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Harvesting Solar Power in India

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Abbreviations Used

AD	Accelerated Depreciation
BoS	Balance of System
CAGR	Compound Annual Growth Rate
CCMT	Climate Change Mitigation Technology
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CFA	Central Financial Assistance
CSR	Corporate Social Responsibility
EEG	Erneuerbare-Energien-Gesetz
EPIA	European Photovoltaic Industry Association
FIT	Feed-in-Tariff
GERMI	Gujarat Energy Research and Management Institute
GW	Gigawatt
Gwh	Gigawatt Hours
Ha	Hectare
IEA	International Energy Agency
JNNSM	Jawaharlal Nehru National Solar Mission
Kwh	Kilowatt Hour
Kwp	Kilowatt power
MNRE	Ministry of New and Renewable Energy
MW	Megawatt
Mwp	Megawatt power
PPA	Power Purchase Agreement
PV	Photovoltaic
SECI	Solar Energy Corporation of India
w	watt

Contents

Abstract

Prime Minister Narendra Modi has set an ambitious target of 100,000 MW of solar power capacity to be achieved by 2022, when India celebrates 75 years of her independence. This is a grand vision for ushering in a sort of revolution in clean energy in India in the next six years. In a country that generates more than 60 percent of its power by burning coal, and where air quality is fast worsening in several Indian cities, the need for clean energy cannot be overstated.

Interestingly, Prime Minister Modi has also set another ambitious target of doubling farmers' incomes by 2022!

The uppermost question in everyone's mind is: can these targets be achieved by 2022?

This is particularly so when the current solar power capacity in the country has just touched 8000 MW by July end, 2016, and no country in the world has such an ambitious target as India has set out for 2022. On farmers' real incomes, the compound annual growth rate (CAGR) in the recent past (FY2003 to FY 2013) has been mere 3.5 percent; and doubling these incomes by 2022 would mean increasing this CAGR from 3.5 percent to more than 12 percent.

Despite these stunningly ambitious targets, our take in this paper is that a significant progress can be made towards achievement of both of these goals, provided both are conceived and implemented in unison, a sort of marrying each other, with innovative policies- like the guaranteed feed-in-tariffs (FIT) for solar power generated on farmers' fields- to back this alliance. It should not be a difficult proposition as FIT already exists in case of wind energy, the scale of which is much more (27 GW) than that of solar power (8GW). Since the costs of solar power have come down drastically during the last couple of years, and now compete very well with the costs of power generation from burning coal, this would help generate clean energy in a cost effective manner as well as help augment farmers' real incomes. A true model of competitiveness with inclusiveness, and this can be scaled up in a sustainable manner. This will also help to reduce power subsidies of state electricity boards (SEBs), wherever solar power can substitute existing connections.

Our confidence in approaching these twin goals comes from the rapidly falling costs of solar power (by about 70percent since 2010-11) and its champion support, which comes from the highest political level, i.e., the Prime Minister himself, and no opposition from any other political parties for such a bold initiative. The only thing to be seen is how to raise advance capital funds to get this going, how to organize farmers on these lines, how to convince the discoms for guaranteed feed-in-tariffs, and how long it is persevered till the goals are reached!

In undertaking such gigantic twin missions, it is always wise to look for best practices and technologies around the world. Japan, China, UK, Israel all offer interesting examples, but the global leader in solar power today is Germany. And it has a lot to offer India, with a win-win collaboration between business to business (B2B) on both sides as well as government to government (G2G) Memorandum of Understanding (MOU) to facilitate transfer of technologies, skills, training and practices, and above all some long term finances. Such an Indo-German alliance for solar power can be a catalyst of change not only generating clean energy but also building green Indian agri-value chains and directly augmenting farmers' incomes. This will be a global showcase of competiveness with inclusiveness and the time to take up this idea and scale it up is NOW!

Keywords: Solar Power, Agriculture, Feed-in-Tariffs, India, Farmer Income

JEL codes: L94, Q180, Q150

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1. Introduction

Climate Change, deteriorating quality of air, and subsequent urgency to increasingly shift to cleaner and sustainable energy consumption are gradually coming to the forefront of policy makers' concerns. Alarming air quality levels in many Indian cities and around the world have highlighted the deteriorating environment, and consequent high cost people are paying through negative impact on their health. Needless to say, it has triggered a desperate quest for clean energy.

From May 7th to 11th, 2016, Portugal made history by working only on renewable energy- solar, wind and hydro- for 107 hours[1]. For the first time, on April 9th, 2016, solar energy surpassed energy from burning coal in meeting power requirements in the UK, when solar energy generated was 29 GWh as compared to 21 GWh from coal power stations[2]. Also in Germany, on May 8th, 2016, renewable sources of energy produced 87percent of the energy consumed[3]. As the world slowly embraces green initiatives and moves towards renewable energy, this paper attempts to take a look at the situation of solar energy as it is evolving globally, and in India in particular.

The world recorded 178 GW[4] of cumulative installed solar power capacity in 2014 with 40 GW installed in 2014 itself (Solar Power Europe 2015-19). Solar Photovoltaic (PV) accounts for more than 7percent of the electricity demand in Germany, Italy and Greece (Solar Power Europe 2015-19)[5]. Also, solar PV is the largest employer among renewable energy sector. From 7.7 million direct and indirect jobs in the renewable sector, about 2.5 million came from the solar PV sector alone in 2014 (Ren21 2015)[6]. Hence, there has been much positivity for and expectation from the solar power industry.

In India, Prime Minister Modi has set an ambitious target of installing 100 GW (100,000 MW) of solar power capacity by 2022. The current solar capacity in India stands at 8 GW as on July end, 2016. Thus, the target of moving from 8 GW in July 2016 to 100 GW by 2022, is one of the most ambitious targets globally.

Prime Minister Modi has also set another interesting target to be achieved by 2022, when India celebrates her 75 years of independence. And that is doubling farmers' incomes, presumably in real terms. Given that agriculture still engages almost half the work force in India, and that in recent past, from 2002-03 to 2012-13, farmers' real incomes increased only at a compound annual growth rate (CAGR) of 3.5 percent (Gulati and Saini, 2016), doubling these incomes by 2022 appears stunningly over-ambitious.

This paper delves into the feasibility of making substantial progress towards achieving both these targets. It suggests ways and means of how to conceive and implement them together, a sort of marriage between the two, which can generate enough synergy to make quantum jump towards these twin objectives. The paper focuses on four pillared principle of CISS: Competiveness (cost efficiency) in producing solar power; Inclusiveness by mainstreaming even small farmers in generating solar power on their fields; Sustainable environmentally and financially, and finally Scalable to contribute significantly in achieving these mega targets.

