZOfKnXV; Sile McMahon, "Spain backtracks on solar subsidies as €24 billion debt looms," PV-Tech, January 30, 2012, http://www.pv-tech.org/news/spain_backtracks_on_solar_subsidies_as_24_billion_debt_looms (all referenced reports and articles last accessed August 21, 2012).

Grid-connected CSP project currently being constructed under the NSM. Photo used with permission.

Looking ahead to Phase 2, stakeholders highlighted key market development challenges that must be analyzed and addressed to avoid project delays and increase investor confidence to help the CSP market in India grow:

Limited solar irradiance data: Some Phase 1 projects experienced delays and higher costs because developers needed to re-design project systems that were initially based on imprecise assessments from satellite data. Developers have now modified these Phase 1 projects and are working to meet commissioning deadlines. For Phase 2, several stakeholders suggested that a coordinated discussion is needed to target additional solutions for DNI data availability and suitability in order to improve project design, meet timeframes, and build market confidence.

Lack of trained technicians to build CSP projects: Some developers struggled to find a sufficient number of adequately trained technicians with fabrication and welding skills for CSP projects. The limited technical workforce slowed some projects. Yet, other stakeholders viewed the sizeable Indian workforce with its transferable skills as a key strength with tremendous potential. For example, engineers with power project development experience are retraining to work on CSP projects. Stakeholders suggested developing focused plans to increase training as the solar market develops.

Financiers' unfamiliarity with CSP: Project developers have struggled to achieve financial closure, a key milestone under the Mission's guidelines. Although familiarity with solar (and CSP) is increasing, the involvement of banks and other financial institutions is hindered by structural issues (including power sector lending limits, financially stressed distribution companies and their resulting inability to pay for purchased power) and practical challenges (market awareness and technological understanding).

Short supply of key CSP components: Escalating prices and limited supplies of heat transfer fluid (HTF) have posed challenges to developers. Long lead-times and an inability by manufacturers to commit to a firm HTF delivery schedule have added to the uncertainty over commissioning projects.[4] Several developers also experienced delays from long lead times for CSP-specific turbines. While India has a turbine manufacturing base, Indian-made turbines are not designed for CSP specifications, which require turbines to be able to operate intermittently. Only three international turbine suppliers, Siemens, GE and Areva, were used for Phase 1 projects (table 2). Stakeholders agreed that the limited supply of these components needs to be addressed while preparing for Phase 2 of the Mission.

Power plant development experience is proving valuable: Successful Phase 1 bidders include large companies with experience in building power plants, such as Abhijeet, Godawari, Lanco, and Reliance. This experience is proving valuable, especially since CSP power-block structures are similar to thermal coal-fired power plants. Across the Mission, less experienced developers new to the power industry have struggled to get projects off the ground. The Phase 1 guidelines require developers to at least work with experienced technology providers, but do not apply any rigid criteria regarding experience in CSP project development.

Recommendations

- **MNRE should ensure that Phase 2 policies continue to encourage CSP technologies along with other solar technologies.** CSP offers unique attributes to India's energy mix, including supplementing base-load requirements, supplying peak-load electricity, and ensuring grid stability. MNRE could explore three options for Phase 2: 1) continue fostering both technologies through the Phase 1 50:50 split; 2) divide the technology allocation into three parts, a third each for PV and CSP, with the remaining third unallocated and technology neutral for any solar technology; or 3) allocate 1,500 MW initially in Phase 2 (rather than the entire 3,000 MW target), mitigating some of the risk associated with supporting CSP technologies and offering more information for a mid-term review of Phase 2. If insufficient progress is found, then Phase 2's second allocation could be technology neutral. This incremental approach could help establish a clearer roadmap for the development of the solar market, without locking into technologies.
- **The government should enforce commissioning timelines for Phase 1 projects to avoid setting a precedent of leniency on delays.** Looking ahead, MNRE should increase involvement during the project commissioning process to independently analyze the root causes of commissioning delays on a quarterly basis, and determine which unforeseeable delays merit extensions. Such planned interventions can help avoid such delays during Phase 2.
- **The Solar Energy Corporation of India (SECI) should establish a sub-committee** to formulate and implement best practices to overcome commissioning delays, incorporating feedback from all stakeholders.
- **MNRE should ensure that Phase 2 guidelines strike a balance between encouraging new players to participate and attracting experienced developers** by maintaining the requirement that selected developers work with experienced technology providers.

[1] CEEW-NRDC Stakeholder Discussions, June-July 2012.

[2] See Ricki Stancich, "CSP project finance strategy: Funding India's Phase 1 CSP projects," *CSP Today,* February 11, 2011, http://social.csptoday.com/markets/csp-project-finance-strategy-funding-india%E2%80%99s-phase-1-csp-projects (accessed August 21, 2012). Due to longer construction time, only one auction was held for CSP during Batch I of Phase 1, whereas PV was divided into two batches during Phase 1.

[3] KPMG-India, "The Rising Sun: A Point of View on the Solar Energy Sector in India," May 2011: www.kpmg.com/IN/en/IssuesAndInsights/ThoughtLeadership/The_Rising_Sun_full.pdf (accessed August 21, 2012).

[4] In California, for example, the large 370 MW Ivanpah solar thermal project is on a 36 month development track, having broken ground in October 2010 and aiming a 2013 completion date. Projects like Ivanpah are generally bigger than the NSM projects, however, and involve lengthy environmental mitigation efforts to protect habitat. See Ivanpah News Releases, "Ivanpah Solar Project meets halfway mark and peak of construction employment," August 6, 2012, http://ivanpahsolar.com/news-releases (accessed August 20, 2012).

