# How Effective Has India's Solar Mission Been in Reaching Its Deployment Targets?

GIREESH SHRIMALI, VIJAY NEKKALAPUDI

India launched the Jawaharlal Nehru National Solar Mission in 2010. Since its introduction, solar deployment has increased in the country. However, there are few analytically sound ex post evaluations of the effectiveness of the JNNSM. This paper presents data on the performance of Phase 1 of the JNNSM and develops quantitative metrics to assess its effectiveness against stated targets. It shows that Phase 1 has been successful in deploying solar photovoltaic technology in a cost-effective manner, but that it has failed to deploy solar thermal technology.

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Gireesh Shrimali (*gireesh_shrimali@isb.edu*) is with the Monterey Institute of International Studies and a Fellow at Stanford University as well as Climate Policy Initiative. Vijay Nekkalapudi (*vijay.kn@gmail.com*) is an independent researcher.

## 1 Introduction

### 1.1 Motivation

India faces the dual challenge of sustaining its rapid economic growth while dealing with the global threat of climate change. In addition, it needs to tackle challenges related to energy security, energy access, and the local environment. To counter these, a National Action Plan on Climate Change (NAPCC) was launched in 2008. One of the key missions (out of eight) formulated under the NAPCC is the Jawaharlal Nehru National Solar Mission (JNNSM), which was launched in 2010 with the aim of deploying an installed capacity of 22,000 MW of solar power by 2022 (JNNSM 2010).

The JNNSM was motivated by two major factors. First, to reduce dependence on fossil fuels and help improve energy security. Second, by the technical potential of solar energy, which is practically unlimited. Most parts of India receive an average annual global solar radiation of 1,600-2,000 kwh/$m^2$, much higher than many countries that have been successful in deploying solar energy, such as Germany and Japan[1] (Garud and Purohit 2010). India's solar potential of 6 billion GWh can be used to generate much more than the country's current electricity needs (Garud and Purohit 2010; CERC 2011).

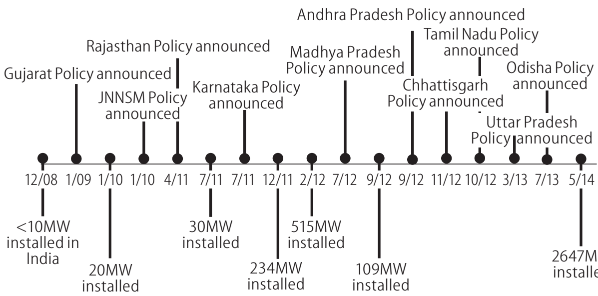
It has been close to four years since the JNNSM was launched. During this time, India has seen tremendous growth in solar power deployment – from 10 MW in 2009 to more than 2,600 MW by May 2014 (MNRE 2014). Given that solar power is still more expensive than conventional energy (IRENA 2012a), it is not competitive in the marketplace. Therefore, this growth is attributed mainly to the state policy of Gujarat and the JNNSM (NRDC 2012a; BTI 2013a) – in particular, to the long-term fixed tariffs guaranteed by these policies[2] (Nelson et al 2012). According to the Ministry of New and Renewable Energy's (MNRE) records, the JNNSM had contributed approximately 640 MW of solar capacity by June 2014 (Section 4).[3]

Based on these numbers it can be hypothesised that the JNNSM has been effective in deploying solar power in India. Further, it has been asserted that the JNNSM has been able to deploy solar power in a cost-effective manner, primarily due to competitive bidding (Khanna and Barrosso 2014; Khanna and Garg 2013; Altenburg and Engelmeier 2013). This has influenced many other states to come up with their own solar policies based on competitive bidding for solar power deployment, and to fulfil their renewable purchase obligations (RPOs) (MNRE 2011a), in particular solar-specific ones (MOP 2011).

Between April 2011 and June 2014, nine states announced solar policies (Figure 1).

**Figure 1: Timeline of Various Solar Policies in India against Deployment in Gujarat and JNNSM**

Indian National and State Solar Policies Timeline




Deployment data for Gujarat from various press releases since 2009. We could not find official data on the commissioning dates for the plants set up under the Gujarat policy.
Source: JNNSM (2012); MNRE (2011b, 2012b, 2012d, 2012e, 2013); CREDA (2012); KRECL (2012); NEDA (2013); own research.

Though the JNNSM has contributed to increased deployment of solar power in India, this does not fully inform us of its effectiveness. The existing literature indicates that the effectiveness of deployment can be measured in many different ways, including simple measures such as capacity added, and complex measures that measure the ratio of capacity added to generation potential (IEA 2008; IEA 2011).[4]

We are interested in a much simpler and targeted metric, which is suited to assessing the performance of specific policies in individual countries – in other words, the success of a policy in reaching its own targets (Mitcell et al 2011; IRENA 2012b). A key question is how effective the JNNSM has been in reaching its own deployment targets. However, this question cannot be examined in isolation, given that the costs of achieving targets are also important, and any deployment at scale needs to contain costs. In this context, a follow-up question is whether the JNNSM has been cost-effective – that is, has the JNNSM been able to deploy solar technology at the least cost possible (IEA 2008; IEA 2011)? Finally, another follow-up question is what can be learned from the performance of the JNNSM so far that can be applied to future policy design?

These are the questions we set out to answer in this paper and, in doing so, we hope to not only assess the effectiveness of the JNNSM, but also diagnose the reasons behind its apparent success or failure in reaching targets. Thus, we aim to assess the effectiveness of the policy until June 2014, and also inform future policymaking, especially to do with subsequent phases of the JNNSM (JNNSM 2010). We also examine other crucial aspects of the JNNSM, such as its cost effectiveness, which will prove key to reaching its ambitious targets in the long run.

## 1.2 Examining JNNSM Targets

Before proceeding, we examine details of the JNNSM's targets. The JNNSM focuses on four application segments – grid-connected utility-scale installations, including rooftop systems; off-grid solar applications; solar collectors; and solar lighting systems (Table 1). Its targets are to be achieved in three phases – Phase 1 (until 2013); Phase 2 (2013-17); and Phase 3 (2017-22). Phase 1 was split into Batch 1 and Batch 2, and has been completed, while Phase 2 is in progress.

**Table 1: JNNSM Targets**

| No | Application Segment | Target for Phase 1 (2010- 13) | Target for Phase 2 (2013-17) | Target for Phase 3 (2017-22) |
|---|---|---|---|---|
| 1 | Solar collectors | 7 million $m^2$ | 15 million $m^2$ | 20 million $m^2$ |
| 2 | Off grid applications | 200 MW | 1,000 MW | 2,000 MW |
| 3 | Utility-scale grid-connected systems, including on rooftops | 1,000-2,000 MW | 4,000-10 000 MW | 20,000 MW |
| 4 | Solar lighting systems | | | 20 million |

Source: JNNSM Policy Document, "Towards Building a Solar India" (JNNSM 2010).

The focus of this paper is on grid-connected utility-scale systems (capacities of 100 kw or higher), mounted on grounds and rooftops, which have the potential to scale well. The JNNSM relies on two categories of technologies to harness solar power – solar photovoltaic (PV), and solar thermal. The JNNSM target was to implement about 500 MW of solar PV and 500 MW of solar thermal in Phase 1, with 150 MW of solar PV and 500 MW of solar thermal in Batch 1, and 350 MW of solar PV in Batch 2 (MNRE 2013).

Phase 1 of the JNNSM was implemented by the National Vidyut Vyapar Nigam (NVVN), the power trading arm of the National Thermal Power Corporation (NTPC), the largest electricity provider in India. Solar energy is more expensive than conventional energy (IRENA 2012a), and to reduce the delivered cost of solar electricity, the NVVN would buy solar energy at the corresponding levelised cost discovered through reverse bidding, bundle it 20%-80% with energy from traditional power sources (for example, coal), and sell the bundled energy to customers. With a 20%-80% bundling, which essentially corresponds to bundling 1 MW of solar power capacity with 1 MW of coal power capacity, for every MWh of solar energy, the NVVN would bundle 4 MWh of energy from coal (NRDC 2012a).[5] The solar tariff was fixed by a pay-as-you-bid scheme where the developers providing the highest discounts from the Central Electricity Regulatory Commission (CERC) feed-in tariff benchmark were selected. In the rest of the paper, we refer to this scheme as the NVVN scheme.

We also examine two other schemes under the JNNSM to compare and contrast them with the NVVN scheme. First, 84 MW of existing utility-scale solar PV projects were merged into JNNSM Phase 1 under a migration scheme. These projects were already under development under existing power plant pilot schemes, and were allowed to collect a tariff of $0.25/kwh (Deshmukh et al 2010a). Second, rooftop systems, with a maximum capacity of two MW each, were selected via the Rooftop PV and Small Solar Power Generation Programme (RPSSGP) and paid a fixed subsidy of $0.36/kwh, called the generation-based incentive (GBI). A total of 98 MW was allotted under the RPSSGP scheme (MNRE 2013).

## 1.3 Prior Work

A lot of work has focused on assessing policy effectiveness. One category has focused on renewable policy effectiveness in a single country context, as well as cross-country comparisons, using different metrics (IEA 2008, 2011). These metrics vary from measuring capacity installed in MW to the percentage of available potential achieved, including cost-effectiveness. Though the list is long, we briefly discuss a few significant papers. Lipp (2007) examines renewable deployment in the UK, Denmark, and Germany, and concludes that the success of the last two in meeting targets is because of feed-in tariffs, a finding supported by Agnolucci (2007). Klessman et al (2011) examine the effectiveness of renewable policies in European countries, and the factors behind differences in performance.

These evaluations, however, suffer from a major drawback – they do not control for potential confounders, such as economic variables (for example, gross domestic product (GDP) per capita) and structural variables (for example, the support for renewable energy). This drawback is addressed in many recent empirical studies (Marques et al 2010; Dong et al 2012; Jenner et al 2013). However, in these studies, the focus has remained on cross-country comparisons, as opposed to what we are interested in – the effectiveness of a policy in a particular country in achieving its stated goals. Further, all this literature, empirical or otherwise, mostly focuses on countries other than India.

In the Indian context, though some ex-post analysis exists on the performance of the renewable energy certificate market (Gupta and Purohit 2013; Shrimali and Tirumalachetty 2013), the literature on the JNNSM is somewhat scarce, and, to the best of our knowledge, there is little analytically sound work on an ex-post analysis of the JNNSM so far, in particular of Phase 1, which has been completed. Despite that there is no direct correspondence with our work, we briefly highlight the contributions of the existing literature on the JNNSM.

Shrimali and Rohra (2012), as well as Basu (2011), in ex-ante analyses of the JNNSM highlight the barriers to development and diffusion that have been dismantled, and those that still remain. They identify the implementation challenges likely to be encountered in various application areas, and discuss approaches based on global best practices to address them. Deshmukh et al (2010a) and Raghavan and Harish (2011) provide ex-ante analysis of the JNNSM in the solar off-grid context, and demonstrate how off-grid systems are at a disadvantage in comparison to utility-scale ones. They argue that to better align with India's development needs, the JNNSM needs to re-prioritise its focus from grid-connected projects. This view is also supported in Deshmukh et al (2010b), who argue that though competitive bidding is an appropriate procurement process, the JNNSM may still not be prudent, given the high cost of solar power. Our work differs from these papers in that we gauge ex-post policy effectiveness as opposed to ex-ante policy analysis.

NRDC (2012a, b) and Khanna and Garg (2013) are similar to our work in that they examine the performance of grid-connected utility-scale projects in JNNSM Phase 1. NRDC (2012a) focuses on solar PV, discusses JNNSM targets and incentives for solar projects, and identifies the challenges remaining in deployment. NRDC (2012b), on the other hand, focuses on solar thermal plants, elaborates on the challenges in financing these projects given the relative immaturity of the sector, and proposes strategies to attract investment. Khanna and Garg (2013), as well as Altenburg and Engelmeier (2013), laud the success of the reverse auction method in the JNNSM, focus on the barriers to scaling it up, and policy choices for future implementation. Gupta and Anand (2013) and Gyanpuri and Kumar (2014) examine solar deployment under the JNNSM and state-level policies. Based on cumulative deployment, they conclude that state-level policies have been more successful than the JNNSM. However, despite these similarities, these papers do not develop a theoretical framework to assess the effectiveness of the JNNSM.

## 2 Methods: The Metrics

In assessing the deployment effectiveness of JNNSM Phase 1, we go beyond qualitative analysis, and develop three quantitative metrics to assess the performance of the JNNSM. Recall that we intend to assess the success of the JNNSM until June 2014 in terms of its stated targets. Given that we also assess the reasons behind the apparent success (or failure), we provide a relevant risk-based framework in Section 4. In this process, we discuss the cost-effectiveness of the JNNSM, from the perspective of cost reductions from domestic as well as international benchmarks.