[1] http://www.theguardian.com/environment/2016/may/18/portugal-runs-for-four-days-straight-on-renewable-energy-alone?utm_source=facebook&utm_medium=post&utm_term=renewable,Portugal&utm_campaign=Climate&__surl__=IgNYa&__ots__=1463716048252&__step__=1

[2] http://www.theguardian.com/environment/2016/apr/13/solar-power-sets-new-british-record-by-beating-coal-for-a-day

[3] http://qz.com/680661/germany-had-so-much-renewable-energy-on-sunday-that-it-had-to-pay-people-to-use-electricity/

[4] 1 GW= 1000 MW, 1MW= 1000 KW, 1KW= 1000 W

[5] http://helapco.gr/pdf/Global_Market_Outlook_2015_-2019_lr_v23.pdf

[6] http://www.ren21.net/wp-content/uploads/2015/07/REN12-GSR2015_Onlinebook_low1.pdf

Accordingly, in section 2, we first take a look at the evolving story of solar power installations globally and where does India appear in this global map of solar power installations. In section 3, we examine how the technology and cost dynamics of solar panels have evolved and how costs have been reducing. This is critical to understand whether solar power can be competitive vis-a-vis say power from burning coal. In section 4, we discuss the challenges and opportunities in marrying solar power generation with Indian agriculture. In brief, solar powering Indian agri-value chains, from farm to fork. This can provide not only inclusiveness but also sustainability and scalability that is so critical to make good progress in achieving both these objectives. In section 5, we take a quick look at various innovations taking place across the globe with a view to transfer best technologies, practices, skills and finances to India. In light of this, we make some concluding observations for tying up with the global leaders in solar power such as Germany, Japan, China, UK, Israel, etc. for scaling up in the most efficient, inclusive, and sustainable manner.

2. Evolution of Solar Power

2.1 The Global Solar Power Movement

The first decade of 21st century has been testimony to the many changes and development that occurred in the solar power industry. Figure-1 presents global cumulative solar power installations from 2000 onwards. It clearly reflects the inflection point somewhere around 2008-09. In 2000, total global installed solar capacity was just 1.3 GW whereas in 2014 the annual global addition itself was 40 GW (EIPA 2014-2018 and Solar Power Europe 2015-19)[7] . The annual addition of 40 GW amounts to almost 109.6 MW of capacity addition each day in 2014 as opposed to 3.5 MW in 2000 each day. This turn in the course of the solar power industry started somewhere around 2008-2009, when solar power industry's demand for polysilicon picked up and raced ahead of the electronics industry (Figure 7 and 8 discussed later).

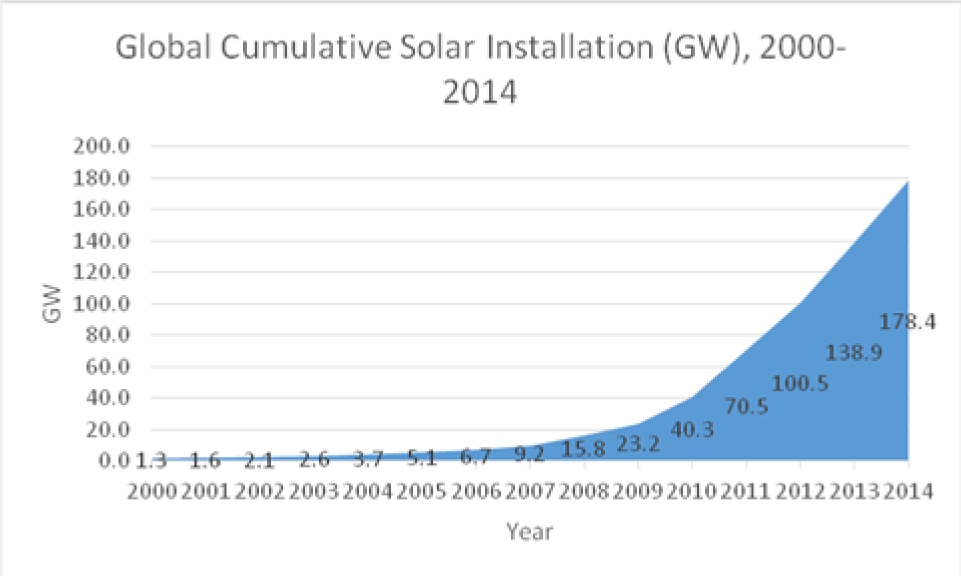

Figure 1: Global Cumulative Solar Power Installations (GW), 2000-2014

Source: European Photovoltaic Industry Association (EPIA) Market Report 2013 and Solar Power Europe Global Market Outlook 2015-19

2.2 The Indian Path of Solar Power

India has substantially paved an upward path in terms of solar power capacity achievement since 2008. It started off with 3 MW in 2008-09 and has touched 8000 MW (8GW) by July end, 2016. India has set a target of 100 GW by 2022, which is divided as: 60GW of land mounted grid connected solar power and 40GW of rooftop grid interactive solar power. This has been further divided into the following yearly targets from FY 2015-16 to FY 2021-22 (Table1):

[7] http://www.cleanenergybusinesscouncil.com/site/resources/files/reports/EPIA_Global_Market_Outlook_for_Photovoltaics_2014-2018_-_Medium_Res.pdf

Table 1: Grid Connected Targets for Solar Power Installations

MW	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Total
Rooftop Solar	200	4800	5000	6000	7000	8000	9000	40000
Ground Mounted Solar	1800	7200	10000	10000	10000	9500	8500	57000
Total	2000	12000	15000	16000	17000	17500	17500	97000

Source: Ministry of New and Renewable Energy (MNRE)[8] , (2015)

India started to add exponentially from 2010-11 onwards. Figure 2 presents a picture of India's solar power journey from 2008-2014. By end of FY 2014-15, 3743 MW of cumulative solar power capacity was achieved in India. During 2015-16, 3019 MW was added (against a target of 2000 MW) and reached a cumulative of 6763 MW (6.76 GW) as on 31 March 2016 (Table 2). Moreover, by the end of first two months of the current financial year (By 31st May 2016), India further reached 7565 MW[9] of cumulative solar power capacity, an addition of about 800 MW in two months. However, the target of 12000 MW capacity creation in FY 2016-17 is going to be the most difficult to reach as it marks an exponential jump in the pace of installations. This would mean adding more than 100percent of the cumulative installed capacity of 7565 MW in one year and this is about 4 times the annual capacity addition in 2015-16. So far by July end, 2016 - India has achieved 8 percent of the total target capacity of 100 GW by 2022. The way ahead for India, therefore is exciting and challenging for scaling up solar power in an accelerated fashion. Farmers' fields can come up very handy for this scaling up, and it will also help to augment farmers' incomes. This is an innovation that India needs to explore at a large scale to emerge as a global leader in generating clean energy in a cost competitive and inclusive manner.