ATTRACTING INVESTMENT: RESOURCE ASSESSMENT AND FINANCE

> *"If solar is going to take off here [in India], the commercial banks are going to have to do the heavy lifting."*
>
> —Michael Barrow, director of infrastructure finance, Asian Development Bank[1]

The burgeoning CSP market in India, like the PV market, depends on access to low-cost domestic financing to continue growing at a healthy rate. The Asian Development Bank estimates around ₹17,000 crore (approximately $3.1 billion) in debt financing would be needed over the next three years to complete all projects that have been announced already.[2] While domestic financiers have shown a general reluctance to fund solar projects, projects employing CSP technology are considered even riskier.[3] Financiers are specifically concerned with CSP's relatively unproven technology, inexperienced players, lack of implementation track record, and inaccurate ground-based solar irradiation data. For the Mission to scale up as quickly as MNRE expects, a concerted effort to reduce barriers to solar finance is required. Market confidence in predicted plant operation and efficiency will take time to build. Information sharing can build awareness and assuage financiers' concerns. Additionally, enforcing renewable purchase obligations (RPOs) are as critical to a flourishing CSP ecosystem as they are to the rest of the renewable energy market.

Grid-connected CSP project currently being constructed under the NSM. Photo used with permission.

Based on research and stakeholder discussions, we have formulated the following key findings about CSP projects' bankability under the NSM:

Bankers want to see a CSP project track record in India: As is the case for most emerging energy technologies, risk-averse financiers have expressed low levels of familiarity and a discomfort with CSP technology that can only be resolved when a consistent performance record develops.[4] For example, reports that PV plants are running at high efficiency rates have started to bolster banker confidence in solar PV technologies.[5] The majority of CSP projects in India employ parabolic trough technology, used by more than 80 percent of international CSP projects with a track record of more than 20 years.[6] Despite a record of CSP performance globally, investors want to see a track record of CSP projects in India.[7] Even as a credible performance record takes time to develop domestically, many bankers recognize the need for third-party expertise and increased information sharing to increase familiarity with CSP technologies.

Non-recourse project finance is unavailable, but vital to CSP growth: CSP developers reported securing financing only after parent companies furnished corporate guarantees. No CSP plant under the Mission has been financed on a non-recourse basis.[8] Banking in India is heavily based on prior strong relationships, particularly in this growing market.[9] However, stakeholders reiterated the importance of non-recourse finance to ensure growth of the CSP sector. In order to meet ambitious solar implementation targets and encourage sector participation by smaller companies, the government must help to ensure non-recourse lending develops.

Endemic power sector issues affect CSP investment: Banks are approaching lending limits for the entire power sector, and lenders are unwilling to increase their exposure to the sector. New coal-fired thermal power plants are also having trouble attracting financing as they struggle to obtain coal to run their plants.[10] These sector lending limits, along with increased competition for power sector financing, are bottlenecks to financing renewable energy projects in particular.

Loan syndication is broadening the lender base for solar projects: When financing CSP projects, a bank will generally take on 25 percent of the project's debt and share the remaining debt and risk among other participating banks. This loan syndication has led to the involvement of a wide range of banks in the Mission's CSP projects to date, including the Power Finance Corporation, Bank of Baroda-Dubai, Punjab National Bank, and State Bank of Bikaner and Jaipur.[11] Syndication helps filter a deeper understanding of the solar sector through to the rest of the banking system and broaden the set of banks willing to invest in solar projects.

Inexperience and over-reliance on poor quality DNI has reduced investor confidence: Raising finance from a range of sources depends on building confidence in the CSP market. A key indicator of commercial viability is the amount of power generated by a plant—data that cannot be confirmed until a performance record develops. A project's expected power output is forecast in part using solar irradiance data from the project site. CSP projects need information on direct normal irradiance, rather than global irradiance data that PV plants rely upon. DNI suffers from more natural variability than global irradiance.

In the Mission's early days, some developers failed to anticipate errors and uncertainty inherent in the limited DNI data available to them. Developers extrapolated satellite data to project site locations using ground-based stations—also limited in number—despite such stations being located as far as a few hundred kilometers away from actual project sites.[12] As a result, some CSP developers and potential financiers share concerns of inaccurate pre-bid assessments of solar irradiation. Lenders consequently worry that selected projects might fail to deliver the expected power output, and thereby not have the cash flows necessary to pay off loans.

DNI issues are exacerbated by aerosols: Poor DNI data is compounded by a lack of sufficient ground-level data on aerosols (including dust, sand, and other airborne particles), which further reduce the available DNI.[13] As a result, some Phase 1 projects had flawed solar resource data at the bidding stage. For instance, in Rajasthan, where five out of the seven CSP projects under the NSM are located, frequent sandstorms and prevalent dust conditions have significantly impacted projects within the state.[14] For some projects, subsequent ground measurements carried out after the reverse auction deviated from initial estimates by as much as 20 percent.[15] These projects now face escalating costs as plants are redesigned to increase the size of the solar field due to aerosol issues.

MNRE and C-WET are addressing the irradiance data gaps: MNRE has taken steps to improve assessments of DNI. The Centre for Wind Energy Technology (C-WET), an autonomous research and development (R&D) institution established by MNRE, implemented 51 solar radiation resource assessment stations across the country between May and September 2011.[16] These MNRE C-WET stations collect high-quality solar irradiance data at 10-minute intervals and data from the newly-installed stations' first year of operation are available to project developers for a fee.[17] An additional 60 stations will be installed in the near future, increasing the DNI data available as the Mission enters Phase 2.