The simplest metric, Metric 1, measures the basic completion percentages of projects (in terms of capacity) under the JNNSM by June 2014. Here, by "completed" we mean "commissioned", that is, projects that are in operation. For example, if 70 MW of projects were commissioned by June 2014, compared to a planned capacity of 100 MW, Metric 1 would be 0.7. However, while this basic completion percentage (Metric 1) tells us how many of the planned projects were completed by June 2014, it does not tell us how many of the projects were completed by their target date, which, to some extent, is a more accurate metric of policy performance.

This is captured by Metric 2, which captures the percentage of projects (in terms of capacity) completed by their respective due dates. For example, if 70 MW of projects were commissioned by June 2014, compared to the planned 100 MW, but only 50 MW were complete by the due date, Metric 2 would be 0.5. Given that Metric 2 is more stringent than Metric 1, we expect it to be less than or equal to Metric 1. However, Metric 2 does not provide any information on the projects that were completed later than the due date. These projects were somewhat completed by the due date, and it can, therefore, be argued that they should be given partial credit.

To capture this, we develop another metric, Metric 3, which captures elements of both Metrics 1 and 2 but essentially provides partial credit to late projects. For example, if there are N projects of equal capacity, each in-time project is given a credit equal to 1/N, whereas each delayed project is given a credit equal to (1/N)* (number of months from beginning of a programme to due date divided by the number of months from beginning of a programme to completion). Thus, late projects are given a partial credit that diminishes with increasing delay. The normalisation by the number of months from the beginning to completion ensures that a comparison is possible between two projects with different lengths. Given the design of this metric, we expect it to be in between the other two metrics – Metric 2 <= Metric 3 <= Metric 1.

When it comes to assessing the performance of different aspects of the JNNSM, though we present Metric 1, which appears to be too lenient, and Metric 2, which appears to be too strict, as suggestive indicators, we rely on Metric 3 for the final assessment, given that it provides the most comprehensive measurement of completed and uncompleted projects, with appropriate penalties for delays. Further, Metric 3 provides a fair comparison between programmes: If the duration for Programme 1, based on Technology 1 (for example, solar PV) is half the duration for Programme 2, based on Technology 2 (for example, solar thermal), then a month's delay in Programme 1 is equivalent to two months delay in Programme 2. That is, delays are normalised according to the duration of programmes, which, in turn, depend on the underlying characteristics of technology development.

We use the following five ranges on the metrics to classify the performance of the JNNSM – greater than 95% highly successful; 75%-95% successful; 50%-75% somewhat successful; 25%-50% unsuccessful; and 0-25% highly unsuccessful. Though this quantitative-to-qualitative classification is somewhat subjective, we believe that it provides a fairly good idea of the relative performance of different aspects of a policy, including the JNNSM. This is because this classification is equitable – it first breaks down the 0-100% range into four equal parts, which mimics well-known scales such as Likert (1932) and Rating (Andrich 1978). The further division of the top range (75%-100%) is simply to differentiate between the top two choices (75%-95% and 95%-100%), in particular, to identify the highly successful outcome.

## 3 Data

Our primary source of data was JNNSM policy documents from the Ministry of New and Renewable Energy (MNRE). Our secondary sources included academic journals, online news articles, and reports by established agencies. However, all the performance indicators (the metrics) were calculated using official data from the MNRE.

Table 2 provides basic aggregate statistics on the two batches in Phase 1.[6] It includes information on the Phase/Batch; original capacity target; capacity for which power purchase agreements (PPAs) were signed; capacity actually commissioned by June 2014; and the target completion date. A comprehensive list of projects, including the date of commissioning and tariff awarded, can be found in Appendices 2 and 3 in the Online Appendix, a supplemental file.[7]

In Batch 1, under the NVVN scheme, though the original target for solar PV was 150 MW, only 140 MW had signed PPAs. The remaining projects, totalling 10 MW, were disqualified because the winning bidders could not furnish the required bank guarantee. All the projects that signed PPAs were commissioned as of June 2014. Under the RPSSGP scheme, the original target for solar PV was 98.5 MW. Though only 8 MW was complete by the due date, approximately 90.8 MW had been completed by June 2014. Under the migration scheme, the original target for solar PV was 54 MW, and 48 MW was completed by the due date and by June 2014.[8]

In Batch 2, under the NVVN scheme, though the original target for solar PV was 350 MW, only 340 MW signed PPAs (*Business Line* 2012). The remaining projects were disqualified because they failed to meet technical criteria (NVVN, 2012c).[9] By June 2014, according to the MNRE (JNNSM 2013b), 310 MW had been commissioned.

In Batch 1, out of a planned 500 MW of solar thermal, 30 MW was added through the migration scheme and the remaining 470 MW was offered through the reverse bidding process under the NVVN scheme. Except for one 50 MW project, all other projects have gone beyond the deadline of March 2014 and an extension of 12 months has been granted without any deduction of bank guarantees or cancellations (PIB 2013).[10]

## 4 Results and Discussion

In a qualitative sense, the aggregate statistics in Table 2 indicate that JNNSM Phase 1 is almost on target for solar PV. Under the JNNSM, solar PV will reach a total deployment of about 588 MW by end of Batch 2.[11] On the other hand, solar thermal projects reached a total deployment of only 52.5 MW by June 2014. Thus, it is apparent that the JNNSM has been successful in deploying solar PV, while failing to meet the deployment target for solar thermal.

**Table 2: Phase 1– Batch 1 and Batch 2 Aggregate Statistics**

| Scheme | Technology | Capacity Planned (MW) | Capacity to be Commissioned as per PPA (MW) | Capacity Actually Commissioned (MW) | Target Date of Commissioning | Balance |
|---|---|---|---|---|---|---|
| Phase 1, Batch 1 | | | | | | |
| Phase 1, Batch 1 under NVVN | Solar PV | 150 | 140 | 140 | January 2012 | 0 |
| | Solar thermal | 470 | 470 | 50 | May 2014 | 420 |
| Total (Phase 1, Batch 1 under NVVN) | | 620 | 610 | 190 | | 420 |
| RPSSGP | Solar PV | 98.5 | 98.05 | 90.8 | March 2012 | 7.25 |
| Migration scheme | Solar PV | 54 | 54 | 48 | October 2011 | 6 |
| | Solar thermal | 30 | 30 | 2.5 | March 2013 | 27.5 |
| Total | | 832.5 | 792.05 | 521.3 | | 460.75 |
| Phase 1, Batch 2 | | | | | | |
| Phase 1, Batch 2 under NVVN | Solar PV | 350 | 340 | 310 | February 2013 | 30 |

Source: JNNSM policy document for Phase 2; MNRE (2013); JNNSM (2012, 2013b).

### 4.1 The Metrics: Was JNNSM Phase 1 Successful in Deploying Solar PV/Thermal?

We now examine the deployment effectiveness of JNNSM using the metrics developed in Section 2 (Table 4, p 58). However, before we do so, we examine how the capacity has come online over time (Table 3, p 58). For example, for solar PV in Phase 1, Batch 1, under the NVVN scheme, 140 MW of total capacity came online by June 2014, with 60 MW coming online by the due date (12 months), 60 MW during 12 to 15 months, 10 MW during 15 to 18 months, 5 MW during 18 to 21 months, and the final 5 MW during 21 to 30 months. Similarly, for solar PV in

**Table 3: Completion Dates Per Scheme**

| Scheme | | | Sizes of Projects (MW) | Price Offered to NVVN (USD /kWh) | Capacity Planned (MW) | Capacity Commissioned as of June 2014 (MW) | Timelines of Capacity Commissioned | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Capacity Commissioned by Due Date (MW) | Capacity Commissioned with 3 Months Delay (MW) | Capacity Commissioned with 3-6 Months Delay (MW) | Capacity Commissioned with 6-9 Months Delay (MW) | Capacity Commissioned with 18 Months Delay (MW) |
| Phase 1 | Under NVVN | Solar PV | Minimum-5 | Minimum- 0.22 | | | | | | | |
| Batch 1 | | | Average-5 | Average- 0.24 | | | | | | | |
| | | | Maximum-5 | Maximum- 0.25 | 150 | 140 | 60 | 60 | 10 | 5 | 5 |
| | | Solar thermal | Minimum-20 | Minimum-0.21 | | | | | | | |
| | | | Average-67 | Average- 0.23 | | | | | | | |
| | | | Maximum-100 | Maximum- 0.24 | 470 | 50 | 50 | 0 | 0 | - | - |
| | RPSSGP | RPSSGP | Minimum-1 | | | | | | | | |
| | | | Average-1 | | | | | | | | |
| | | | Maximum-2 | 0.36 | 98.5 | 90.8 | 8 | 14 | 54.6 | 14.3 | - |
| | Migration | Solar PV | Minimum-1 | | | | | | | | |
| | | | Average-4 | | | | | | | | |
| | | | Maximum-5 | 0.25 | 54 | 48 | 48 | - | - | - | - |
| | | Solar thermal | Minimum-10 | | | | | | | | |
| | | | Average-10 | | | | | | | | |
| | | | Maximum-10 | 0.30 | 30 | 2.5 | 2.5 | - | - | - | - |
| Phase 1 | Under NVVN | Solar PV | Minimum-5 | Minimum-0.15 | | | | | | | |
| Batch 2 | | | Average-14 | Average-0.17 | | | | | | | |
| | | | Maximum-20 | Maximum-0.18 | 350 | 310 | 235 | 65 | 10 | - | - |

1: Due dates for solar PV projects for Batch 1 and Batch 2 were 12 and 13 months, respectively, from the date of signing the PPA. Due date for solar thermal projects were 24 months from the date of signing the PPA.
2: Solar thermal projects were granted two years to finish their projects. However, the MNRE has extended the timelines to three years.
3: As on June 2014, (1) Solar PV Phase 1 Batch 1, RPSSGP, and migration until 14 February 2014; (2) Solar thermal Phase 1 Batch 1 until 18 July 2013; and (3) Solar PV Phase 1 Batch 2 until 31 July 2013.
4: $1 = Rs 50.

**Table 4: Success Rate and Completion Percentages Per Scheme**

| Scheme | | | Total Capacity (MW) | Total Capacity Completed by June 2014 (MW) | Capacity Completed by Due Date (MW) | Metric 1 (%) | Metric 2 (%) | Metric 3 (%) | Success Rate |
|---|---|---|---|---|---|---|---|---|---|
| Phase 1 | Under NVVN | Solar PV | 150 | 130 | 60 | 93.33 | 40.00 | 79.68 | Successful |
| Batch 1 | | Solar Thermal | 470 | 50 | 50 | 10.64 | 10.64 | 10.64 | Highly unsuccessful |
| | RPSSGP | RPSSGP | 98 | 90.8 | 8 | 92.65 | 8.16 | 65.07 | Somewhat successful |
| | Migration | Solar PV | 54 | 48 | 48 | 88.89 | - | - | Successful |
| | | Solar Thermal | 30 | 2.5 | 2.5 | 8.33 | - | - | Highly unsuccessful |
| Phase 1 Batch 2 | Under NVVN | Solar PV | 350 | 310 | 235 | 88.57 | 67.14 | 84.19 | Successful |

Phase 1, Batch 1, under the RPSSGP scheme, 90.8 MW of capacity came online by June 2014, with 8 MW coming online by the due date, 14 MW during 12 to 15 months, 54.6 MW during 15 to 18 months, and 14.3 MW during 18 to 21 months.

In Batch 1, under the NVVN scheme, solar PV has been successful according to Metric 1, unsuccessful according to Metric 2, and successful according to Metric 3. That is, many projects were delayed, but not by much. Overall, based on Metrics 1 and 3, it is reasonable to call this performance successful. Under the RPSSGP, solar PV has been successful according to Metric 1, highly unsuccessful according to Metric 2, and somewhat successful according to Metric 3. That is, most of the projects were delayed, but were completed over time. Given that we use Metric 3 as our primary indicator, it is reasonable to call this performance somewhat successful. Finally, under the migration scheme, we have data only for Metric 1, according to which solar PV deployment has been successful. Thus, for Batch 1, the performance for solar PV ranges from somewhat successful (for the RPSSGP) to successful (for the NVVN and migration). If one were to focus simply on the NVVN scheme, given that the other two were somewhat peripheral to the main focus of this paper, we can say the performance of the JNNSM in Batch 1 was successful for solar PV.

In Batch 2, given the stated targets, we focus on only NVVN projects. Solar PV has been successful according to Metric 1, somewhat successful according to Metric 2, and successful according to Metric 3. The large difference between Metrics 1 and 2 indicates that many projects were delayed beyond the due date, perhaps due to their large size. The maximum size allowed under Batch 2 was 20 MW and the average size was about 14 MW, almost three times that under Batch 1. Thus we can infer that requirements for capital, land (roughly five acres per MW Deshmukh et al 2010a), and skilled labour went up, pushing the timeline for completion (NRDC 2012a). However, the small difference between Metrics 1 and 3 indicates that the delayed projects were commissioned with small delays. We believe that it is reasonable to call this performance successful.