[8] http://mnre.gov.in/file-manager/grid-solar/100000MW-Grid-Connected-Solar-Power-Projects-by-2021-22.pdf

[9] http://mnre.gov.in/file-manager/UserFiles/grid-connected-solar-power-project-installed-capacity.pdf

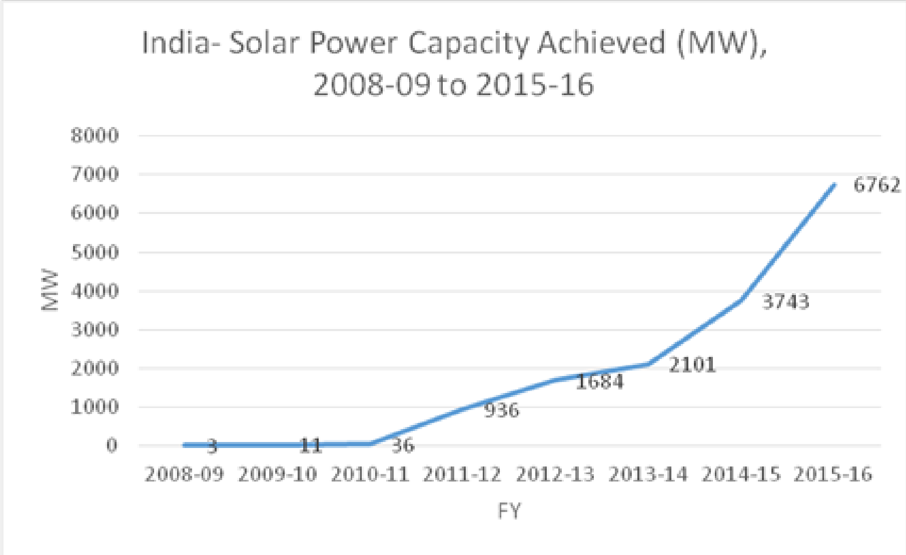

Figure 2: India- Solar Power Capacity Achieved (MW), 2008-09 to 2015-16

Source: SECI[10] (2014) and MNRE[11] (2016)

2.3 Indian States in the Solar Power Story

Several Indian States have been active in developing solar power policies in recent years. Sixteen states[12] have notified their solar power policies as per MNRE. From among them, only Jharkhand and Odisha are the eastern states to have notified solar power policies. Others include Andhra Pradesh, Chhattisgarh, Haryana, Gujarat, HP, J&K, Karnataka, Kerala, MP, Rajasthan, TN, Telangana, Uttarakhand and UP.

During 2015-16, five states/UTs opened their solar power accounts, that is, moved from zero capacity to some installed capacity. Bihar installed 5.1 MW, Daman & Diu 4 MW, J&K 1 MW, HP added 0.2 MW and Mizoram added 0.1 MW. Given lack of grid lines in far eastern and north eastern regions of the country, there is much scope for solar power in these areas. During 2015-16, south shined all the way: Tamil Nadu was the largest contributor with 919 MW commissioned capacity, Andhra Pradesh was next with 435 MW followed by Telangana with 361 MW. Rajasthan followed close with 328 MW. There is a spatial differential observed in solar energy installations. The eastern and north eastern states lag behind quite a bit with less than 2 percent of all India commissioned capacity. The southern states of Andhra Pradesh, Karnataka, Kerala, TN and Telangana account for about 34 percent. The western states of Rajasthan, Gujarat, MP and Maharashtra account for more than 52 percent of total commissioned capacity (Figure 3; Annexure 1A).

[10] http://seci.gov.in/upload/uploadfiles/files/Shpercent20Rajendrapercent20Nimjepercent20-Febpercent202014.pdf (Accessed 18 May 2016)

[11] http://mnre.gov.in/file-manager/UserFiles/grid-connected-solar-power-project-installed-capacity.pdf (Accessed 18 May 2016)

[12] http://mnre.gov.in/file-manager/UserFiles/state-solar-power-policies.htm

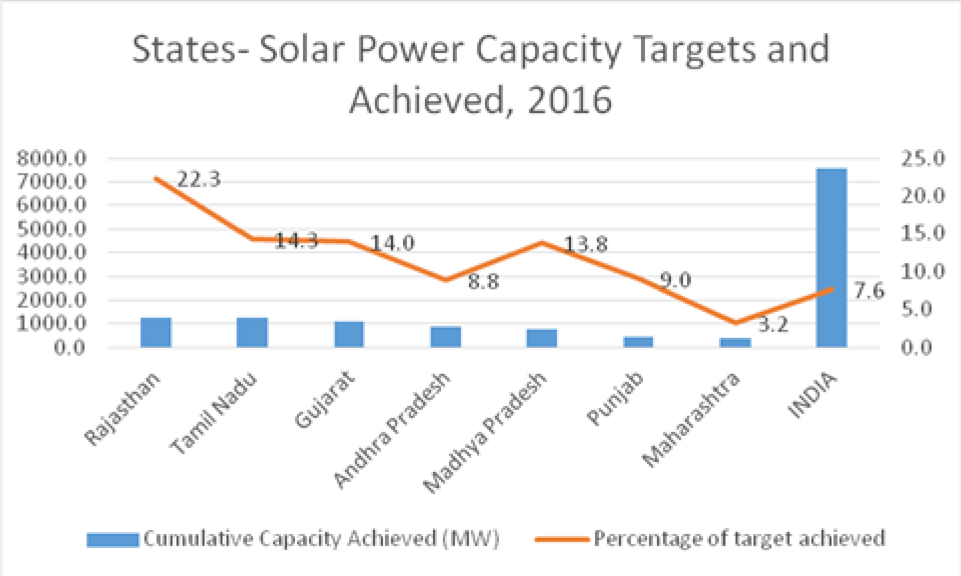

Figure 3: Indian States- Solar Power Capacity Targets and Achieved, 2016

Source: MNRE[13]