Solar investment depends on a strong RECs market: A thriving market for renewable energy certificates (RECs) is crucial to spur investment in renewable energy, including solar. Trading RECs to meet renewable purchase obligations (RPOs) is slowly gaining traction with more than 10 percent of the total installed capacity of renewable energy sources registered with the REC scheme as of August 2012.[18] As the RECs market continues to develop, long-term signals such as extending the REC timeframe from the current 5-year timeline to match project cash flows are needed to increase reliance upon RECs as a source of project income.

Enforcing RPOs is necessary to meet NSM targets: The NSM will directly drive implementation of at least 3,000 MW of solar power. But meeting the remaining 6,000 MW target contemplated under Phase 2 requires stricter enforcement of RPOs, in addition to robust state-specific initiatives. Making a state's receipt of central funding contingent on having RPO enforcement policies in place could help achieve this goal. With a rapidly increasing supply of RECs, ensuring that public utilities and state electricity distribution companies meet RPO targets, and thereby create the demand for RECs, is central to guaranteeing cost-effective project implementation and increasing the purchase of solar power.[19]

Recommendations

- **In order to attract investment, MNRE should coordinate stakeholders to develop strategies to encourage non-recourse project financing**, such as government-backed loan guarantees; work with the Indian Banks' Association (IBA) to share information on the developing CSP market track record; and empanel engineers with CSP technical knowledge as trusted advisors to financiers.
- **The Solar Energy Corporation of India (SECI) should facilitate a set of detailed case studies about key CSP projects highlighting financial viability and loan syndication.** SECI and the IBA should then disseminate such syndication experiences to encourage new players, including additional developers and financiers, and existing players to increase their participation in the solar market.
- **MNRE should continue to facilitate collection of direct normal irradiance (DNI) data and mandate data sharing by project developers**, as set forth under MNRE guidelines. SECI should independently collect and verify this information on a regular basis to supplement data collected by MNRE's own ground-based weather stations, and build up confidence in the accuracy of DNI data.
- **The Indian government should continue to analyze effective approaches to enforcement of RPOs and development of a RECs market.** A thriving REC market will foster greater investment in solar projects and allow for a variety of technologies and business models to be implemented. The central government should consider requiring states to develop RPO enforcement policies prior to receiving central funds.

1 Natalie Obiko Pearson, "Indian Banks Exposure to Coal Limits Lending to Solar, SBI Says," *Bloomberg*, April 25, 2012, http://www.bloomberg.com/news/2012-04-26/indian-banks-exposure-to-coal-limits-lending-to-solar-sbi-says.html (accessed August 21, 2012).

2 See Pearson Solar Setback Article.

3 CEEW-NRDC Stakeholder Discussions, June-July 2012.

4 See id.

5 See id.

6 Stewart Taggart, "Parabolic troughs: Concentrating Solar Power (CSP)'s quiet achiever," *Renewable Energy Focus*, April 2008, http://www.renewableenergyfocus.com/view/3390/parabolic-troughs-concentrating-solar-power-csp-s-quiet-achiever/ (accessed August 16, 2012).

7 See IRENA CSP Cost Report.

8 Off-balance sheet financing does not give the lender recourse to the developer's other assets in lieu of non-payment of loan obligations. See CEEW-NRDC Stakeholder Discussions, June-July 2012.

9 CEEW-NRDC Stakeholder Discussions, June-July 2012.

10 Sarita C. Singh, "Lack of coal, reforms & funds may lead India's power sector into crisis," *Economic Times*, June 1, 2011, http://articles.economictimes.indiatimes.com/2011-06-01/news/29608610_1_power-sector-power-companies-power-generation (accessed August 21, 2012).

11 See id.

12 CEEW-NRDC Stakeholder Discussions, June-July 2012.

13 DNI can be measured on the ground or from satellite data, but while clouds are easy to recognize from satellite data, it is difficult to distinguish sandstorms from the ground underneath. Sandstorms severely impact available DNI, necessitating ground-level aerosol measurement in addition to satellite data. See CSP Today, "Technical Top Tip: Solar Resource Assessment," www.csptoday.com/india/pdf/suntrace2.pdf (accessed August 21, 2012).

14 CEEW-NRDC Stakeholder Discussions, June-July 2012.

15 Conversely, one developer with a project under the Gujarat state policy reported that this issue was virtually non-existent for their site. See CEEW-NRDC Stakeholder Discussions, June-July 2012.

16 Centre for Wind Energy Technology, "Solar Radiation Resource Assessment," http://www.cwet.tn.nic.in/html/departments_srra.html (accessed August 21, 2012); CEEW-NRDC Stakeholder Discussions, June-July 2012.

17 "Solar Data Sharing and Accessibility Policy (SDSAP-2012)," CWET, http://www.cwet.tn.nic.in/html/srra.html (accessed August 22, 2012).

18 On August 5, 2012, 2,913 MW out of the total 25,409 MW of renewable energy sources was registered with the REC scheme. See Manu P. Toms, "Renewable energy trade picks up speed in India," *Hindustan Times*, August 5, 2012, http://www.hindustantimes.com/India-news/Mumbai/Renewable-energy-trade-picks-up-speed-in-India/Article1-908772.aspx (accessed August 21, 2012).