We also examine the reduction in solar PV tariffs with respect to benchmark fixed tariffs – $0.36/kwh and $0.30/kwh in Batch 1 and Batch 2, respectively – initially determined by the CERC (MNRE 2012a). The lowest bids were $0.22/kwh in Batch 1 and $0.15/kwh in Batch 2 (MNRE 2013) – that is, reductions of 39% and 50% from the corresponding benchmark prices. The average tariffs were $0.24/kwh in Batch 1 and

$0.17/kwh in Batch 2 – that is, reductions of 30% and 50% from the Batch 1 benchmark.

We now examine the performance of solar thermal projects, which were allocated only in Batch 1, under the NVVN and migration schemes. These projects were supposed to be commissioned by March 2013. With only 52.5 MW of capacity deployed until June 2014, according to all metrics, the JNNSM has failed to deploy solar thermal. That very little capacity has been deployed so far is worrisome. On the other hand, given the deadlines, we caution the reader against drawing long-term conclusions.

### 4.2 Discussion: A Diagnosis of the Variable Performance of JNNSM

We now examine the reasons behind the performance of different aspects of the JNNSM. The deployment success of new technologies depends on the investment climate and related risks (Nilsson and Wene 2001; Gross et al 2010; Luthi and Prassler 2011; Luthi and Wustenhagen 2012; Komendantova et al 2012), including categories such as policy/regulatory, credit, market, operational, and so on. Given that many of these are common to solar PV and solar thermal, we focus on three specific risks that allow us to critically examine the variable performance of the JNNSM – technology, developer, and offtake risks.

Technology risk is related to whether a technology will perform as expected. This risk typically declines as developers gain more experience with the technology, locally and worldwide. Developer risk is related to whether a project developer will finish the project on time, and whether he/she will operate the plant as expected. This risk goes down as individual developers gain more experience with a technology and create a reputation in the marketplace. Finally, the offtake risk is related to issues of non-payment by the buyer. This is typically related to the financial health of the buyers concerned.

These risks, though not comprehensive, contribute to whether a policy will be successful in reaching its target. Each of these risks, if not handled appropriately, may result in projects either getting delayed or not performing as expected. Thus, in our examination of the JNNSM, we discuss how each of these risks could have potentially contributed to the performance of solar PV and solar thermal.

**4.2.1 Solar PV: Effective Risk Management and Cost-Effective Deployment at Scale Risk Management in Solar PV**: The deployment success of solar PV can be mainly attributed to low technology risk, low developer risk, and low offtake risk. First, the technology risk of solar PV is low. Solar PV plants have a simple mechanical set-up, with no moving parts and no cooling mechanism (Gage and Borry 2012). This makes the maintenance and operation of solar PV plants relatively easy and risk-free. Further, there is considerable experience with installing solar PV, not only worldwide but also in India, from before the JNNSM (for example, in Gujarat, primarily via the Gujarat policy).[12]

The distinction between worldwide (related to new technology) and Indian (related to new market) experience is crucial, however. Though considerable solar PV deployment experience existed worldwide before 2009-10 (EPIA 2013) – 24 GW in 2009 and 41 GW in 2010 – the first solar PV installations in India were under the Gujarat policy (in 2009) and the RPSSGP scheme (in 2010). So, these policies dealt with most of the learning related to solar PV technology development in India. However, this also meant delays in implementation.[13] NVVN Batch 1, on the other hand, greatly benefited from the learning from the Gujarat policy and the RPSSGP. Thus, NVVN Batch 1 had a lower technology risk than the RPSSGP scheme, which is seen in its better performance.

Second, the developer risk of JNNSM projects is low and is declining over time. In Phase 1, Batch 1, the NVVN scheme received 343 applications, amounting to about 5,000 MW. The NVVN reduced participation by non-serious players by incorporating a bid-bond of $100,000 per MW that penalised delays in commissioning. If the solar project developer failed to commence supply of power to the NVVN by the specified date, the performance bank guarantee would kick in. For a delay of more than three months from the commissioning date, the penalty was $2,000 per MW per day; and for delays beyond 18 months, the PPA would be cancelled (NVVN 2010a). This ensured that only players confident about finishing the projects in time participated. Further, Phase 1, Batch 2 received only 152 applications, amounting to 1,900 MW. Thus, although fewer developers vied for solar PV projects under Batch 2, the average project size was much larger, indicating that only serious developers were staying in.

However, it must be noted that though bid-bonds will always be critical in the long run, they may not be effective in absence of local technology learning, which may be a teething issue. Both the RPSSGP and NVVN schemes required developers to deposit very similar bank guarantees. Moreover, projects under the RPSSGP were paid a higher tariff ($0.361/kwh) compared to the average tariff in the NVVN ($0.24/kwh in Batch 1 and

**Table 5: State Policies with Signed Power Purchase Agreements**

| | Andhra Pradesh* | Tamil Nadu* | Karnataka | Madhya Pradesh | Punjab | Rajasthan | Uttar Pradesh |
|---|---|---|---|---|---|---|---|
| PPA signed for as of June 2014 | 350 MW | 0 (LOIs signed: 708 MW) | Phase 1 (April 2012): 60MW; Phase 2 (July 2013): 80 MW | Phase 1 (May 2012): 225MW; Phase 2 (February 2014): 120 MW | 250 MW | 75 MW | 110 MW |
| Tariff (in USD/kWh) | 0.13 | 0.13 with 5% escalation for first 10 years | Phase 1: 0.16-0.17; Phase 2: 0.11-0.16 | Phase 1: 0.16-0.17; Phase 2: 0.13-0.14 | 0.15-0.17 | 0.13 | 0.16-0.19 |
| Price discovery method | Fixed feed in tariff* | Fixed feed in tariff* | Reverse bidding | Reverse bidding | Reverse bidding | Fixed feed in tariff | Reverse bidding |

* These policies started off by inviting developers under a reverse bidding scheme. Later, this scheme was changed for a fixed feed in tariff based on the lowest bid received from the developers (BTI 2013b); $1 = Rs 50.
Source: BTI 2014 and various news sources.

$0.17/kwh in Batch 2). Thus, the projects under the RPSSGP had more to lose due to delays. Given almost identical timelines, the projects under the RPSSGP were delayed more than those under the NVVN because of the lack of experience in deploying solar PV in India.

Third, the offtake risk was low. All the projects under Phase 1 have a 25-year PPA signed with the NVVN, the power trading arm of NTPC, which has a market capitalisation of $35 billion and net worth of $11.4 billion (NVVN 2010b). Thus, the PPA enjoys a strong credit rating and bankability (IEP 2012). This has allowed these projects to secure funding in a timely manner. This would not have been possible if the off-takers were state electricity boards (SEBs), given that most of them are in financial distress (ET 2012).

**Cost-effectiveness and Role of Reverse Auctions**

We believe that the JNNSM has achieved its solar PV target in a cost-effective manner (Khanna and Barroso 2014; Altenburg and Engelmeier 2013), aided by good solar resources in India and rapidly falling solar PV module prices.

The resource risk of solar PV is low. To begin with, India is blessed with very good solar resources (MNRE 2012a, 2013) – the average capacity utilisation factor of most solar PV plants in India is in the 15% to 19% range. In particular, Rajasthan, where most of these plants are located, has a high solar resource, which results in capacity utilisation factors in the low 20%.[14] Further, solar PV plant output is estimated using global horizontal irradiance (GHI), the total amount of radiation received on a horizontal surface (3TIER 2010). For the JNNSM, the GHI values used in designing solar PV plants and determining the energy output are based on satellite data provided by the National Renewable Energy Laboratory (NREL) in the US. The variation – that is, risk – between data based on satellites and on-ground stations is found to be low (less than 5%) for GHI (3TIER 2010).

The role of the reverse bidding process in facilitating cost-effective deployment was crucial. Under this scheme, starting from a tariff fixed by the CERC, projects offering the largest discounts were selected. The JNNSM obtained really low winning bids. The lowest bids were around $0.22/kwh in Batch 1 and around $0.15/kwh in Batch 2 (MNRE 2013). These were much below the benchmark fixed tariffs – $0.36/kwh and $0.30/kwh in Batch 1 and Batch 2, respectively – initially determined by the CERC (MNRE 2012a). That is, the reverse bidding process resulted in reductions of 39% and 50% from the corresponding benchmark prices.

The JNNSM has thus been successful in designing a price-discovery mechanism that has brought down the average delivered cost of electricity from solar PV by more than half in less than two years – compared to the Batch 1 benchmark tariff ($0.361/kwh), a 30% reduction in Batch 1 ($0.24/kwh) and a 50% reduction in Batch 2 ($0.17/kwh). The resulting solar tariffs are one of the lowest in the world (Khanna and Barroso 2014), with the global average tariff comparable to the Batch 1 benchmark tariff ($0.361/kwh). This is crucial, given that unsubsidised solar PV is still considerably more expensive – approximately 130% (Shrimali et al 2014) – than conventional electricity, and successful large-scale deployment will require keeping solar tariffs down as much as possible.

Given the success of the reverse bidding process in the JNNSM, many states (for instance, Karnataka and Madhya Pradesh) have followed its method of price discovery through reverse bidding and bid-bonds (BTI 2013b, 2014). On the other hand, some states have used fixed feed-in tariffs combined with bid-bonds. However, these feed-in tariffs were essentially the lowest bids in reverse auctions held a priori. It is clear that all these policies have learned from the JNNSM since they have mostly maintained tariffs in the vicinity of the lowest bid ($0.15) in NVVN Batch 2.

It should be noted, however, that there were a lot of concerns about aggressive bidding by players in the JNNSM. Further, developers benefited from rapidly falling prices of solar PV modules (Leibreich 2013),[15] resulting in solar PV modules contributing 70% to 80% of the cost of the project in 2010 but less than 50% in 2012 (BNEF 2013).[16] It is not clear whether the trend of rapidly falling PV module prices driving down system costs and hence solar tariffs will continue in the future.

**4.2.2 Solar Thermal: Ineffective Risk Management Leading to Non-deployment:** Solar thermal technology offers many advantages compared to solar PV. Solar thermal plants, especially with molten-salt storage can keep producing electricity even after sunset, offsetting the peak load during early evening hours (Laing et al 2010; NRDC 2012b). Thus solar thermal can provide better grid stability, given that it offers more stable output than solar PV. For these reasons, Indian policymakers were eager to promote solar thermal.

However, as we have shown, the JNNSM has been very unsuccessful in getting solar thermal deployed, despite it sharing some of the elements behind the successful take-off of solar PV – low offtake, and developer risks. The offtake risk is low due to the PPA with the NVVN, and the developer risk is low due to the participation of serious developers (for example, Reliance, Lanco, Godawari Power and Ispat) in the bid-bonds. Since only a tenth of the capacity came online by the due date of March 2013, the projects were first given an extension till May 2013 and then till March 2014, all without any penalties (PIB 2013). Not penalising projects for delays may have negative repercussions on policy credibility in the long run, however.

There have been multiple challenges in getting solar thermal projects off the ground, primarily related to technology, including construction risk. For solar thermal technologies, worldwide installations stood at 500 MW in 2009 and 1.1 GW in 2010 (REN 2013), much lower than the corresponding numbers for solar PV. With very few installations, India had 5.5 MW as of March 2013.[17] Thus, with solar thermal, the JNNSM faced not only a new technology (that is, worldwide) risk, but also a new market (that is, India) risk, and trying to deploy a large amount of solar thermal capacity, without incremental approaches such as pilot projects, was a risky proposition. Despite this higher risk, JNNSM solar thermal projects were given a target of 24 months from the time of signing PPAs to commissioning. Given that financial closure takes about three to six months from the time of, signing, this was actually less than the average time – 24 months – taken by solar thermal projects worldwide from financial closure to commissioning.[18] This suggests that the JNNSM solar thermal timelines were not realistic to begin with, independent of the new technology issue.

In terms of what contributed to delays, it is instructive to examine the issues around resources. These large projects require a lot of land, with good direct normal irradiance (DNI), the total amount of radiation received on a surface always kept horizontal to the sun's direct rays (3TIER 2010). In the JNNSM, the DNI values used in designing a solar thermal plant and determining the energy output were again based on satellite data provided by the NREL. These, given that they are not on-ground measurements, contain a significant margin of error (BTI 2012; PIB 2013) – around 20% (3TIER 2010). Hence, developers have had to set up measuring instruments on site to measure the exact DNI before starting construction, adding to delay.

Further, solar thermal plants also require large amounts of water for cooling and cleaning (BTI 2012). Almost all the solar thermal projects have been allocated to the desert state of Rajasthan, with insufficient sources of water (Bloomberg 2013).[19] Thus the projects have had to figure out how to obtain large quantities of water in a water-poor environment. This has also been a factor in delaying them.

To summarise, these were the very first solar thermal projects in India, and the developers did not have a good sense of how long it would take to implement these labour- and resource-intensive projects. This task was made more complicated by the domestic content requirements for solar thermal (JNNSM 2010), which resulted in long lead times for severely capacity constrained domestic manufacturers. The key point is that given these risks, concentrated solar power (CSP) bidding may have been too aggressive and, considering the lower than expected DNI resource data, these projects are no longer viable at that price. This results in delays and even abandoning of projects (CPI 2014).