Interestingly, Gujarat has been a pioneer under the former Chief Minister, Narendra Modi (Now the PM) that was first to come up with a solar power policy. It was also the first to come up with an innovation of solar panels atop canals- 1 MW in Mehsana and 10 MW in Vadodra. The 10 MW canal solar project on a stretch of 3.6 km was inaugurated by UN Secretary Ban-Ki-Moon in January 2015 in Vadodra[14] . This innovative practice, fixing solar panels atop canals, not only saves land but also water resources as it helps in reducing evaporation[15] . According to a media report[16] , Gujarat would also soon become the first state with an Agro-solar power policy in the country. Similarly, Haryana is trying to replicate the Gujarat model of solar energy generation atop canals. Some state agriculture universities are also experimenting with the concept of harvesting solar power in fields. This will involve farmers leasing out land to discoms to install solar plants in order to generate electricity. Farmers will continue to cultivate land and also get 30-40percent profit sharing in power generation (GERMI)[17] . This is also being experimented through use of irrigation solar pumps in Gujarat. MNRE also has a scheme of setting up at least 25 solar parks each with a capacity of at least 500 MW, as a target to be achieved by 2018-19[18] . State wise list of solar parks approved is given in Annexure 1B[19] . In some hilly terrains like J&K, Assam, Nagaland etc, parks of lower than 500 MW capacity have also been approved. All solar park projects translate into total capacity of 19,900 MW spread across 21 states of India. This approximately meets 20 GW of the 100 GW target for solar power capacity by

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[13] *1 MNRE, http://mnre.gov.in/file-manager/UserFiles/Tentative-State-wise-break-up-of-Renewable-Power-by-2022.pdf [Accessed: 4th May 2016]
*2 Press Release, MNRE, 15th Jan 2016, http://pib.nic.in/newsite/printrelease.aspx?relid=134497 [Accessed: 4th May 2016]
*3 MNRE, http://mnre.gov.in/file-manager/UserFiles/grid-connected-solar-power-project-installed-capacity.pdf [Accessed: 5th May 2016]

[14] http://in.reuters.com/article/2015/01/16/india-solar-idINKBN0KP0ZO20150116

[15] http://geda.gujarat.gov.in/policy_files/gujarat_solar_power_policy_2015.pdf

[16] http://indiatoday.intoday.in/education/story/gujarat-first-state-to-implement-agro-solar-policy/1/460625.html

[17] Gujarat Energy Research and Management Institute, http://www.germi.org/news/economictimes-2-9-15.pdf

[18] http://mnre.gov.in/file-manager/grid-solar/Scheme-forpercent20development-of-Solar-Park-&-Ultra-Mega-Solar-Power-Project-2014-2019.pdf

[19] http://seci.gov.in/content/innerpage/statewise-solar-parks.php

2022. So far, these solar parks have been approved during November 2014 to February 2016. Hopefully, in the years to come, more capacity will be added through myriad innovative ways, and one such innovation will be to use farmers' fields for generating solar power.

2.4 Understanding Solar Power within the Context of Overall Energy Needs

At all India level, the total installed power capacity in March 2016 was 302 GW. Of this, coal based power accounted for 61.25 percent at 185 GW while solar was merely 2.2 percent with 6.7 GW[20] . The share of thermal power including coal, gas and diesel was 69.53 percent with about 210.67 GW. This shows a great dependence on polluting thermal sources. Renewable energy accounted for only 42.85 GW from this total of 302 GW. And solar made up a mere 15.78 percent of this renewable capacity of 42.85 GW[21] . But importance of green energy is gaining momentum, despite the current low levels. The solar potential across Indian states is much higher at about 748 GW[22] against a target of 100 GW given that India is a sunshine abundant country. Much emphasis on solar power is made due to 3 reasons: a) sunshine is a freely available, abundant and non-polluting source b) It can help to electrify remote villages where grid lines are absent or difficult to reach or suffer from sporadic supply and, c) with falling costs it is financially viable for industrial and commercial consumers. We need to cover more than 90 GW in a span of 6 years from now. It is important to understand how achievable it is, in the given time span, and with given policies and infrastructure. A cross country comparison (Table-2) can help to understand how big a target this is.

Table 2: Cross Country Comparison of Solar Power Capacity Targets

COUNTRY	INSTALLED (2014), GW	TARGET (YEAR), GW	Compound Annual Growth Rate needed to meet targets (Percent)
Canada	1.7	6.3 (2020)	24
UK	5.1	7.20 (2020)	6
France	5.7	15 (2020)	17
Germany	38.2	52 (2020)	5
Italy	18.5	23 (2017)	7
China	28.2	100 (2020)	23
Japan	23.3	65.7 (2020)	19
Thailand	1.3	3 (2021)	12
India	3	100 (2022)	55

Source: Bridge to India, India Solar Handbook, 2015

According to these targets, China would need to grow solar capacity at CAGR of 23 percent. In comparison to other listed countries, India needs to grow its solar power capacity at CAGR of about 55 percent to meet its target by 2022 (Given 7.5 GW in 2016). This is the highest effort amongst all the major countries listed in Table-2. Even the leader, Germany, with maximum installed capacity of 38 GW in 2014 targets mere 52 GW by 2020, which will require CAGR of just 5 percent.

India's total power generation capacity is expected to rise to 746 GW in 2030 (OECD/IEA 2015) with the share of coal falling to about 44percent while share of solar should rise to at least 13 percent (with 100GW) in total power generation capacity. The IEA, however, has projected only 40GW solar

[20] As per Central Electricity Authority (CEA).

[21] http://www.cea.nic.in/reports/monthly/installedcapacity/2016/installed_capacity-03.pdf [Accessed: 6th May 2016]

[22] MNRE

power capacity in India by 2022. This would be way below the ambitious target of 100 GW set by the Prime Minister. Any significant failure to achieve 100 GW would adversely affect India's global credibility. With more than 90 GW to be added in next six years, India needs to ensure at least 15 GW capacity addition every year henceforth. India thus needs well planned and concentrated efforts to achieve this ambitious target, and some out-of-box thinking too. Learning from international best practices and tying up with international expertise in solar power may prove to be fruitful in realizing this dream of 100 GW.