19 See id.

HORIZON PLANNING: SUSTAINABLE TECHNOLOGY CHOICES

> *"In order to fully realize our potential in the realm of solar energy, solar thermal projects need encouragement."*
>
> —Pranab Mukherjee, India's current president and former finance minister[1]

Drawing on Phase 1 experiences, India can develop a robust domestic CSP industry—but key barriers remain. Discussions with CSP stakeholders focused on five areas for driving sustainable CSP technology choices: 1) domestic manufacturing; 2) storage to create uninterrupted power opportunities; 3) hybridization with base-load capacity; 4) availability of heat transfer fluid and turbines; and 5) water use and availability.

Based on research and stakeholder discussions, we have formulated the following key findings on horizon planning for CSP projects under the NSM:

Initial successes in creating a domestic CSP industry: In order to develop a domestic solar manufacturing base, Phase 1 of the NSM includes a domestic content requirement (DCR) for CSP projects. For NSM Batch 1 CSP projects, the MNRE guidelines mandated a cost-based measure of "30 percent of local content in all plants/installations," excluding land.[2] As long as such DCR measures do not discriminate between Indian and foreign firms, and are geared towards servicing the domestic market for increased energy access, there is a lower chance of these measures being challenged at the World Trade Organization.[3]

While challenges exist, several CSP developers found the DCR achievable for CSP projects in India for two primary reasons.[4] First, the relatively broad definition of "content" in the DCR includes both labor and equipment that was manufactured in India, even if the company is foreign-owned.[5] For example, the steel construction, pylons, and foundations of a parabolic trough system constitute more than 30 percent of its total cost.[6] Other technologies may use even more domestic content. For example, the tower and boiler of a power tower can be constructed on-site. Additionally, both power towers and linear Fresnel collectors use flat mirrors, which can be simpler than the curved mirrors typically used for parabolic trough collectors and could likely be sourced domestically.[7]

Secondly, a large proportion of CSP equipment production requires minimal workforce training.[8] In addition to cheaper, trainable labor and lower costs of sourcing simple components locally, many of the components of a CSP plant's power block are similar to thermal power plants, where domestic manufacturing expertise already exists. India has a thriving industry focused on the manufacture of steel, power components, control systems, and civil construction, all of which are inputs for a CSP project. As the CSP market develops, Indian manufacturers have an opportunity to step into the industry, promote cost reduction and localization, and also cater to the global market.

Developing domestic manufacturing capacity in a new area such as solar energy requires a medium- to long-term outlook and foreseeable market demand. Some local players, such as Cargo Power, operating under Gujarat's state initiative, have established a facility to manufacture tempered mirrors using raw glass as input.[9] The company plans to use these components to supply to its own CSP project and meet export demand.[10] Other areas where domestic manufacturers can enter the market include manufacture of heat transfer fluids and hydraulic drives. Developers and local manufacturers expressed confidence that the manufacture of increasingly complex CSP components would become possible in India as the market develops. One developer decided to have the entire solar frame structure manufactured in India. Another developer saw no reason why 80 percent to 90 percent of the CSP plant components could not eventually be locally sourced.[11]

Despite this initial success, many key CSP components do not have a local manufacturing base yet.[12] According to project developers, turbines, generators, evacuated tubes, and hydraulic drives have all been hard to source locally.[13] Projects under the NSM and state missions have imported these components from China, Spain, Germany, and the United States.

The CSP industry offers many avenues for efficiency improvement and cost reduction via research and development, technology transfer, and application engineering. Key areas of focus include molten salts for storage and heat transfer fluids.

CSP storage presents an opportunity for 24-hour clean energy power supply, at a price: Using CSP, storage of solar thermal energy in the form of heat costs less and is more efficient than electrical storage of electricity generated by wind and solar PV systems.[14] Using materials such as molten salt to store thermal energy costs ₹2,200 to ₹3,960 ($40 to $72) per kWh capacity, giving CSP a significant advantage to other energy storage alternatives, though making storage expensive overall.

With storage, a CSP plant's capital cost increases as the size of its solar field expands. However, capacity utilization—the amount of electricity produced—also increases and can even double. [15] As a result, the levelized cost of electricity for a CSP plant with storage remains largely flat or increases slightly as compared to a plant without storage.[16] CSP with storage can play a unique role in the country's energy mix by acting as a dispatchable renewable energy source, helping address India's electricity demand.[17]

Within a typical storage system for a parabolic trough system, salt is currently the most expensive component and constitutes about half the cost. The heat-proof and insulated tanks for storage are another quarter of the system costs.[18] Significant opportunities exist to optimize components of the storage system for efficiency and cost. Tower technology is more efficient and requires less salt, allowing further cost reduction in storage. Some stakeholders suggested that Phase 2 of the Mission should focus on R&D for storage to create an enabling environment for CSP projects.

Opportunities for hybridization of existing fossil fuel and biomass plants: CSP plants can be combined with new or existing conventional coal or gas plants, thermal industrial systems, or with renewable sources such as biomass. These steam generation plants share the basic power block infrastructure of a CSP plant, including the steam turbine generator. The addition of CSP can effectively increase the fuel efficiency of the hybridized or retrofitted plant for each unit of electricity generation. Hybrid plants also provide dispatchable electricity that can be supplied continuously and reduce emissions by lowering fossil fuel use. Hybridization of CSP with biomass plants (so long as the latter draw on sustainably produced or sourced biomass) would produce an almost entirely renewable and dispatchable source of energy. Some stakeholders suggested that Phase 2 policies should encourage hybrid base-load plants. Currently MNRE (along with support from organizations such as the Asian Development Bank) is exploring establishing demonstration projects that cover a variety of technologies, including hybridization and dry cooling.[19]

DECENTRALIZED SOLAR THERMAL: AN OPPORTUNITY FOR BROAD APPLICATION

In addition to its application for grid-scale utility projects, concentrated solar thermal technologies can provide electricity, heating, and cooling for a range of decentralized applications. Two key areas where solar thermal can be easily incorporated into existing requirements are the use of solar heat in industry and for small- and medium-scale distributed energy generation. As domestic experience of solar thermal technologies evolves, these applications can supplement the grid-scale electricity generation application of CSP. India has a large manufacturing base for low-cost, low-capacity turbines, but these turbines must be modified for solar use. Local manufacturers can target industry and distributed generation applications and, in the process, achieve the economies of scale required to progress along the technology's learning curve. Many of these applications are simpler to deploy and provide a stepping stone to domestic CSP manufacturing as local firms widen their product portfolios to address a range of applications with CSP.