In addition, the cost of electricity from solar thermal plants is likely to be higher compared to solar PV, given high capital costs. The average cost of parabolic trough technology, which is the most dominant technology (NRDC 2012b), is in the range of $2.1 – $2.7 million/MW, much higher than the average cost of solar PV, which is in the range of $1.4 – 1.8 million/MW (CERC 2013; GERC 2012). One of the reasons for such high cost is the storage feature of solar thermal plants (CERC 2013). Although storage increases the peak-power availability even after the sunsets, solar thermal becomes commercially viable only at higher capacities (NRDC 2012b), where a high initial investment often deters investors. Further, a solution to the water problem – efficient technologies, which can decrease the water requirement by 90% – increase the cost of electricity by 9% (BTI 2012).

## 5 Conclusions

The JNNSM has been a key driving factor behind solar energy deployment in India. In this paper, we assess the performance of Phase 1 against JNNSM targets, using quantitative metrics. We show that the JNNSM has been successful in reaching its solar PV targets, and in a cost-effective manner due to its reverse-bidding process. However, we also show that the JNNSM has failed in reaching its solar thermal targets. There are many lessons to be learned from this experience, given that JNNSM Phase 2 plans to deploy 4 GW through a scheme similar to the NVVN and 6 GW through state policies (MNRE 2013).

In terms of what has worked, we see that the JNNSM has demonstrated that auctions can be successful, provided they are combined with bid-bonds. The bid-bonds proved to be an effective mechanism, especially when combined with somewhat mature technologies (for example, solar PV) to reduce the developer risk. These auctions have provided a price-discovery mechanism that has brought down the delivered cost of electricity from solar PV considerably, largely removing the biggest barrier against solar adoption. This has encouraged many states to adopt solar deployment policies that use reverse auctions with bid-bonds. Finally, the JNNSM has greatly benefited from the low offtake risk provided by the NVVN PPA, given that the NVVN is backed by the NTPC, which is in good financial condition. This indicates that mechanisms that lower the offtake risk will be crucial to solar deployment in India.

The dismal performance of solar thermal plants embodies all that has not worked. There are many reasons for this, including not addressing technology and resource risks appropriately. In particular, given the low worldwide deployment before 2010, the Indian government should have spent more time understanding the underlying technical challenges. It could have avoided these by taking the following steps. First, it should have promoted some pilot projects for solar thermal, so as to reduce the technology risk of the projects (BNEF 2010). Second, it should have ensured that the plants had adequate information on DNI as well as adequate access to resources – this was done later (in 2012) through C-WET (IRENA 2013). Finally, our results suggest that the JNNSM should have removed technology-specific requirements. If the JNNSM had made the Phase 1 target technology-agnostic, given the success of solar PV, most of the deployment would have happened in it, and JNNSM Phase 1 would have been closer to its target of 1 GW.

The most important contribution of the JNNSM has been providing an impetus to solar energy – in particular, solar PV – in India, and in a cost-effective manner, without which no deployment at scale can be justified. This has led many states to not only declare solar targets, but also use the reverse auction mechanism for procurement.

However, given that we are still in the early stages of the JNNSM, successful implementation in the long run will require addressing many challenges. One of the key success factors for JNNSM Phase 1 was the PPA with the NVVN, a creditworthy off-taker. This would be required in all phases of the JNNSM. However, keeping the NVVN as the counterparty was not guaranteed from Phase 2 onwards. This presented a challenge to the government on providing the subsidy for solar power, and options such as a viability gap funding, where developers would participate in reverse bidding on capital subsidies, were explored (MNRE 2013). This resulted in the Solar Energy Corporation of India (SECI), a not-for-profit company dedicated to the solar sector, becoming the counterparty for JNNSM Phase 2, Batch 1.[20] A key supporting policy combination, the renewable portfolio obligation (RPO) and renewable energy certificate (REC) market, has not taken off as expected (Nuwal 2012), primarily due to a faulty mechanism design and implementation issues (Shrimali and Tirumalachetty 2013).[21]

Despite these challenges, the JNNSM has got off to a reasonable start and, hopefully, will learn from its own experience. We realise that our work is not complete by any means. Future research avenues include monitoring the JNNSM's performance over time. Further, measuring the performance of a policy with respect to its own targets can be misleading, especially if the policy is not ambitious. Thus, future work may focus on assessing the performance of the JNNSM in relation to the potential of solar energy in India.

## NOTES

1 See the solar resource map (Figure 6) in Appendix 6 of the Online Appendix.
2 The JNNSM policy works independently of state-level policies (BTI 2014); however, so far, most of the solar deployment has happened under the JNNSM and Gujarat state policy.
3 So far refers to the date this analysis was performed – that is, June 2014.
4 These indicators include the EC Effectiveness Indicator, the Policy Impact Indicator, and the Deployment Status Indicator. However, these indicators are more suitable for cross-country comparisons and, though useful in alternative analysis, are not so in this paper, which focuses on individual country performance.
5 For example, the eventual price of bundled electricity would be \$0.11/kWh, given the price of solar and conventional electricity as \$0.35/kWh and \$0.05/kWh, respectively.
6 The completion dates for the projects data in mainly based on various news articles and announcements. The status of these projects is already published by the MNRE. As discussed, all the projects have had financial closure and were expected to be completed by May 2013.
7 The Online Appendix is a supplemental file that includes details on technical potential by state; details on individual plants in JNNSM; and state RPO requirements.
8 Among the remaining 6 MW, 5 MW belong to Enterprise Solutions and 1 MW to Entegra Ltd (JNNSM 2013a), which were not finished.
9 This 10 MW project belonged to Sujana Towers.
10 The project belonged to Godawari Power.
11 This includes in Batch 1: 130 MW, 89 MW, 54 MW corresponding to the NVVN, RPSSGP, and migration schemes respectively; and in Batch 2: 300 MW.
12 See Solar PV plant installed capacity (Figure 1) in Appendix 2 of the Online Appendix.
13 See commissioning dates for projects under the RPSSGP (Table 3) in Appendix 2 of the Online Appendix.
14 See CERC estimated plant output for various cities across India (Table 1) in Appendix 1 of the Online Appendix.
15 See Solar PV module price trends (Figure 3) in Appendix 5 of the Online Appendix.
16 See Cost of Solar PV plants from 2010 to 2012 (Figure 4) in Appendix 5 of the Online Appendix.
17 See projects under migration and other experimental schemes (Tables 7 and 8) in Appendix 3 of the Online Appendix.
18 From the Bloomberg New Energy Finance Project database.
19 See projects under NVVN Batch 1 and Migration schemes (Tables 6 and 7) in Appendix 3 of the Online Appendix.
20 However, now it appears that the NVVN is back as counterparty in Phase 2, Batch 2.
21 See RPO obligations for every state (Tables 9 and 10) in Appendix 4 of the Online Appendix.

## REFERENCES

Agnolucci (2007): "Wind Electricity in Denmark: A Survey of Policies, Their Effectiveness and Factors Motivating their Introduction", *Renewable and Sustainable Energy Reviews*, Vol 11, No 5, pp 951-63.

Altenburg, T and T Engelmeier (2013): "Boosting Solar Investment with Limited Subsidies: Rent Management and Policy Learning in India", *Energy Policy*, 59: 866-74.

Andrich, D (1978): "A Rating Formulation for Ordered Response Categories", *Psychometrika*, 43: 357-74.

Basu, S (2011): "India Solar Policy: Elements Casting Shadow on Harnessing the Potential", http://www.idfc.com/pdf/publications/India-Solar-Policy-Element-Casting-Shadow-on-Harnessing-the-Potential.pdf

Bloomberg (2013): "India May Defer Fines on \$1 Billion Solar Thermal Plants", http://www.bloomberg.com/news/2013-05-08/india-may-defer-fines-on-1-billion-solar-thermal-plants.html

BNEF (2010): "Crossing the Valley of Death: Solutions to the Next Generation Clean Energy Project Financing Gap", http://bnef.com/PressReleases/view/119

– (2013): *Sustainable Energy in America Factbook*, Business Council for Sustainable Energy, http://www.bcse.org/ sustainableenergyfactbook.html

BTI (2012): "Concentrated Solar Power", *Bridge to India*, http://bridgetoindia.com/in-the-press/2012-10-16_BRIDGE% 20TO%20INDIA_SWE_CSP_India.pdf

– (2013a): "Delayed Projects Under Solar Thermal Policy of JNNSM", *Bridge to India* blog, http://bridgetoindia. com/blog/? p=1628

– (2013b): *India Solar Compass*, October, http://bridgetoindia.com/our-reports/india-solar-compass

– (2014): *India Solar Compass*, July, http://bridgetoindia.com/our-reports/india-solar-compass

*Business Line* (2012): "27 Solar Project Cos Achieve Financial Closure", 12 September, http://www.thehindubusinessline.com/industry-and-economy/27-solar-project-cos-achieve-financial-closure/article3889020.ece

CERC (2011): "Performance of Solar Power Plants in India", http://www.cercind.gov.in/2011/Whats-New/PERFORMANCE %20OF%20SOLAR %20POWER%20PLANTS.pdf

– (2013): "Benchmark Capital Cost for Solar PV and Solar Thermal", http://www.cercind.gov.in/2013/orders/SO242.pdf

CPI (2014): "The Role of Public Finance in CSP: Rajasthan Sun Technique 100MW CSP Plant, India", Climate Policy Initiative Report, Retrieved from http://climatepolicyinitiative.org/publication/san-giorgio-group-case-study-the-role-of-public-finance-in-csp-india-rajasthan-sun-technique/

CREDA (2012): Chhattisgarh State Renewable Energy Development Agency, http://new.credacg.org/ content. php? cid=98

Deshmukh, R, G Sant and A Gambhir (2010a): "Need to Re-align India's National Solar Mission", *Economic & Poliitcal Weekly,* 45 (12): 41-50.

– (2010b): "India's Solar Mission: Procurement and Auctions", *Economic & Political Weekly*, 46 (28): 22-26.

Dong, C G (2012): "Feed-in Tariff vs Renewable Portfolio Standard: An Empirical Test of Their Relative Effectiveness in Promoting Wind Capacity Development", *Energy Policy*, 42 (3): 476-85.

EPIA (2013): *Global Market Outlook: For Photovoltaics 2013-17*, European Photovoltaic Industry Association, http://www.epia. org/fileadmin/user_upload/Publications/GMO_2013_-_Final_PDF.pdf

ET (2012): "Power Distribution Companies Losses Cross Rs 2 Lakh Crore", *The Economic Times*, 7 May, http://articles. economictimes.indiatimes.com/2012-05-07/news/31610764_1_power-tariffs-hike-in-electricity-tariff-discoms

Gage, B and R Borry (2012): "Concentrated Solar Thermal vs Photovoltaic Solar", http://www.principalsolarinstitute.org/uploads/custom/3/_documents/CSvsPV_WhitePaper.pdf

Garud, S and I Purohit (2010): "Making Solar Thermal Power Generation in India a Reality: Overview of Technologies, Opportunities and Challenges", http://www.aprekh.org/files/SolarThermalPowergeneration_Final.pdf

GERC (2012): "Determination of Tariff for Procurement by Distribution Licensees and Others from Solar Energy Projects", http://www.gercin.org/renewablepdf/Solar%20Tariff%20Order%201%20of%202012.pdf

Gross R, W Blyth and P Heptonstall (2010): "Risks, Revenues and Investment in Electricity Generation: Why Policy Needs to Look Beyond Costs", *Energy Economics*, 32: 796-804.

Gupta, S K and R S Anand (2013): "Development of Solar Electricity Supply System in India: A Review", *Journal of Solar Energy*, Article ID 632364, http://dx.doi.org/ 10.1155/2013 /632364

Gupta, S K and P Purohit (2013): "Renewable Energy Certificate Mechanism in India: A Preliminary Assessment", *Renewable and Sustainable Energy Reviews*, 22: 380-92.

Gyanpuri, Y and A Kumar (2014): "Solar Power and Its Development in India: A Review", *Progress in Science and Engineering*, 2(6): 292-303.

IEA (2008): "Deploying Renewables: Principles for Effective Policies", http://www.iea.org/publications/ freepublications/ publication/DeployingRenewables2008.pdf

– (2011): "Deploying Renewables: Best and Future Policy Practice", http://www.iea.org/pub lications/freepublications/publication/Deploy ing_Renewables2011.pdf

IEP (2012): "NVVN and the Solar Mission", http:// www.indiaenvironmentportal.org.in/files/NV VN.pdf

IRENA (2012a): "RE Technologies Cost Analysis of Solar PV", http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_ Cost_Analysis-SOLAR_PV.pdf

– (2012b): "Evaluating Policies in Support for Renewable Power", http://www.irena.org/menu /index.aspx?mnu=Subcat&PriMenuID=36&C atID=141&SubcatID=251

– (2013): "C-WET Solar Mapping", http://www.irena.org/menu/% 5CDocumentDownloads% 5Cevents%5CDelhiEvent%5C1.3%20CWET-GIZ%20solar%20mapping.pdf

Jenner, S, F Groba and J Indvik (2013): "Assessing the Strength and Effectiveness of Renewable Electricity Feed-in-Tariffs in European Union Countries", *Energy Policy*, 52(1): 385-401.