2.5 Learning from the leader- Germany

Many countries have been climbing up the solar power ladder but Germany has been an important leader setting an example of successfully adopting solar power. Before 2013, European nations like Germany and Italy led in terms of annual installations. But from 2013, China took a lead in annual installations followed by Japan and US in that order[23] . In 2013, China added over 11 GW, Japan added 7 GW while USA added over 4 GW. The lead order stood intact with China adding 10.6 GW, Japan 9.7 GW and USA 6.5 GW in 2014. Around 2008, exporting 98 percent of its solar products, China became the largest PV manufacturer globally (Centre for Study of Science, Technology and Policy (CSTEP) 2015)[24] . By the turn of the first decade of 21st century, China was responsible for half of world's PV panel production. In 2014, China and Taiwan accounted for 69 percent of total PV module production (Fraunhofer Institute for Solar Energy Systems, ISE)[25] .

Despite Germany's lag in annual additions in the past two- three years, it remains a renewable energy leader in total cumulative installations globally and leads by a successful model. In 2014, Germany led with 38 GW cumulative installed solar capacity, China had 28 GW while Japan recorded 23 GW. In terms of per million population solar power capacity, in 2014, Germany had 469 MW/million population, Japan had 181 MW/million while China had only 20 MW/million population. India was way below at just 2.3MW/million people. Germany's 38 GW accounts for nearly 21percent of total solar installed capacity in the world (2014). All this makes Germany a key leader in solar power.

There are 2 key elements in Germany's solar power success- guaranteed grid connection to renewable energy producers and Feed-in-Tariffs (FITs)- that have contributed to substantial rooftop installations. By 2013, 23 percent of global residential solar rooftops and 37 percent of global commercial solar rooftop installations took place in Germany[26] . Governed by the Renewable Energy Sources Act 2000 (Erneuerbare-Energien-Gesetz EEG), renewables including solar enjoy priority grid connection and are supported through Feed-in-Tariffs (FITs) in Germany. This has enabled even the small producers and farmers to connect to the grid and earn revenue by selling solar power. To ensure marketability and profitability of renewable energy (EEG), the renewable operators receive FIT which is a cost based payment and ensures return on investment. The EEG surcharge which is the difference between FIT and average electricity price is what finances FIT and it is passed onto all consumers of power in the form of higher electricity bill (Weiss 2014). This excludes energy intensive industries to ensure their competitiveness in international trade. This model prompted many consumers to shift to solar rooftop installations whereby they consumed as well as fed units into the grid to earn revenue (RECC 2015). But owing to European Commission's opposition to this unequal distribution of EEG burden on consumers without rooftop installations who have to pay higher bills,

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[23] https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapSolarPhotovoltaicEnergy_2014edition.pdf

[24] http://www.cstep.in/uploads/default/files/publications/stuff/dc6ff09f580c30a0a6fc0d1a90ed813f.pdf

[25] https://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles/photovoltaics-report-in-englischer-sprache.pdf

[26] http://marketrealist.com/2015/02/german-rooftops-domniate-global-photovoltaic-capacity/ (Accessed: 6th June 2016)

EEG version of 2014 looks to phase out FITs gradually (for systems exceeding 100kwp) and move to reverse auctioning (where the sellers of renewable energy bid to sell power to the buyer).

In India, FITs are not compulsory and there is no guaranteed grid connection to renewable energy operators. Also, it is at the discretion of the discoms/regulators to decide if they want to use FIT or not[27] . India can take a leaf out of Germany's lead in solar power achievements and learn from its successful model by engaging in collaborative ventures between the two countries, at business-to-business (B2B) and government to government (G2G) levels. The innovative learning for India will be to mainstreaming farmers in generation of solar power through guaranteed FITs policy at attractive prices.

[27] http://mnre.gov.in/file-manager/UserFiles/Scheme-Grid-Connected-Rooftop-&-small-solar-power-plants.pdf

3. The Cost Dynamics- Competitiveness of Solar Power

3.1 An overview of costs

From 2003-08, there was a polysilicon shortage which led to very high prices of this crucial input, inviting big investments. But then came the Global financial crisis of 2008, which saw the price of polysilicon tumbling down during 2009-13 (GTM Research)[28] . The year 2013 also saw many bankruptcies of solar companies which had made large investments earlier but could not recover their costs. Some also lost in the race to fast moving technology of PVs. However, going ahead from 2013, the fall in PV prices seem to have been somewhat under control. Nevertheless, it has now brought the prices of solar modules down to below $0.50/watt through technological innovations, increasing scale of production, changing market structures, and learning by doing!

3.2 Understanding costs- value chain

To make an attempt to understand the cost dimension behind solar energy, it is best to break it down into various components of a solar power system. A solar PV system that we see installed is made from many solar modules which may appear to be black rectangular structures (see Figure 4). PV modules, themselves, are made from many solar cells put together.

Figure 4: Solar Power Value Chain

Source: Market Realist

The starting point in the chain is sand from which silicon is obtained. It is liquefied to form ingots to further cut into wafers. Wafers are then used in making cells by involving electrical circuit and layers of glass cover, anti-reflective coating etc. Crystalline silicon wafers are of three types- a) Monocrystalline b) Pollycrystalline c) Silicon ribbon. Monocrystalline is the most efficient on account of highest degree of purity but is also costly in comparison. Typically and the most widely used is polycrystalline in the industry which is also the mainly referred in the discussion here. PV Modules

[28] Greentech Media- http://www.greentechmedia.com/articles/read/Solar-and-Silicons-Shifting-Relationship-in-Charts

are more labour intensive than capital and technology intensive, as compared to other stages of production. This is opportune for developing countries.