PROCESS APPLICATIONS

Heat produced from solar energy can be used in several industry applications. Key characteristics that make an industry a good candidate for solar thermal applications include: high energy requirement, significant fraction of energy consumption for cooling/heating, and use of low-grade process heat for drying and water heating. A recent analysis by GiZ and MNRE identified the textiles, pulp and paper, and pharmaceutical industries as having the largest potential for savings from the use of a combination of solar technologies (i.e., PV, solar thermal, and concentrated solar).

DISTRIBUTED CSP

Small CSP systems deployed in remote or weakly interconnected grid locations can address a wide range of applications. Locations that have the advantage of readily available biomass (e.g., animal residue) can use biogas hybridization. Combining two or more applications in one system has the benefit of utilizing a larger fraction of available solar energy, resulting in higher efficiency and reduced average cost of energy. Some of these technologies are currently being piloted for specific applications in parts of India. For example, Thermax, an Indian engineering company, is piloting a hybrid solar cooling system that uses biomass backup and can be used for off-grid cold storage application.

Other applications such as dairy, agro-malls, and desalination could benefit from CSP due to their energy demand profile and remote location. Thermax's activities are a good example of application engineering that would help CSP and solar thermal technologies address gaps where existing solutions are inefficient, unavailable, or simply do not exist.

Another key challenge to scaling up CSP in distributed and off-grid applications is the development of new business models. Policy interventions are needed as part of the NSM to drive growth in these segments. An international policy initiative that could be emulated in India is Germany's Renewable Energies Heat Act, introduced in 2009, which makes the use of renewable energy mandatory for space and water heating in new buildings.

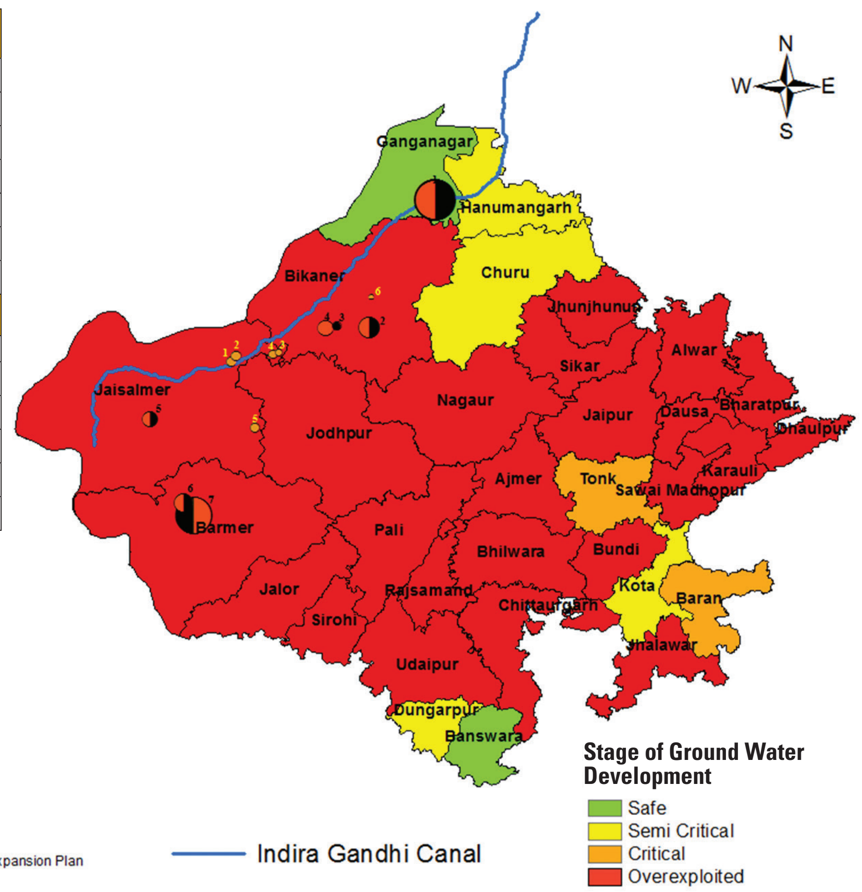
See GiZ, PWC, "Identification of Industrial Sectors Promising for Commercialization of Solar Energy," December 2011, http://www.giz.de/Themen/en/SID-1D38E17B-919FFF8C/dokumente/giz2011-commercialisation-solar-energy-india-en.pdf, (accessed August 22, 2012); Thermax website, "What's New: R&D Projects," http://thermaxindia.com/Solar-Power-Business-Solutions/Whats-New.aspx (accessed August 22, 2012); "Act on the Promotion of Renewable Energies in the Heat Sector" (a.k.a. the Heat Act or EEWärmeG), enacted January 1, 2009, http://www.erneuerbare-energien.de/doc/42351.php (accessed August 22, 2012);CEEW-NRDC Stakeholder Discussions, June-July 2012.