JNNSM (2010): "JNNSM Mission Document", http: //www.mnre.gov.in/file-manager/User Files/ mission _document_ JNNSM. pdf

– (2012): "Commissioning Status SPV Batch 1 Phase 1", Ministry of New and Renewable Energy, http://www.mnre.gov.in/file-manager/ UserFiles/commissioning_status_spv_batch1_ phase1.pdf

– (2013a): "MNRE State-wise Installed Capacity", Ministry of New and Renewable Energy, http://mnre.gov.in/file-manager/ UserFiles/ Solar%20RPO/State%20-%20wise% 20solar %20 installed%20capacity%20break-up.xlsx

– (2013b): "JNNSM Commissioning Status for Batch 2", Ministry of New and Renewable Energy, http://mnre.gov.in/file-manager/User Files/ commissioning_status_spv_phaseI_batchII.pdf

– (2013c): "JNNSM Commissioning Status for Batch 1 Solar Thermal Capacity", Ministry of New and Renewable Energy, http://mnre.gov. in/file-manager/UserFiles/commissioning_ status _grid-connected-st_batch1_phase1.pdf

Komendantova N, A Patt, L Barras and A Battaglini (2012): "Perception of Risks in Renewable Energy Projects: The Case of Concentrated Solar Power in North Africa", *Energy Policy*, 40: 103-09.

Khanna, A and L Barroso (2014): "Promoting Renewable Energy through Auctions: The Case of India", World Bank, http://documents.worldbank.org/curated/en/2014/06/19670595/promoting-renewable-energy-through-auctions-case-india

Khanna, A and K Garg (2013): "Paving the Way for a Transformational Future: Lessons from Jawaharlal Nehru Solar Mission Phase I", Energy Sector Management Assistance Program, World Bank, https://www.esmap.org/node/ 3509.

Klessmann, C, A Held, M Rathmann and M Ragwitz (2011): "Status and Perspectives of Renewable Energy Policy and Deployment in the European Union: What Is Needed to Reach the 2020 Targets?", *Energy Policy*, Vol 39, 12.

KRECL (2012): Karnataka Renewable Energy Corporation Limited, http://kredlinfo.in/

Laing, D, W D Steinmann, P Viebahn, F Gräter and C Bahl (2010): "Economic Analysis and Life Cycle Assessment of Concrete Thermal Energy Storage for Parabolic Trough Power Plants", *Journal of Solar Energy Engineering*, Vol 132, No 4, http://solarenergyengineering.asmedigitalcollection.asme.org/article.aspx? articleid = 1458222

Leibreich, M (2013): "Global Trends in Clean Energy Investment", http://about.bnef.com/presentations/global-trends-in-clean-energy-investment-3/

Likert, R (1932): "A Technique for the Measurement of Attitudes", *Archives of Psychology*, 140: 1-55.

Lipp, J (2007): "Lessons for Effective Renewable Electricity Policy from Denmark, Germany and the United Kingdom", *Energy Policy*, 35(11): 5841.

Luthi, S and T Prassler (2011): "Analysing Policy Support Instruments and Regulatory Risk Factors for Wind Energy Deployment: A Developers' Perspective", *Energy Policy*, 39 (9): 4876-92.

Luthi, S and R Wustenhagen (2012): "The Price of Policy Risk: Empirical Insights from Choice Experiments with European Photovoltaic Project Developers", *Energy Economics*, 34(4): 1001-11.

Marques, A C, J A Fuinhas and J Pires Manso (2010): "Motivations Driving Renewable Energy in European Countries: A Panel Data Approach", *Energy Policy*, 38(11): 6877-85.

Mitcell, C et al (2011): "Policy, Financing, and Implementation" in IPCC's *Special Report on Renewable Energy Sources and Climate Change Mitigation*, Cambridge University Press, pp 865-950.

MNRE (2011a): "Analysis of State RPO Regulations", http://mnre.gov.in/file-manager/User Files/Solar%20RPO/analysis-of-state-RPO-regulations.pdf

– (2011b): "Rajasthan Solar Policy", http://mnre.gov.in/file-manager/UserFiles/guidelines_ sbd_tariff_gridconnected_res/Rajasthan%20 Solar%20Policy%202011.pdf

– (2012a): "JNNSM Updata, 6 September 2012", http://mnre.gov.in/file-manager/UserFiles/ presentations-pwc-workshop-06092012/MNRE. pdf

– (2012b): "Madhya Pradesh Solar Policy", http://mnre.gov.in/file-manager/UserFiles/ guidelines_sbd_tariff_gridconnected_res/ Madhya%20Pradesh%20Solar%20Policy%20 2012.pdf

– (2012c): "JNNSM Documents", http://www.mnre.gov.in/solar-mission/jnnsm/introduction-2/

– (2012d): "Tamil Nadu Solar Policy", http:// mnre.gov.in/file-manager/UserFiles/guidelines_sbd_tariff_gridconnected_res/Tamilnadu%20Solar%20Energy%20Policy%202012. pdf

– (2012e): "Andhra Pradesh Solar Policy", http:// mnre.gov.in/file-manager/UserFiles/guidelines_sbd_tariff_gridconnected_res/Andhra %20Pradesh%20Solar%20Policy%202012.pdf

– (2013): "JNNSM, Phase 2 Draft Policy Document", http://mnre.gov.in/file-manager/User Files/draft-jnnsmpd-2.pdf

– (2014): "Physical Progress (Achievements)", http://www.mnre.gov.in/mission-and-vision-2 /achievements/

MOP (2011): "Power Compendium: A Compilation of Acts, Rules, Policies, Guidelines", http:// powermin.nic.in/acts_ notification/ pdf/power_compendium.pdf

Nelson, D, G Shrimali, S Goel, C Konda and R Kumar (2012): "Meeting Indias Renewable Targets: The Financing Challenge", http://climatepolicyinitiative.org/wp-content/uploads/ 2012/12/Meeting-Indias-Renewable-Targets-The-Financing-Challenge.pdf

Nilsson, H and C-O Wene (2001): "United Nations Framework Convention on Climate Change", http://unfccc.int/files/meetings/ workshops/ other_meetings/application/pdf/nilsson.pdf

NRDC (2012a): "Laying the Foundation for a Bright Future", http://www.nrdc.org/international/ india/files/layingthefoundation.pdf

– (2012b): "Concentrated Solar Power: Heating Up Solar Thermal Market under JNNSM", http://www.nrdc.org/international/india/ files/india-concentrated-solar-power.pdf

Nuwal, Vibhav (2012): "Issues in Implementing Solar REC Mechanism", REConnect Energy Solutions, http://natgrp.files. wordpress.com/2013 /05/session-4_reconnect-energy.pdf

NVVN (2010a): "NVVN Power Purchase Agreement", http:// www.nvvn.co.in/Annexure%20 2%20-4%20Power %20 Purchase %20Agreement%20(PPA)%20for%20NEW%20 PROJECTS.pdf

– (2010b): "NVVN Guidelines for Solar Grid Power Projects", http://www.nvvn.co.in/NVVN % 20Presentation.pdf

– (2012c): "NVVN Financial Report 2011-12", http://nvvn.co.in/FinReports/NVVNAnnual-Report2011-12.pdf

PIB (2013): "Status of Projects under JNNSM", http://pib.nic.in/newsite/PrintRelease.aspx? relid=98693

Raghavan, S and S Harish (2011): "Redesigning the National Solar Mission of Rural India", *Economic & Political Weekly*, 46 (23): 51-58.

REN (2013): "Renewables 2013 Global Status Report", http:// www.ren21. net/Portals/0/documents/Resources/GSR/2013/GSR2013_lowres. pdf

Shrimali, G and S Rohra (2012): "India's Solar Mission: A Review", *Renewable and Sustainable Energy Reviews*, 16(8): 6317-32.

Shrimali, G and S Tirumalachetty (2013): "Renewable Energy Certificate Markets in India: A Review", *Renewable and Sustainable Energy Reviews*, 26: 702-16.

Shrimali, G, S Goel, S Srinivasan and D Nelsom (2014): "Solving India's Renewable Financing Challenge: Which Federal Policies Can Be Most Effective?", http://climatepolicyinitiative.org/ wp-content/uploads/2014/03/Which-Federal-Policies-can-be-Most-Effective.pdf

3TIER (2010): "3TIER Global Solar Dataset: Methodology and Validation Retrieved", http:// www.3tier.com/static/ttcms/us/documents/ publications/validations/3TIER_Global_Solar_Validation.pdf

**Appendix 1: Estimated plant output across India by CERC**

**Table 1: Estimated Plant Output/MWp** (from CERC)

| Sl No | City | Average Radiation (KWh/m²) | Ambient Temp Deg | Crystalline Output MWh | CUF % | Thin Film Output MWh | CUF % | Optimum Tilt (Deg) |
|---|---|---|---|---|---|---|---|---|
| 1 | Srinagar | 4.1 | 13.6 | 1,337.97 | 15.27 | 1,373.51 | 15.68 | 34.1 |
| 2 | Delhi | 5.09 | 25.1 | 1,611.90 | 18.4 | 1,708.40 | 19.5 | 28.6 |
| 3 | Jodhpur | 5.52 | 26.1 | 1,732.40 | 19.78 | 1,845.10 | 21.06 | 26.3 |
| 4 | Jaipur | 5.52 | 26.1 | 1,741.10 | 19.88 | 1,854.40 | 21.17 | 26.8 |
| 5 | Varanasi | 4.88 | 25.1 | 1,521.90 | 17.37 | 1,609.20 | 18.37 | 25.3 |
| 6 | Patna | 4.83 | 25.3 | 1,509.80 | 17.24 | 1,596.40 | 18.22 | 25.6 |
| 7 | Shillong | 4.54 | 16.5 | 1,510.05 | 17.24 | 1,556.50 | 17.77 | 25.6 |
| 8 | Ahmedanad | 5.35 | 27.5 | 1,643.20 | 18.76 | 1,753.80 | 20.02 | 23.1 |
| 9 | Bhopal | 5.23 | 25.3 | 1,635.35 | 18.67 | 1,734.89 | 19.8 | 23.3 |
| 10 | Ranchi | 4.7 | 24.3 | 1,484.00 | 16.94 | 1,562.46 | 17.84 | 23.4 |
| 11 | Kolkata | 4.5 | 26.9 | 1,378.60 | 15.74 | 1,458.30 | 16.65 | 22.5 |
| 12 | Bhavnagar | 5.7 | 27.2 | 1,743.20 | 19.9 | 1,863.80 | 21.28 | 21.8 |
| 13 | Nagpur | 5.12 | 27 | 1,563.27 | 17.85 | 1,662.80 | 18.98 | 21.1 |
| 14 | Mumbai | 5.03 | 27.5 | 1,506.13 | 17.19 | 1,601.85 | 18.29 | 19.1 |
| 15 | Pune | 5.41 | 24.7 | 1,648.50 | 18.82 | 1,745.40 | 19.92 | 18.5 |
| 16 | Hyderabad | 5.67 | 26.7 | 1,706.00 | 19.47 | 1,818.70 | 20.76 | 17.5 |
| 17 | Vishakapatnam | 5.13 | 28.4 | 1,537.20 | 17.55 | 1,638.90 | 18.71 | 17.7 |
| 18 | Panjim | 5.5 | 27.4 | 1,645.87 | 18.79 | 1,756.70 | 20.05 | 15.5 |
| 19 | Chennai | 5.36 | 28.8 | 1,560.40 | 17.81 | 1,667.60 | 19.04 | 13 |
| 20 | Bangalore | 5.47 | 24.1 | 1,642.90 | 18.75 | 1,736.10 | 19.82 | 13 |
| 21 | Port Blair | 4.73 | 26.2 | 1,420.00 | 16.21 | 1,500.27 | 17.13 | 11.7 |
| 22 | Minicoy | 27.2 | 27.5 | 1,487.30 | 16.98 | 1,577.50 | 18.01 | 8.3 |
| 23 | Thiruvanantapuram | 5.41 | 27.3 | 1,581.30 | 18.05 | 1,682.50 | 19.21 | 8.5 |
| 24 | Chandrapur | 5.12 | 27.5 | 1,562.59 | 17.84 | 1,664.87 | 19.01 | 20 |
| 25 | Pahalgam | 4.7 | 0 | 1,703.90 | 19.45 | 1,698.50 | 19.39 | 34 |
| 26 | Gangapur | 4.97 | 25 | 1,569.60 | 17.92 | 1,659.70 | 18.95 | 26.5 |
| 27 | Ludhiana | 5.23 | 22.6 | 1,708.10 | 19.5 | 1,801.80 | 20.57 | 30.9 |
| 28 | Manali | 4.59 | 1.6 | 1,664.50 | 19 | 1,650.20 | 18.84 | 32.3 |
| 29 | Dehra Dun | 5.32 | 11.4 | 1,837.40 | 20.97 | 1,884.20 | 21.51 | 30.3 |
| 30 | Churu | 4.92 | 24.1 | 1,555.70 | 17.76 | 1,641.50 | 18.74 | 28.3 |
| 31 | Jaisalmer | 5.17 | 25.9 | 1,609.10 | 18.37 | 1,708.40 | 19.5 | 26.9 |
| 32 | Allahbad | 5.79 | 25.9 | 1,822.50 | 20.8 | 1,943.90 | 22.19 | 25.5 |
| 33 | Darjeeling | 4.8 | 9 | 1,641.00 | 18.73 | 1,663.60 | 18.99 | 27.1 |
| 34 | Dibrugarh | 3.92 | 17.1 | 1,320.58 | 15.08 | 1,357.42 | 15.5 | 27.5 |
| 35 | Kota | 5.08 | 25.4 | 1,592.70 | 18.18 | 1,686.70 | 19.25 | 25.2 |
| 36 | Palanpur | 5.15 | 26.6 | 1,594.80 | 18.21 | 1,694.90 | 19.35 | 24.2 |
| 37 | Vadodara | 5.29 | 27.5 | 1,621.60 | 18.51 | 1,730.20 | 19.75 | 22.3 |
| 38 | Bhuvaneshwar | 4.82 | 26.9 | 1,476.63 | 16.86 | 1,566.03 | 17.88 | 20.3 |
| 39 | Ahmadnahar | 5.17 | 25.6 | 1,582.70 | 18.07 | 1,678.87 | 19.17 | 19.1 |
| 40 | Machilipatnam | 4.95 | 28 | 1,479.50 | 16.89 | 1,573.60 | 17.96 | 16.2 |
| 41 | Mangalore | 5.08 | 27.3 | 1,513.06 | 17.27 | 1,608.91 | 18.37 | 12.9 |
| 42 | Coimbatore | 5.12 | 26.2 | 1,512.30 | 17.26 | 1,601.90 | 18.29 | 11 |
| 43 | Dindigul | 5 | 24.9 | 1,485.40 | 16.96 | 1,566.20 | 17.88 | 10.4 |
| 44 | Amini | 5.76 | 27.4 | 1,690.90 | 19.3 | 1,690.90 | 19.3 | 11.1 |
| 45 | Jallandhur | 5.39 | 20.4 | 1,766.80 | 20.17 | 1,856.30 | 21.19 | 31.3 |
| 46 | Rae Bareli | 5.05 | 24.9 | 1,594.80 | 18.21 | 1,687.60 | 19.26 | 26.2 |
| 47 | Nadiad | 5.6 | 28.16 | 1,630.6 | 18.61 | 1,741.80 | 19.88 | 22.7 |
| 48 | Okha | 6.11 | 26.1 | 1,895.3 | 21.64 | 2,025.6 | 23.12 | 22.2 |
| 49 | Bhatinda | 5.08 | 23.4 | 1,648.70 | 18.82 | 1,740.4 | 19.87 | 30.2 |
| 50 | Dindigul | 5 | 24.9 | 1,501.4 | 17.14 | 1,583.1 | 19.87 | 10.4 |
| 51 | Siliguri | 4.85 | 19.4 | 1,626 | 18.56 | 1,693.9 | 19.34 | 26.7 |
| 52 | Ajmer | 5.14 | 24.7 | 1,633.9 | 18.65 | 1,728.3 | 19.73 | 26.5 |