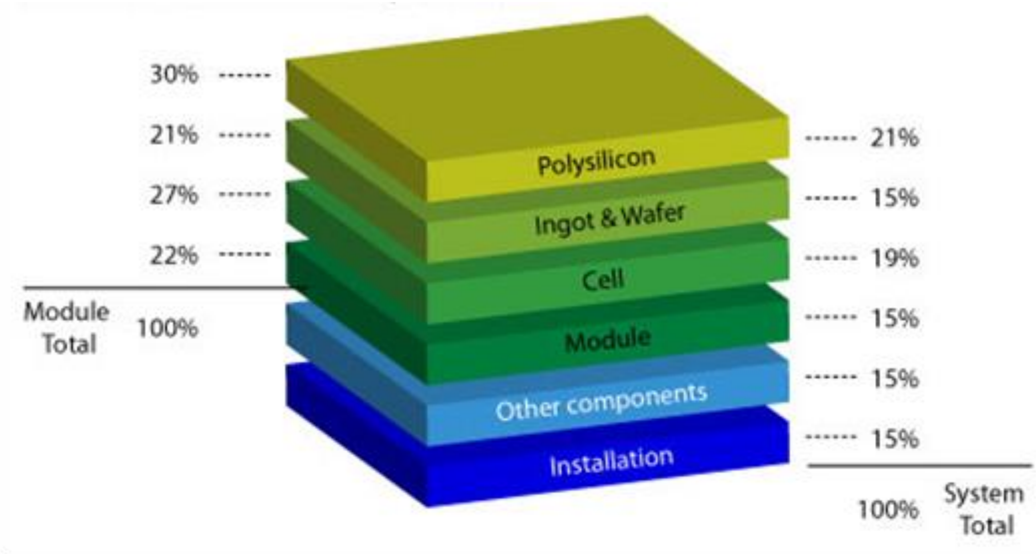


Figure 5: The Photovolatic Value Chain

Source: Green Rhino Energy

Typically, in terms of contribution to cost as Figure 5 shows, 70 percent[29] comes from the module with remaining 30 coming from other system and soft costs like installations, land acquisition, labour, inspection and the like. In India, module costs is about 60 percent while remaining 40 percent is accounted for by balance of systems (details in section 3.4).

3.3 Falling PV Module costs and Balance of System costs

A major development in the industry has been falling costs of PV modules (Figure 6[30]). The PV Module prices have fallen by more than 80percent since 2008. This has lowered the total system costs. Falling module cost can be attributed to[31] a) fall in polysilicon prices, b) cost reducing technological innovations and c) fall in price of consumables d) scale and other factors. Structural changes in the industry have played an important role as well. PV industry started off by consuming the leftover silicon of the electronics industry[32] . But 2005 onwards, investments were made and demand for silicon by PV industry started to rise, competing with the demand from that of the electronics industry. Over time, while PV industry's share in demand for polysilicon has been increasing, silicon's cost share in module manufacturing has come down (Table 7 and 8), indicating the trend of increasing dependency of silicon industry on solar industry and hence a change in relationship (Shyam Mehta, GTM Research, 2014).

[29] http://www.greenrhinoenergy.com/solar/industry/ind_valuechain.php

[30] Ezysolare has used NREL and pvexchange.com data: http://www.ezysolare.com/blog/knowledge-center/trend-analysis-on-solar-pv-module-prices/

[31] http://www.pv-tech.org/news/technology_not_materials_to_drive_down_chinese_solar_costs_gtm

[32] http://www.greentechmedia.com/articles/read/Solar-and-Silicons-Shifting-Relationship-in-Charts

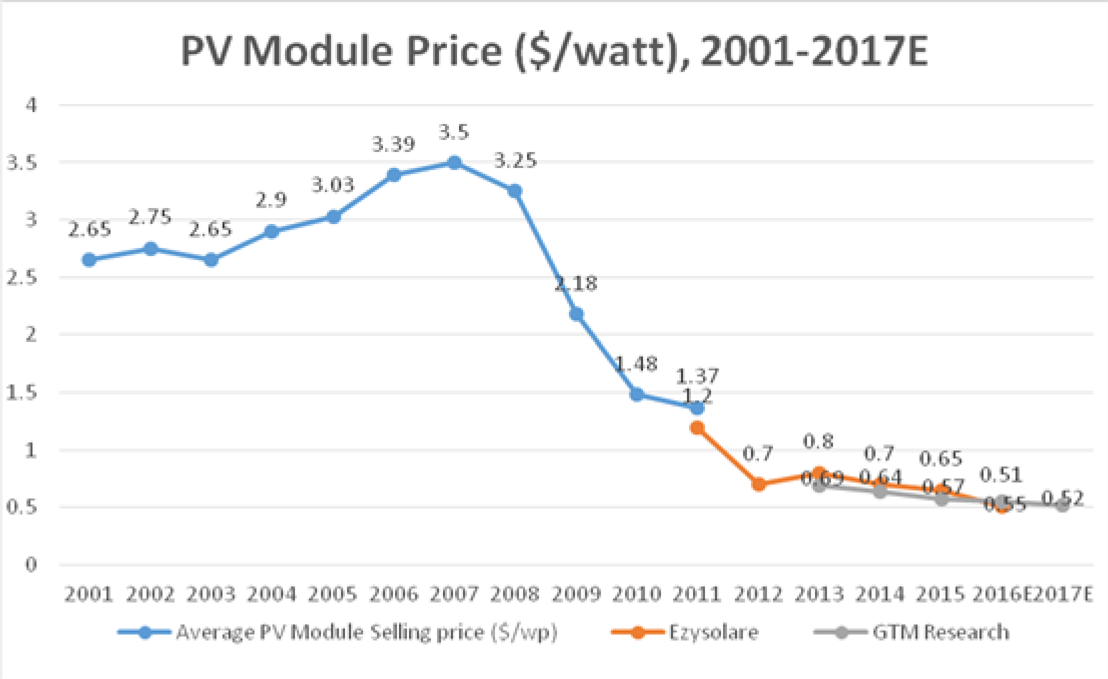


Figure 6: PV Module Price ($/watt), 2001-2017E

Source: Paula Mint, Principal Analyst, Solar Services Program, Navigant, Ezysolare and GTM Research