Heat transfer fluid availability has been a bottleneck for trough technology, but is also an avenue for local research and development: The low availability of heat transfer fluid (HTF) has plagued CSP parabolic trough projects in India where project designs have specifically required an oil-based heat transfer fluid. Dow Chemicals or Solutia (now a subsidiary of Eastman Chemical Company), the only companies with a track record of supplying HTF for CSP application, have supplied the HTF used by all but one of the Indian CSP plants to date.[20] A number of stakeholders were concerned about HTF prices, already at ₹385,000 ($7,000) per ton, and having risen almost 50 percent in only a few years.[21] One developer had ordered HTF from Lanxess, a German specialty chemicals manufacturer, representing a break from the effective duopoly of the two major suppliers. Another developer reported that issues of HTF supply had significantly influenced their technology choice, encouraging them to choose steam-based linear Fresnel technology that avoids the use of oil-based HTF. Rapidly escalating HTF prices and the impact on the projects demonstrate that HTF is a strong candidate for R&D interventions to reduce costs. Other HTFs such as mineral oil are also available, but such solutions currently reduce performance. Local oil companies, including Indian Oil Corporation and Bharat Petroleum, are working to find local solutions for HTFs.

Water efficient technology options are available, but need to be encouraged: If the NSM meets its target of 20 GW of solar by 2022, with 30 percent of the total solar capacity drawn from CSP, the water requirement from CSP plants using water cooled systems will be 36.2 million cubic meters per year, equivalent to the water requirement for 736,000 Indians per day.[22] Lack of water supply has already resulted in occasional shutdowns for coal-based plants, and CSP plants under the NSM will be susceptible to this water stress as well.[23] Regions rich in DNI resource—the most suitable locations for CSP generation—are frequently arid with limited water supply, such as Rajasthan, where five of the seven NSM CSP projects are located. These projects rely on the Indira Gandhi Canal

Figure 3. Power Plants and Ground Water Availability in Rajasthan

	Plant	Present MW	Proposed MW	Cusec
1	Suratgarth Super Thermal Power Plant	1500	1320	100
2	Barsingsar Thermal Power Plant	250	250	45
3	KSK Energy Ventures	135	Nil	13.5
4	Bithnok Thermal Power Plant	Nil	250	25
5	Ramgarh Gas Thermal Power Plant	113.5	160	25
6	Giral Lignite Thermal Power Plant	250	250	24
7	JSW Lignite Power Plant	1080	Nil	80
	SOLAR THERMAL POWER PLANTS			
1	Dikwakar Solar Projects Pvt Ltd	Nil	100	2.9
2	KVK Energy Ventures Pvt Ltd	Nil	100	2.9
3	Godawari Green Energy Ltd	Nil	50	1.6
4	Corporate Ispat Alloys Ltd	Nil	50	2.02
5	Rajasthan Sun Technique Energy Pvt Ltd	Nil	100	2.5
6	ACME Solar Thermal Power Plant	10	Nil	0.8



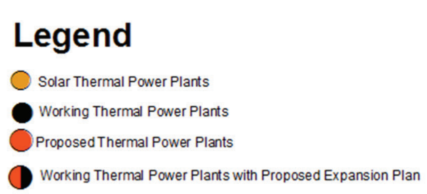


Table 3: Water Efficient Condenser Cooling Technologies			
	Wet	**Hybrid**	**Dry**
Working Mechanism	■ Uses cooling water for cooling steam in condensers ■ Evaporative cooling tower dissipates heat from water	■ Uses air or water for cooling condensers depending on ambient conditions	■ Uses air to directly cool steam in condenser
Typical Technology	■ Once-through ■ Closed-cycle	■ Hybrid cooling	■ Direct dry cooling ■ Indirect dry cooling
Water Consumption	■ Parabolic Trough and Linear Fresnel plants use approximately 3,000 liters/MWh ■ Central Receiver type CSP uses less water	■ Up to 50% of wet cooled system	■ 300 liters/MWh, or 10% of wet cooling for parabolic trough CSP
Impact on Production (relative to wet cooled)	■ N/A	■ Up to 1% production loss compared to a wet cooled system	■ Up to 7% production loss compared to a wet cooled system ■ Loss is lower with solar tower technology
Impact on Cost (relative to wet cooled)	■ N/A ■ High maintenance and cleaning requirement ■ Effluent treatment requirement	■ Increase in LCOE less than that for dry cooling ■ Increased capital cost ■ Maintains consistent performance during hot weather ■ More complicated system involving wet and dry cooling ■ Shares disadvantages of wet system to a lesser extent	■ Approximately 8 percent to 9 percent increase in levelized cost of electricity produced, depending on technology ■ Captive power usage for air cooling fans ■ Greater loss of efficiency on hotter days

Note that cooling for conventional coal or nuclear power plants can be done using a once-through, or closed-cycle type cooling system. A once-through type cooling system uses circulating seawater to dissipate heat to the water body. Once-through type cooling using a fresh water source is prohibited via an MOEF stipulation dated January 2, 1999. See "Environment (Protection) (Second Amendment) Rules, 1998", Ministry Of Environment and Forests Notification, December 22, 1998, serial number 84, pp 5, www.moef.nic.in/legis/noise/gsr7.doc (accessed August 22, 2012). A study carried out by the central electricity authority (CEA) in 2009-10 to evaluate the potential for dry cooling as an alternative to reduce water consumption by power plants found that dry cooling can cause an increase in base tariff by 8 percent to 9 percent. The committee constituted of members drawn from BHEL, NTPC, MAHAGENCO, and other stakeholders found that dry cooling reduces plant output by 7 percent, and causes an increase in power consumption by 0.2 percent to 0.3 percent as a percentage of gross power production. See CEA Water Requirement of Coal Report. See also, NREL, "NREL and Contractor Aim to Reduce Water Use in CSP Plants," April 4, 2011, http://www.nrel.gov/csp/news/2011/958.html (accessed August 21, 2012); GEI Industrial Systems, Ltd, "Air Cooled Steam Condensers,"www.geiind.com/acsc.php (accessed August 1, 2012).

as their source of water and water supply shortages present a key risk to power generation. Figure 3 shows the five CSP plants and existing and proposed thermal plants that rely on the Indira Gandhi Canal for water.