Source: Central Electricity Regulatory Commission India – Performance of solar power plants in India (CERC 2011).

**Appendix 2: Status of Solar PV Projects**

**Table 2: Solar PV Phase 1-Batch 1 (Under NVVN)**

(A) Phase 1- Batch 1: Individual status of projects (Under NVVN)

| No | Name of Project Commissioned | State | Capacity (MW) | Commissioned (MW) | Date of Commissioning | Tariff Awarded (In INR) | Tariff Awarded (In USD) [i] |
|---|---|---|---|---|---|---|---|
| 1 | Aftaab Solar Pvt. Limited | Odisha | 5 | 5 | Jul-12 | 12.72 | 0.25 |
| 2 | Alex Spectrum Radiation Private Limited | Rajasthan | 5 | 5 | Feb-12 | 12.49 | 0.25 |
| 3 | Amrit Energy Pvt. Limited | Rajasthan | 5 | 5 | Feb-12 | 12.75 | 0.26 |
| 4 | Azure Power (Rajasthan) Pvt Ltd | Rajasthan | 5 | 5 | Jan-12 | 11.94 | 0.24 |
| 5 | CCCL Infrastructure Limited | Tamilnadu | 5 | 5 | Mar-12 | 12.7 | 0.25 |
| 6 | DDE Renewable Energy Private Limited | Rajasthan | 5 | 5 | Feb-12 | 11.55 | 0.23 |
| 7 | Electromech Maritech Pvt Ltd | Rajasthan | 5 | 5 | Jan-12 | 11.99 | 0.24 |
| 8 | EMC Limited | UP | 5 | 5 | Apr-12 | 11.6 | 0.23 |
| 9 | Finehope Allied Engineering Private | Rajasthan | 5 | 5 | Jul-12 | 11.65 | 0.23 |
| 10 | Greentech Power Private Ltd | Rajasthan | 5 | 5 | Aug-12 | 11.7 | 0.23 |
| 11 | Indian Oil Corporation Limited | Rajasthan | 5 | 5 | Feb-12 | 12.54 | 0.25 |
| 12 | Karnataka Power Corporation Limited | Karnataka | 5 | 5 | Jun-12 | 11.69 | 0.23 |
| 13 | Khaya Solar Projects Private Limited | Rajasthan | 5 | 5 | Jan-12 | 11.5 | 0.23 |
| 14 | Maharashtra Seamless Limited | Rajasthan | 5 | 5 | Jul-12 | 12.24 | 0.24 |
| 15 | Mahindra Solar One Private Limited | Rajasthan | 5 | 5 | Mar-12 | 11.89 | 0.24 |
| 16 | Newton Solar Private Limited | Rajasthan | 5 | 5 | Sep-12 | 11.7 | 0.23 |
| 17 | Northwest Energy Private Limited | Rajasthan | 5 | 5 | Jul-12 | 12.38 | 0.25 |
| 18 | Oswal Woollen Mills Limited | Rajasthan | 5 | 5 | Oct-12 | 12.75 | 0.26 |
| 19 | Precision Technik Private Limited | Rajasthan | 5 | 5 | Mar-12 | 12.76 | 0.26 |
| 20 | Punjlloyd Solar Power Limited | Rajasthan | 5 | 5 | Aug-12 | 12.73 | 0.25 |
| 21 | Saidham Overseas Private Limited | Rajasthan | 5 | 5 | Jan-12 | 11.97 | 0.24 |
| 22 | Saisudhir Energy Limited | AP | 5 | 5 | May-12 | 11.75 | 0.24 |
| 23 | SEI Solar Energy Private Limited | Rajasthan | 5 | 5 | Jan-12 | 12 | 0.24 |
| 24 | Vasavi Solar Power Pvt. Limited | Rajasthan | 5 | 5 | Feb-12 | 12.39 | 0.25 |
| 25 | Viraj Renewables Energy | Rajasthan | 5 | 5 | May-12 | 11.65 | 0.23 |
| 26 | Welspun Solar AP Private limited | AP | 5 | 5 | Jan-12 | 12.37 | 0.25 |
| 27 | Rithwik Projects Private Limited | AP | 5 | – | – | | |
| 28 | FireStone Trading Private Limited | Maharashtra | 5 | – | – | | |
| | | Total | 140 | 130 | | | |

Source: JNNSM, Ministry of New and Renewable energy, documents, Commissioning status SPV Batch 1 Phase 1 (JNNSM 2012).

**Table 3: Solar PV Phase 1-Batch 1 (Under RPSSGP)**

(B) Phase 1- Batch 1: Individual status of projects (Under RPSSGP)
*(Tariff: USD 0.35/Kwh) [i]

| No | Name of Project Commissioned | State | Solar PV Capacity Allocated as per PPA (MW) | Solar PV Capacity Actually Commissioned (MW) | Date of Commission-ing |
|---|---|---|---|---|---|
| 1 | Sri Power Generation (India) Private Limited | Andhra Pradesh | 1 | 1 | 14-1-2012 |
| 2 | AmritJal Ventures Pvt Ltd | Andhra Pradesh | 1 | 1 | 7-3-2012 |
| 3 | Andhra Pradesh Power Generation Corporation Ltd | Andhra Pradesh | 1 | 1 | 10-1-2012 |
| 4 | Ramakrishna Industries | Andhra Pradesh | 1 | 1 | 16-9-2011 |
| 5 | Singhal Forestry Private Limited | Chhattisgarh | 2 | 2 | 15-11-2011 |
| 6 | Chhattisgarh Investments Ltd | Chhattisgarh | 2 | 2 | 14-10-2011 |
| 7 | Chandraleela Power Energy Private Limited | Haryana | 0.8 | 0.8 | 15-1-2012 |
| 8 | Zamil New Delhi Infrastructure Private Limited | Haryana | 1 | 1 | 27-1-2012 |
| 9 | SDS Solar Private Limited | Haryana | 1 | 1 | 21-10-2011 |
| 10 | Sukhbir Solar Energy Private Limited | Haryana | 1 | 1 | 15-12-2011 |
| 11 | C&S Electric ltd | Haryana | 1 | 1 | 28-6-2011 |
| 12 | Dr Babasaheb Ambedkar Sahakari Sakhar Karkhana Ltd | Maharashtra | 1 | 1 | 30-7-2011 |
| 13 | Sepset Constructions Limited | Maharashtra | 2 | 2 | 16-11-2011 |
| 14 | Citra RealEstate Limited | Maharashtra | 2 | 2 | 16-11-2011 |
| 15 | MGM Minerals Ltd | Odisha | 1 | 1 | 13-10-2011 |
| 16 | Raajratna Energy Holdings Private Limited | Odisha | 1 | 1 | 30-6-2011 |
| 17 | S N Mohanty | Odisha | 1 | 1 | 23-8-2011 |
| 18 | Molisati Vinimay Pvt Ltd | Odisha | 1 | 1 | 22-12-2011 |
| 19 | Soma Enterprise Limited | Punjab | 1 | 1 | 3-12-2011 |
| 20 | AEW Infratech Pvt Ltd | Rajasthan | 1 | 1 | 5-1-2012 |
| 21 | Asian Aero- Edu Aviation Private Limited | Rajasthan | 1 | 1 | 2-12-2011 |
| 22 | Basant Enterprises | Rajasthan | 1 | 1 | 13-1-2012 |
| 23 | Zamil New Delhi Infrastructure Private Limited | Rajasthan | 1 | 1 | 11-1-2012 |
| 24 | Navbharat Buildcon Pvt Ltd | Rajasthan | 1 | 1 | 10-2-2012 |
| 25 | Lanco Solar Pvt Ltd | Rajasthan | 1 | 1 | 19-9-2011 |
| 26 | B&G Solar Private Limited | Tamil Nadu | 1 | 1 | 10-6-2011 |
| 27 | RL Clean Power Pvt Ltd | Tamil Nadu | 1 | 1 | 25-7-2011 |
| 28 | Great Shine Holdings Pvt Ltd | Tamil Nadu | 1 | 1 | 28-1-2012 |
| 29 | RV Akash Ganga Infrastructure Ltd | Uttarakha-nd | 2 | 2 | 13-1-2012 |
| 30 | Technical Associates Ltd | Uttar Pradesh | 2 | 2 | 30-1-2012 |
| 31 | Kijalk Infrastructure Pvt Ltd | Jharkhand | 2 | 2 | 16-1-2012 |
| 32 | Metro Frozen Fruits and Vegetables Ltd | Uttrakhand | 1 | 1 | 9-3-2012 |
| 33 | Andromeda Energy Tech Pvt Ltd | Andhra Pradesh | 0.75 | 0.75 | 15-3-2012 |
| 34 | Vivek Pharmachem (India) Limited | Rajasthan | 1 | 1 | 10-3-2012 |
| 35 | Ecoenergy Inc | Punjab | 1 | 1 | 2-3-2012 |
| 36 | Sovox Renewables Private Limited | Punjab | 1 | 1 | 16-3-2012 |
| 37 | G S Atwal & Co (Engineers) Pvt Ltd | Punjab | 1.5 | 1.5 | 10-3-2012 |
| 38 | Amson Power Private Limited | Tamil Nadu | 1 | 1 | 14-3-2012 |
| 39 | SunEdison Energy India Private Limited | Rajasthan | 1 | 1 | 10-3-2012 |
| 40 | Kishore Electro Infra Pvt Ltd | Andhra Pradesh | 1 | 1 | 13-3-2012 |
| 41 | Harrisons Power Private Limited | Tamil Nadu | 1 | 1 | 14-3-2012 |
| 42 | Gajanan Financial Services Pvt Ltd | Andhra Pradesh | 1 | 1 | 14-3-2012 |
| 43 | Dhruv Milkose Pvt Ltd | Uttar Pradesh | 1 | 1 | 13-3-2012 |
| 44 | Photon Energy Systems Limited | Andhra Pradesh | 1 | 1 | 15-3-2012 |
| 45 | Dante Energy Private Limited | Uttar Pradesh | 2 | 2 | 16-3-2012 |
| 46 | Tayal & Co | Haryana | 1 | 1 | 13-3-2012 |
| 47 | VKG Energy Pvt Ltd | Haryana | 1 | 1 | 15-3-2012 |
| 48 | HR Minerals and Alloys Pvt Ltd | Haryana | 1 | 1 | 10-3-2012 |
| 49 | Carlil Energy pvt ltd | Punjab | 1.5 | 1.5 | 24-2-2012 |
| 50 | Abacus Holdings Pvt Ltd | Odisha | 1 | 1 | 13-3-2012 |
| 51 | Bhavani Engineering | Andhra Pradesh | 1 | 1 | 14-3-2012 |
| 52 | PCS Premier Energy Pvt Ltd | Jharkhand | 2 | 2 | 24-2-2012 |
| 53 | Jay ace Technologies Ltd | Uttarakha-nd | 2 | 2 | 13-3-2012 |
| 54 | Sovox Renewables Private Limited | Rajasthan | 1 | 1 | 13-3-2012 |
| 55 | Andhra Pradesh Industrial infracstructure Corp ltd | Andhra Pradesh | 1 | 1 | 15-3-2012 |
| 56 | New Era Enviro Ventures Pvt Ltd | Jharkhand | 2 | 2 | 31-3-2012 |
| 57 | Premier solar systems Pvt Ltd | Jharkhand | 2 | 2 | 30-3-2012 |
| 58 | Conflux Infratec Private Limited | Rajasthan | 1 | 1 | 16-3-2012 |
| 59 | Enertech Engineering Private Limited | Jharkhand | 2 | 2 | 20-4-2012 |
| 60 | Pantime Finance Company Private Limited | Odisha | 1 | 1 | 16-03-2012 |
| 61 | Shri Mahavir Ferro Alloys Private Limited | Odisha | 1 | 1 | 15-3-2012 |
| 62 | KVR Constructions | Jharkhand | 2 | 2 | 21-4-2012 |
| 63 | AKR Constructions Ltd | Jharkhand | 2 | 2 | 7-6-2012 |
| 64 | Saimeg Infrastructure Pvt Ltd | Jharkhand | 2 | 2 | 16-6-2012 |
| 65 | Priapus Infrastructure Ltd | Uttar Pradesh | 2 | 2 | 16-3-2012 |
| 66 | Adora Energy Private Limited | Madhya Pradesh | 2 | 2 | 19-6-2012 |
| 67 | J S R Developers Pvt Ltd | Madhya Pradesh | 1.25 | 1.25 | 13-6-2012 |
| 68 | Shiv-Vani Energy Limited | Madhya Pradesh | 2 | 2 | 16-6-2012 |
| 69 | Rays Power Private Limited | Rajasthan | 1 | 1 | 14-2-2012 |
| 70 | Jay Iron & Steels Limited | Orissa | 1 | - | |
| 71 | Noel Media & Advertising Pvt Ltd | Tamil Nadu | 1 | - | |
| 72 | Eastern Bearings Pvt Ltd | Uttar Pradesh | 1 | - | |
| 73 | Ganges Enterprises Private Limited | Rajasthan | 1 | - | |
| 74 | Bharat Petroleum Corporation Ltd | Punjab | 1 | - | |
| 75 | Reliable Manpower Solutions Ltd | Haryana | 1 | - | |
| 76 | Solar Semiconductor Pvt Ltd | Andhra Pradesh | 0.75 | - | |
| 77 | Gemini Geoss Energy Pvt Ltd | Tamil Nadu | 1 | - | |
| 78 | Enterprise Business Solutions | Punjab | 1.5 | - | |
| | | Total | 98.05 | 88.80 | |