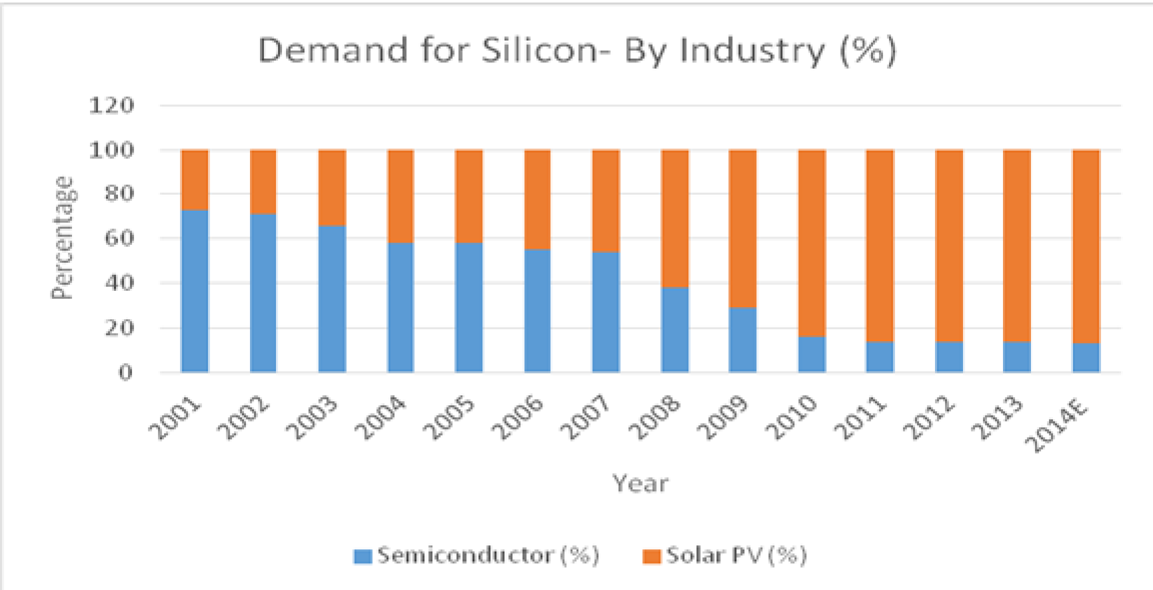


Figure 7: Demand for silicon by industry, 2001-2014

Source: GTM Research, Sage Concepts, Prometheus Institute[33]

[33] http://www.greentechmedia.com/articles/read/Solar-and-Silicons-Shifting-Relationship-in-Charts

Improvements in cell efficiency, wafer thickness, manufacturing yields, diamond wire cutting, conversion efficiency etc. have brought down the use of silicon from 15 grams per watt in 2000 to about 5.2 grams per watt in 2014 (Shyam Mehta, GMT Research, 2014). This in turn has contributed to the falling cost of PV Modules. There has been considerable improvement in cell and module efficiency over the years as well. The efficiency of commercial wafer based silicon modules has increased from 12percent to 17percent in the last one decade (ISE, 2016)[34] . First Solar Inc. is already producing solar panels at 40cents/watt. Another innovation has been the bi-facial solar PV modules. These are installed vertically such that sunlight falls on both sides of the modules. This increases efficiency as electricity is produced from both the sides. This would be a boost to efficiency of the panels if more can be produced from the same structure. This is yet to achieve commercial viability though. Other than modules, the total costs of balance of system have also come down over the years. These cost components like inverter, cables, and transformers have declined with improved design and engineering technology. Also, increase in the average size of projects has brought scale economies and contributed to falling costs. Hence, substantial technology developments have played a role in bringing down the cost of solar power.

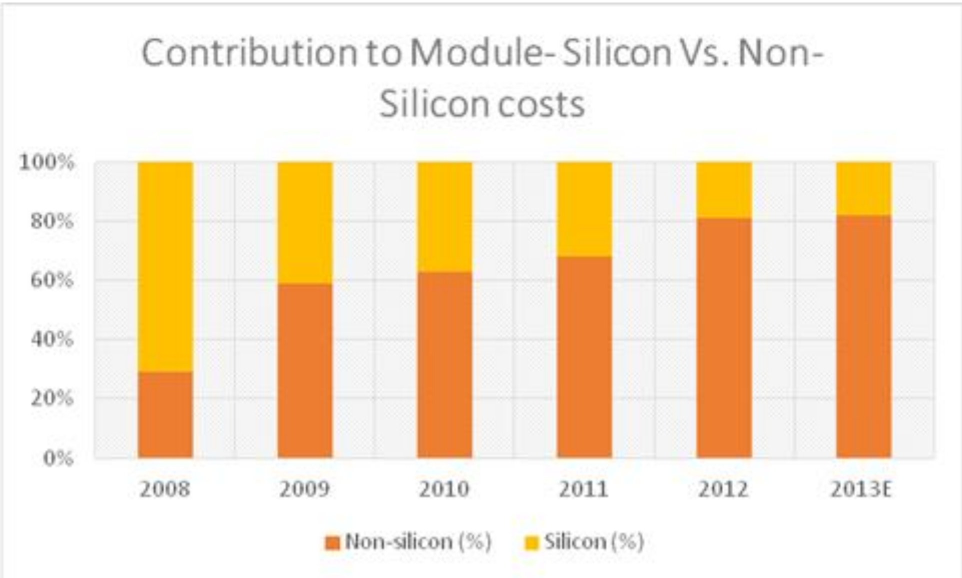


Figure 8: Changing Structure of Silicon-Vs-Non-silicon in Module costs (Chinese Module supplier, 2008-2013E[35])

Source: GTM Research, Sage Concepts, Prometheus Institute[36]

[34] https://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles/photovoltaics-report-in-englischer-sprache.pdf
[35] http://www.greentechmedia.com/articles/read/Solar-and-Silicons-Shifting-Relationship-in-Charts
[36] http://www.greentechmedia.com/articles/read/Solar-and-Silicons-Shifting-Relationship-in-Charts

3.4 Contribution towards falling cost

Cost contribution of modules has also fallen down as seen in Figure 9 below and accounted for about 33 percent in 2013 as opposed to more than 50 percent in 2010 (USA data).

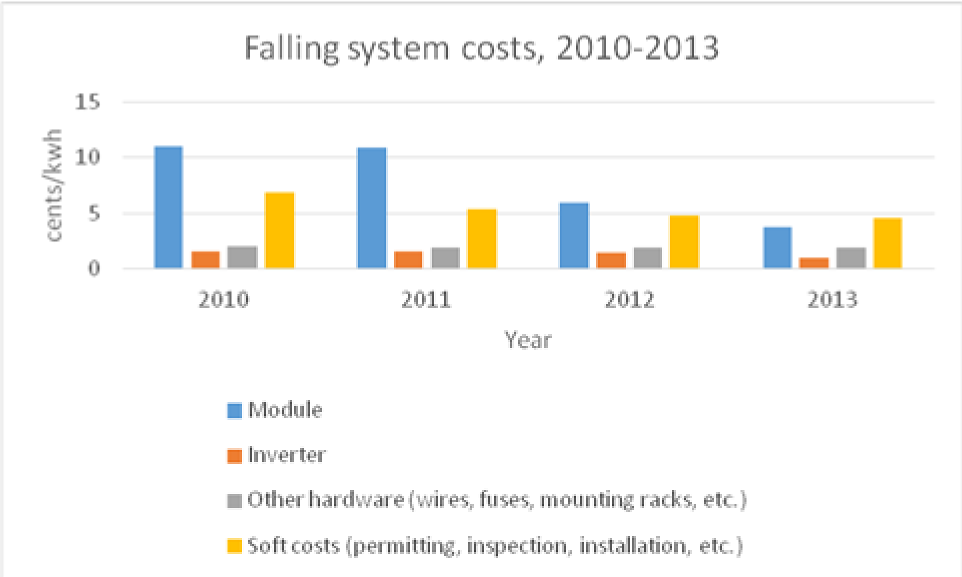
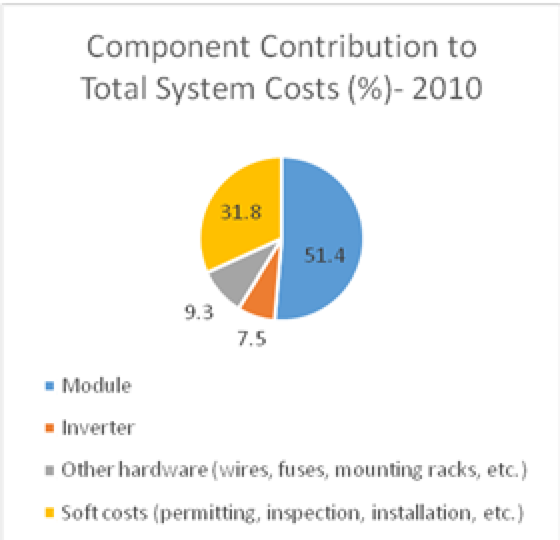