Water-cooled CSP systems are more efficient in converting solar energy to electricity. However, they have significantly higher water consumption compared to plants that use other cooling technologies, such as dry cooling.[24] In areas where water is in short supply, less efficient air-cooled systems or hybrid systems that reduce water consumption significantly could be employed (table 3 lists various cooling technology choices). Some stakeholders noted that government policies should address water-efficiency in Phase 2 of the Solar Mission, particularly since industrialization, urbanization, agriculture needs, and food security will lead to increased competition for water resources.[25] Some stakeholders advocated for government policies to encourage water-efficient technologies for electricity generation from coal, nuclear, and CSP technologies alike.

Recommendations

- **In order to encourage a domestic CSP industry, the Indian government should:** maintain a domestic content requirement or consider other support mechanisms such as non-discriminatory equipment production subsidies for Phase 2; foster R&D collaboration and innovation to encourage domestic production and cost reductions in a growing CSP industry; and consider employing support measures such as production subsidies to encourage CSP manufacturers to establish facilities in India.
- **MNRE should incentivize the adoption of storage technologies in CSP plants and evaluate mechanisms to spur storage-enabled generation**, such as: carving out CSP projects with storage under the NSM; or longer NSM commissioning timelines for projects with storage.
- **MNRE should assess opportunities for hybrid CSP base-load plants** with sustainably-produced biomass and other fuels and develop policy guidelines to encourage such projects.
- **By providing incentives like tariff premiums, MNRE should encourage water-efficient technologies in CSP plants**, including dry-cooled and hybrid systems, and use of treated wastewater.

1 "Concentrated Solar Power in India," *Solar India*, March 28, 2012, http://thesolarindia.com/article/concentrated-solar-power-in-india/ (accessed August 22, 2012).

2 MNRE, "Jawaharlal Nehru National Solar Mission Guidelines for Selection of New Grid-Connected Solar Power Projects," July 25, 2010, mnre.gov.in/file-manager/UserFiles/jnnsm_gridconnected_25072010.pdf ("NSM Phase 1 Guidelines," accessed August 21, 2012).; see also, PWC, "Financial Engineering as a Means to Support Jawaharlal Nehru National Solar Mission," April 2012 at 9, http://www.indiaenvironmentportal.org.in/files/file/final%20report_pwc.pdf (accessed August 21, 2012).

3 Arunabha Ghosh with Himani Gangania, "Governing Clean Energy Subsidies: What, Why, and How Legal?" *International Centre for Trade and Sustainable Development* (August 2012).

4 South Asia Energy Unit, Sustainable Development Department, "Report on Barriers for Solar Power Development in India," World Bank, 2010, at 13, http://www.esmap.org/esmap/sites/esmap.org/files/The%20World%20Bank_Barriers%20for%20Solar%20Power%20Development%20in%20India%20Report_Final.pdf (accessed August 21, 2012); CEEW-NRDC Stakeholder Discussions, June 2012.

5 See NSM Phase 1 Guidelines at 13.

6 See IRENA CSP Cost Report at 17.

7 CEEW-NRDC Stakeholder Discussions, June-July 2012.

8 See id.

9 Thermosol Glass Limited Company Website, http://www.thermosolglass.com (accessed August 21, 2012).

10 CEEW-NRDC Stakeholder Discussions, June-July 2012.

11 See id.

12 Bridge to India, "Solar Thermal Will Now be Exempt from Import Duty in India," http://www.bridgetoindia.com/blog/?p=155 (accessed August 10, 2012, Geneva).

13 CEEW-NRDC Stakeholder Discussions, June-July 2012.

14 Storage materials such as flywheels, batteries, and pumped air or hydro can range from ₹55,000 to ₹165,000 ($1,000 to $3,000) per kWh capacity. Atoni Gil, et al, "State of the art on high-temperature thermal energy storage for power generation, Part 2 – Case Studies," *Renewable and Sustainable Energy Reviews*, 2010;14(56–72). doi:10.1016/j.rser.2009.07.035.

15 See NREL CSP Report; Brian Fan, Robert Murphy, and Joshua Mayer, *Technology Innovation Report: Concentrated Solar Thermal*, Cleantech Group LLC, 2008.

16 Levelized cost of electricity (LCOE) is the amortized price at which a plant generates electricity over its lifetime, including cost of equipment, installation, operations and maintenance, and finance. For a solar thermal plant with storage, LCOE depends on the size of the solar field, amount of storage, and the solar resource. See "Potential for Renewable Energy in the San Diego Region August 2005," San Diego Renewable Energy Study Group, 2005, at 30-31, http://www.renewablesg.org/docs/Web/Renewable_Study_AUG2005_v4.pdf, (accessed August 21, 2012).

17 See IEA India Electricity Report.

18 See IRENA CSP Cost Report at 25.

19 Asian Development Bank, "Support to Jawaharlal Nehru National Solar Mission: India," http://pid.adb.org/pid/TaView.htm?projNo=45380&seqNo=01&typeCd=2 (accessed August 21, 2012).