Source: JNNSM, Ministry of New and Renewable energy, documents, Commissioning status SPV Batch 1 Phase 1 (JNNSM 2012).

**Table 4: Solar PV- Phase 1-Batch 1 (Under Migration)**

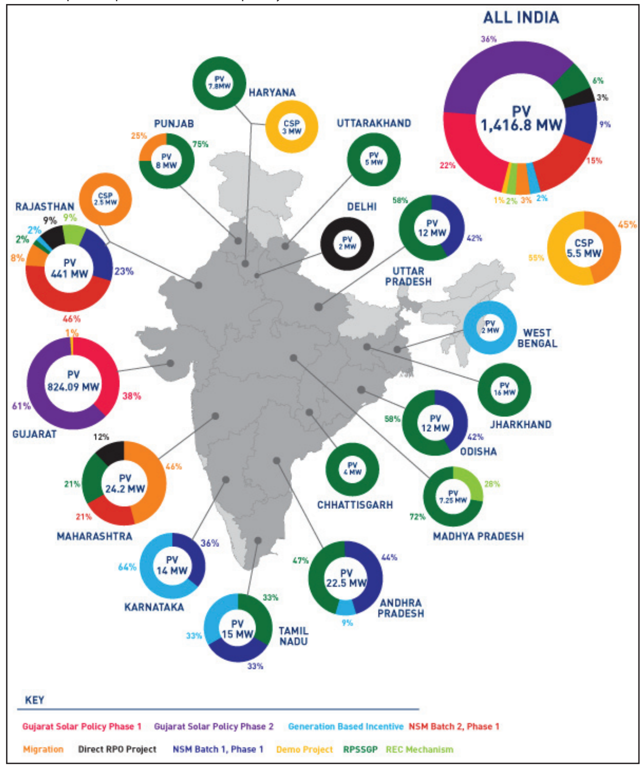
(C) Phase 1- Batch 1: Individual status of projects[1] (Under Migration)
(CERC Applicable tariff)

| No | Name of Project Commissioned | State | Solar PV Capacity Allocated as per PPA (MW) | Solar PV Capacity Actually Commissioned (MW) |
|---|---|---|---|---|
| 1 | Clover Solar Pvt Ltd, Mumbai | Maharashtra | 2 | 2 |
| 2 | Maharashtra State Power Generation Co Limited, Mumbai | Maharashtra | 4 | 4 |
| 3 | Videocon Industries Ltd, Mumbai | Maharashtra | 5 | 5 |
| 4 | Azure Power (Punjab) Pvt Ltd, Amritsar Pvt Ltd, Gurgaon, Haryana | Punjab | 2 | 2 |
| 5 | AES Solar Energy | Rajasthan | 5 | 5 |
| 6 | Aston Field Solar (Rajasthan) Pvt Ltd | Rajasthan | 5 | 5 |
| 7 | Comet Power Pvt Ltd, Mumbai | Rajasthan | 5 | 5 |
| 8 | Moser Baer Photo Voltaic Ltd, New Delhi | Rajasthan | 5 | 5 |
| 9 | OPG Energy Pvt Ltd, Chennai, Tamil Nadu | Rajasthan | 5 | 5 |
| 10 | Refex Refrigerants Limited, Chennai | Rajasthan | 5 | 5 |
| 11 | Swiss Park Vanijya Pvt Ltd | Rajasthan | 5 | 5 |
| 12 | Enterprise Business Solutions | Rajasthan | 5 | - |
| 13 | Entegra Ltd | Rajasthan | 1 | - |
| | Total | | 54 | 48 |

[1] No data on the completion dates has been published by MNRE till date.
Source: JNNSM, Ministry of New and Renewable energy, documents, Commissioning status SPV Batch 1 Phase 1 (JNNSM 2012).

**Figure 1: Solar Power Plants Installed Capacity: State-wise**

(E) Solar power plants installed capacity: State wise




Source: Bridge to India Solar compass, April 2013 (BTI 2013).

**Table 5: Solar PV Phase 1-Batch 2 (Under NVVN)**

(D) Phase 1- Batch 2: Individual status of projects (Under NVVN)

| Developer | State | Capacity (MW) | Commissioned (MW) | Date | Balance | Tariff Awarded (in INR) | Tariff Awarded (in USD)[i] |
|---|---|---|---|---|---|---|---|
| Solaire Direct | Rajasthan | 5 | 5 | Feb-13 | 0 | 7.49 | 0.15 |
| Welspun Solar | Rajasthan | 15 | 15 | Jan-13 | 0 | 8.14 | 0.16 |
| Welspun Solar | Rajasthan | 15 | 15 | Jan-13 | 0 | 8.05 | 0.16 |
| Welspun Solar | Rajasthan | 20 | 20 | Feb-13 | 0 | 8.21 | 0.16 |
| Azure power | Rajasthan | 35 | 35 | Feb-13 | 0 | 8.21 | 0.16 |
| Sai Sudhir Energy | AP | 20 | 20 | Apr-26 | 0 | 8.22 | 0.16 |
| VS Lignite power(KSK-Sai maithili) | Rajasthan | 10 | 10 | Feb-13 | 0 | 8.28 | 0.17 |
| Symphony Vyapara | Rajasthan | 10 | 10 | Feb-13 | 0 | 8.48 | 0.17 |
| Jackson power | Rajasthan | 20 | 20 | Feb-13 | 0 | 8.615 | 0.17 |
| Shree Sai baba Sugar | Maharasthra | 5 | 5 | Mar-13 | 0 | 8.73 | 0.17 |
| Lepl Projects | Rajasthan | 10 | 10 | Mar-13 | 0 | 8.91 | 0.18 |
| Sunbourne Energy | Rajasthan | 5 | 5 | Mar-13 | 0 | 8.99 | 0.18 |
| Sujana towers | Rajasthan | 10 | Cancelled | | | 9.09 | 0.18 |
| Fonroche Energies | Rajasthan | 5 | 5 | Dec-12 | 0 | 9.1 | 0.18 |
| Fonroche Energies | Rajasthan | 15 | 15 | Mar-13 | 0 | 9.16 | 0.18 |
| NVR infrastructure | Rajasthan | 10 | 10 | Feb-13 | 0 | 9.16 | 0.18 |
| Enfield Infrastructure | Rajasthan | 10 | 0 | -- | 10 | 9.27 | 0.19 |
| Essel Infra projects | Maharasthra | 20 | 0 | -- | 20 | 9.28 | 0.19 |
| SEI Power (Sun edison) | Rajasthan | 20 | 20 | Mar-13 | 0 | 9.32 | 0.19 |
| GAIL | Rajasthan | 5 | 5 | Feb-13 | 0 | 9.32 | 0.19 |
| Mahindra Solar One | Rajasthan | 30 | 30 | Feb-13 | 0 | 9.34 | 0.19 |
| Kiran Energy Solar (aka Solar field energy) | Rajasthan | 20 | 20 | Feb-13 | 0 | 9.34 | 0.19 |
| Green infra Solar project | rajasthan | 5 | 5 | Dec-12 | 0 | 9.44 | 0.19 |
| Green infra solar farm | rajasthan | 20 | 20 | Feb-13 | 0 | 9.39 | 0.19 |
| Lexicon Vanigya | Rajasthan | 10 | 10 | Feb-13 | 0 | 8.69 | 0.17 |
| Total | | 340 | 310 | | 30 | | |

Source: JNNSM, Ministry of New and Renewable energy, documents, Commissioning status SPV Batch 2 Phase 1 (JNNSM 2013).

## Appendix 3: Solar Thermal under Phase 1

**Table 6: Solar Thermal Phase 1-Batch 1 (Under NVVN)**

(A) Phase 1-Batch 1: Individual status of projects (Under NVVN)

| No | Bidder Name | State | Capacity (MW) | Commissioned (MW) | Tariff Awarded (In RS) |
|---|---|---|---|---|---|
| 1 | Rajasthan Sun Technique Energy Private Limited | Rajasthan | 100 | 0 | 11.97 |
| 2 | Lanco Infratech Limited | Rajasthan | 100 | 0 | 10.49 |
| 3 | KVK Energy Ventures Private Limited | Rajasthan | 100 | 0 | 11.20 |
| 4 | Megha Engineering and Infrastructures Ltd | AP | 50 | 0 | 11.31 |
| 5 | Godawari Power and Ispat Limited | Rajasthan | 50 | 50 | 12.20 |
| 6 | Corporate Ispat Alloys Limited | Rajasthan | 50 | 0 | 12.24 |
| 7 | Aurum Renewable Energy Private Limited | Gujarat | 20 | 0 | 12.19 |
| | Total | | 470 | 50 | |

Source: JNNSM, Ministry of New and Renewable energy, documents, Commissioning status SPV Batch 1 Phase 1 (JNNSM 2013).