20 CEEW-NRDC Stakeholder Discussions, June-July 2012.

21 See id.

22 Assuming CSP water consumption of 3,000 liters/MWh, capacity utilization factor of 23 percent (i.e. CSP without storage) and per capita water requirement of 135 liters per day. Such water consumption would also be required for new nuclear or coal plants.

23 Special Correspondent, "One of five 210-MW units shut down," *The Hindu*, June 19, 2012, http://www.thehindu.com/todays-paper/tp-national/tp-tamilnadu/article3545250.ece (accessed August 21, 2012).

24 CEEW-NRDC Stakeholder Discussions, June-July 2012.

25 Martin A. Burton, Rahul Sen, Simon Gordon-Walker, Anand Jalakam, and Arunabha Ghosh, *National Water Resources Framework Study: Research Report Submitted to the Planning Commission for the 12th Five Year Plan*, Council on Energy, Environment and Water and 2030 Water Resources Group (September 2011, New Delhi, India).

CONCLUSION

The NSM has catalyzed solar energy growth in India. As the Mission matures, appreciation for the unique roles PV and CSP can play in the energy mix are key to ensuring flexible policy emphasis on each solar technology. CSP's ability to easily add storage can unlock dispatchable and base-load power that sets the stage for larger renewable energy penetration.

Implementing three key policy priorities will help support the development of the CSP industry, as well as the broader solar industry:

Building a Solar Roadmap: The NSM has kick-started the solar industry in India. To reach the Phase 2 targets, the sector needs long-term signals about the direction of the market, policy priorities and support measures. As planning for Phase 2 gains momentum, the government should send strong policy signals, such as tying state-level RPO enforcement mechanisms to central funds, to help develop confidence in the CSP market. In doing so, the unique characteristics of the available technologies need to be recognized and accommodated. An incremental approach to Phase 2 technology allocation could also provide a roadmap for solar development without locking in technologies that prove unsuccessful.

Strategic Finance: Attracting investment for solar projects, especially CSP, remains a bottleneck to the growth of the industry in India. As noted in our earlier PV report, MNRE should lead in developing a strategy to optimize the potential role of different financial institutions and stakeholders. For the Mission to succeed, significant amounts of financing from a variety of channels need to be unlocked and policymakers need to continue engaging industry stakeholders in dialogue to quickly address issues as they arise. For CSP in particular, more available and credible data on direct normal irradiance, and access to non-recourse financing are key.

Encouraging Innovation: The early stage of the CSP market allows room for innovation in product development, and for a local manufacturing base to develop. The Mission should encourage research, development, and deployment of CSP to allow the technology to fulfill its potential (e.g., through improved storage and more water efficient cooling systems) as an enabling renewable technology.

Grid-connected CSP project currently being constructed under the NSM. Photo used with permission.

Continued action by all stakeholders is required to support India's emerging solar energy market. The findings and recommendations in this report are intended to effectively strengthen the development of the CSP ecosystem to help make India's immense solar potential a long-term reality.

LIST OF STAKEHOLDER ORGANIZATIONS

From January to August 2012, we held discussions and roundtables with many stakeholders, including the following organizations, to develop this report:

ADB-NREL Solar Training Workshop, Stakeholder Attendees, May 10 to 11, 2012

ADB-Regional Taskforce CSP Workshop, Stakeholder Attendees, January 25, 2012

Acira Solar Pvt. Ltd.

Asian Development Bank (ADB)

Aurum Renewable Energy Pvt. Ltd

Axis Bank

BrightSource Energy Inc.

Cargo Power & Infrastructure

CDTI (Centro para el Desarrollo Tecnologico Industrial)

Centre for Science and Environment

Corporate Ispat Alloys Pvt. Ltd.

Diwaker Solar Projects Pvt. Ltd.

eSolar

Forum for Advancement of Solar Thermal

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit)

Godawari Green Energy Pvt. Ltd

Government of Rajasthan, Water Resources Department

ICICI Bank

IDBI Bank

Indira Gandhi Nahar Project (Bikaner)

KPMG

KVK Energy Ventures Pvt. Ltd.

Lanco Infratech

Lauren CCL

Maharishi Solar

Ministry of New and Renewable Energy

NTPC Vidyut Vyapar Nigam

Power Finance Corporation

Punj Lloyd Delta Renewables

Rajasthan Renewable Energy Corporation Pvt. Ltd.

Rajasthan Sun Technique Pvt. Ltd.

SkyFuel Inc.

Solar Energy Centre

Solar Energy Society of India

Steag Energy Services (India) Pvt. Ltd.

Sunbourne Energy

Thermax India

U.S. Export-Import Bank

U.S. Overseas Private Investment Corp.

Welspun Energy Ltd.

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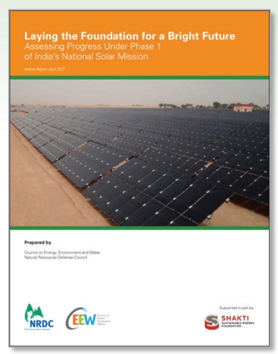
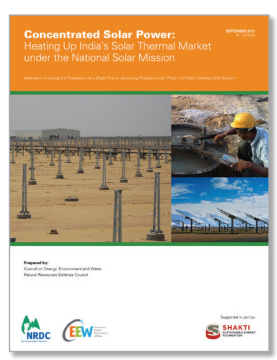


http://www.nrdc.org/international/india/national-solar-mission-ph1.asp



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