**Table 7: Solar Thermal Phase 1-Batch 1 (Under Migration Scheme)**

(CERC Applicable Tariff)

(B) Phase 1-Batch 1: Individual status of projects (Under Migration Scheme)

| No | Bidder Name | State | Capacity(MW) | Commissioned (MW) |
|---|---|---|---|---|
| 8 | Acme | Rajasthan | 10 | 2.5 |
| 10 | Entegra | Rajasthan | 10 | 0 |
| 11 | Dalmia Cements | Rajasthan | 10 | 0 |
| | Total | | 30 | 3.5 |

Source: JNNSM, Ministry of New and Renewable energy, documents, Commissioning status SPV Batch 1 Phase 1 (JNNSM 2012).

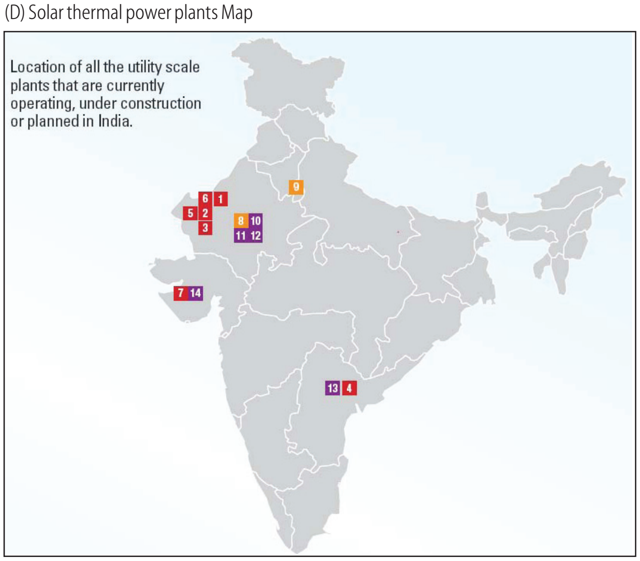
**Table 8: Solar Thermal Prior JNNSM**

(C) Projects launched prior to JNNSM

| No | Bidder Name | State | Capacity (MW) | Commissioned (MW) |
|---|---|---|---|---|
| 9 | MNRE R&D Project | Haryana | 3 | 3 |
| 12 | NTPC Pilot Project | Rajasthan | 15 | 0 |
| 13 | Sunbourne Energy | Andhra Pradesh | 50 | 0 |
| 14 | Cargo Solar Power Project Gujarat Pvt Ltd | Gujarat | 25 | 0 |
| | Total | | 93 | 3 |

**Figure 2: Solar Thermal Power Plants Installed or under Construction**

(D) Solar thermal power plants Map




The numbering for the above plants is based on the tables 6, 7 and 8 in appendix 3.

Source: CSPT (2013).

## Appendix 4: State RPO Requirements

**Table 9: State-wise RPO Requirements for Financial Year 2013**

(A) State RPO requirements for FY 2013

| State | | Projected Demand* (MU) (2012-13) | Solar RPO Target (2012-13) (%) | Solar RPO Target (2012-13) (MU) | Capacity Required for Meeting Solar RPO (MW) | Total Capacity Tied Up as on 9 March 2013 (MW) | Installed Capacity as on 9 March 2013 (MW) | Gap to be Fulfiled 2012-13 (MW) |
|---|---|---|---|---|---|---|---|---|
| 1 | Andhra Pradesh | 98,956 | 0.25 | 247.39 | 148.6 | 77.7 | 23.35 | 70.94 |
| 2 | Arunachal Pradesh | 631 | 0.10 | 0.63 | 0.4 | 0.025 | 0.03 | 0.35 |
| 3 | Assam | 6,810 | 0.15 | 10.21 | 6.1 | 5 | – | 1.14 |
| 4 | Bihar | 15,272 | 0.25 | 38.18 | 22.9 | 0 | – | 22.94 |
| 5 | Chhattisgarh | 21,174 | 0.50 | 105.87 | 63.6 | 29 | 4.00 | 34.61 |
| 6 | Delhi | 28,598 | 0.15 | 42.90 | 25.8 | 2.525 | 2.53 | 23.25 |
| 7 | JERC (Goa & UT) | 12,860 | 0.40 | 51.44 | 30.9 | 1.685 | 1.69 | 29.22 |
| 8 | Gujarat | 79,919 | 1.00 | 799.19 | 480.2 | 968.5 | 824.09 | -488.33 |
| 9 | Haryana | 40,167 | 0.05 | 20.08 | 12.1 | 8.8 | 7.80 | 3.27 |
| 10 | Himachal Pradesh | 8,647 | 0.25 | 21.62 | 13.0 | 0 | – | 12.99 |
| 11 | Jammu and Kashmir | 14,573 | 0.25 | 36.43 | 21.9 | 0 | – | 21.89 |
| 12 | Jharkhand | 6,696 | 1.00 | 66.96 | 40.2 | 36 | 16.00 | 4.23 |
| 13 | Karnataka | 65,152 | 0.25 | 162.88 | 97.9 | 159 | 14.00 | -61.14 |
| 14 | Kerala | 21,060 | 0.25 | 52.65 | 31.6 | 0.025 | 0.03 | 31.61 |
| 15 | Madhya Pradesh | 53,358 | 0.60 | 320.15 | 192.3 | 211.75 | 11.75 | -19.40 |
| 16 | Maharashtra | 150,987 | 0.25 | 377.47 | 226.8 | 75.5 | 34.50 | 151.29 |
| 17 | Manipur | 608 | 0.25 | 1.52 | 0.9 | 0 | – | 0.91 |
| 18 | Mizoram | 418 | 0.25 | 1.04 | 0.6 | 0 | – | 0.63 |
| 19 | Meghalaya | 2,154 | 0.40 | 8.62 | 5.2 | 0 | – | 5.18 |
| 20 | Nagaland | 596 | 0.25 | 1.49 | 0.9 | 0 | – | 0.90 |
| 21 | Orissa | 24,284 | 0.15 | 36.43 | 21.9 | 78 | 13.00 | -56.11 |
| 22 | Punjab | 48,089 | 0.09 | 43.28 | 26.0 | 51.825 | 9.33 | -25.82 |
| 23 | Rajasthan | 55,057 | 0.75 | 412.93 | 248.1 | 331.15 | 442.25 | -83.05 |
| 24 | Sikkim | 436 | 0.00 | – | – | 0 | – | 0.00 |
| 25 | Tamil Nadu | 91,441 | 0.05 | 45.72 | 27.5 | 20.105 | 17.06 | 7.36 |
| 26 | Tripura | 1,010 | 0.10 | 1.01 | 0.6 | 0 | – | 0.61 |
| 27 | Uttarakhand | 11,541 | 0.05 | 5.77 | 3.5 | 5.05 | 5.05 | -1.58 |
| 28 | Uttar Pradesh | 85,902 | 1.00 | 859.02 | 516.1 | 93.375 | 12.38 | 422.74 |
| 29 | West Bengal | 41,896 | 0.25 | 104.74 | 62.9 | 52.05 | 2.00 | 10.88 |
| | Total | | | | 2,328.5 | 2,207.07 | 1,440.81 | |

Source: MNRE (2012, 2013).

**Table 10: State-wise RPO Requirement Percentage from Financial Year 2013 to 2017**

(B) State RPO requirement percentage from FY 13 to FY 17

| | State | FY13 | FY14 | FY15 | FY16 | FY17 |
|---|---|---|---|---|---|---|
| 1 | Andhra Pradesh | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| 2 | Assam | 0.15 | 0.20 | 0.25 | | |
| 3 | Bihar | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 |
| 4 | Chhattisgarh | 0.50 | | | | |
| 5 | Delhi | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 |
| 6 | Gujarat | 1.00 | | | | |
| 7 | Haryana | 0.05 | 0.10 | | | |
| 8 | Himachal Pradesh | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| 9 | Jammu and Kashmir | 0.25 | | | | |
| 10 | Jharkhand | 1.00 | | | | |
| 11 | Karnataka | 0.25 | | | | |
| 12 | Kerala | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| 13 | Madhya Pradesh | 0.60 | 0.80 | 1.00 | | |
| 14 | Maharashtra | 0.25 | 0.50 | 0.50 | 0.50 | |
| 15 | Manipur | 0.25 | | | | |
| 16 | Mizoram | 0.25 | | | | |
| 17 | Meghalaya | 0.40 | | | | |
| 18 | Nagaland | 0.25 | | | | |
| 19 | Orissa | 0.15 | 0.20 | 0.25 | 0.30 | |
| 20 | Punjab | 0.09 | 0.13 | 0.19 | | |
| 21 | Rajasthan | 0.75 | 1.00 | | | |
| 22 | Tamil Nadu | 0.05 | | | | |
| 23 | Tripura | 0.10 | | | | |
| 24 | Uttarakhand | 0.05 | | | | |
| 25 | Uttar Pradesh | 1.00 | | | | |
| 26 | West Bengal | 0.25 | 0.30 | 0.40 | 0.50 | 0.60 |

Source: JNNSM Phase 2 policy document (MNRE 2013).

**Table 11: State Level Solar Policy Announced Capacities**

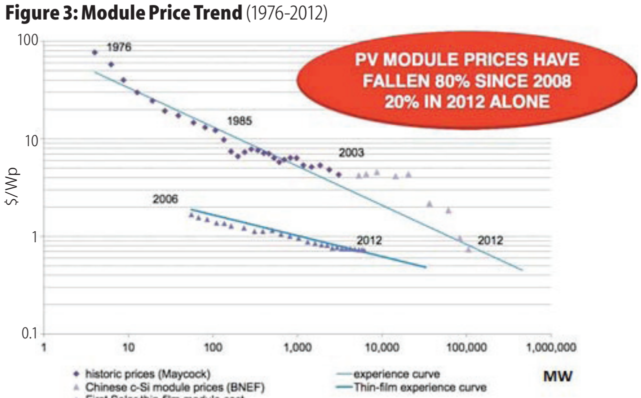
(C) Capacities of State level solar policies either announced or already under construction

| No | State | Capacity (MW) |
|---|---|---|
| 1 | Gujarat | 968.5 |
| 2 | Maharasthra | 205 |
| 3 | Karnataka | 210 |
| 4 | Rajasthan | 200 |
| 5 | Odisha | 50 |
| 6 | Madhya Pradesh | 200 |
| 7 | Tamil Nadu | 3,000 |
| 8 | Andhra Pradesh | 1,000 |
| 9 | Chattisgarh | 1000 |
| 10 | Uttar pradesh | 500 |
| 11 | Punjab | 300 |
| 12 | Bihar | 150 |
| | Total | 7,783.5 |

Source: Multiple state Solar policy documents. APTRANSCO (2013); BSPHCL (2012); KRECL, ORED (2012); PEDA (2012); MNRE (2013).

**Appendix 5: Module and Plant Pricing**

**Figure 3: Module Price Trend** (1976-2012)




Prices inflation indexed to US PPI

Source: Presentation on Global trends in clean energy investment by Bloomberg new energy finance CEO, Leibreich (2013).

**Figure 4: Cost of a Solar PV Plant, Including various Components**

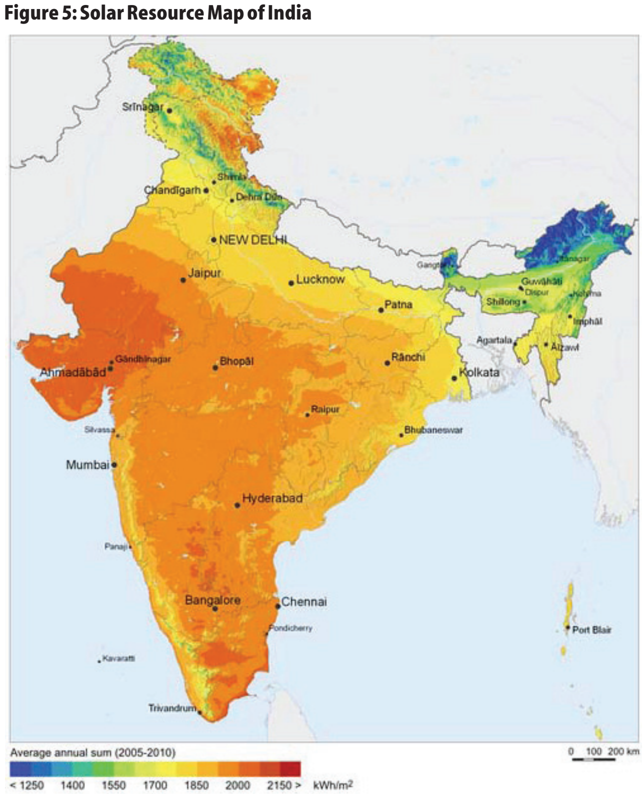

EPC- Engineering, procurement, Construction

BOP: Balance of plant (Balance plant equipment other than Module and Inverter)

Source: Bloomberg NEF, Sustainable energy in America factbook (BNEF, 2013)

**Appendix 6: Solar Resource Map of India**

**Figure 5: Solar Resource Map of India**




Source: Solar radiation maps, Global horizontal Irradiation (SolarGIS 2013).