Figure 9: Falling system costs, 2010-2013

Source: energy.gov by Daniel Wood



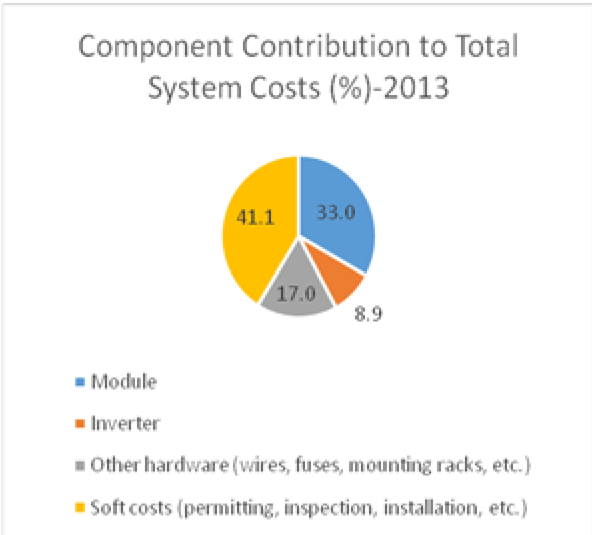


Figure 10 (left): Component Contribution to Total Costs (%)-2010

Figure 10 (right): Component Contribution to Total Costs (%)-2013

Source: energy.gov by Daniel Wood

Looking at the four years from 2010-2013, total price of utility scale solar PV projects in USA has come down by almost 48 percent, from 21.4 cents/kwh to 11.2 cents/kwh[37] . The component cost contribution can be seen in Figure 10a and 10b. Out of this 48 percent reduction in project costs between 2010 and 2013, 71.5 percent has been contributed by falling module costs and about 22 percent by soft costs. This shows that each has contributed, towards cost reduction, in proportions close to their own proportional contribution towards total cost, particularly modules. Module prices by themselves have come down by 66 percent while soft costs alone have declined by 32 percent between 2010 and 2013. Hence, both module and balance of system price reductions have contributed to lowered cost of solar power. However, balance of system (BOS) costs are slower to respond than module costs. Moreover, increasing land costs are adding to greater share of balance of systems in overall cost contribution as we will see below in the Indian case. In India also, there have been declining capital costs of solar PV projects, about 68 percent since 2010-11 (Figure 11).

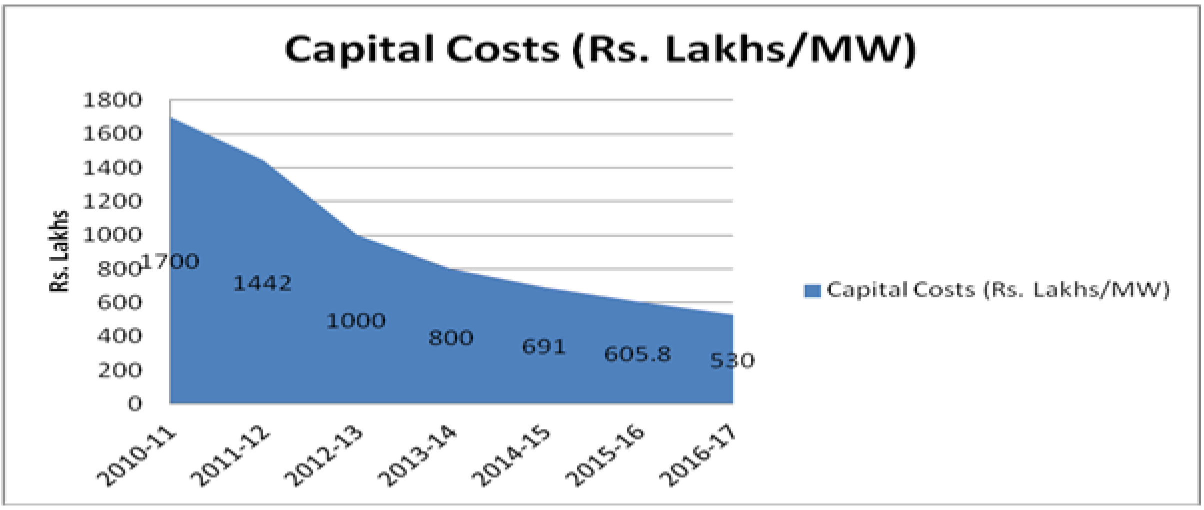


Figure 11: Capital costs (Rs. Lakhs/MW), 2010-11 to 2016-17

Source: CERC 2016, http://cercind.gov.in/2016/orders/sm_3.pdf

For India, Central Electricity Regulatory Commission (CERC) has determined benchmark costs for various components and their contribution in a solar PV project – this is given below for 2016-17[38] (Figure 12- For detailed table refer to Annexure 2). Despite overall decline in capital costs, India still needs to work on reducing module share in overall cost on the lines of global trends, which has come below 50 percent, by eliminating cost inefficiencies in manufacturing in particular. In India, PV modules still contribute greater than 60 percent to total project costs.

[37] http://energy.gov/maps/falling-price-utility-scale-solar-photovoltaic-pv-projects

[38] http://www.cercind.gov.in/2016/orders/SO17.pdf

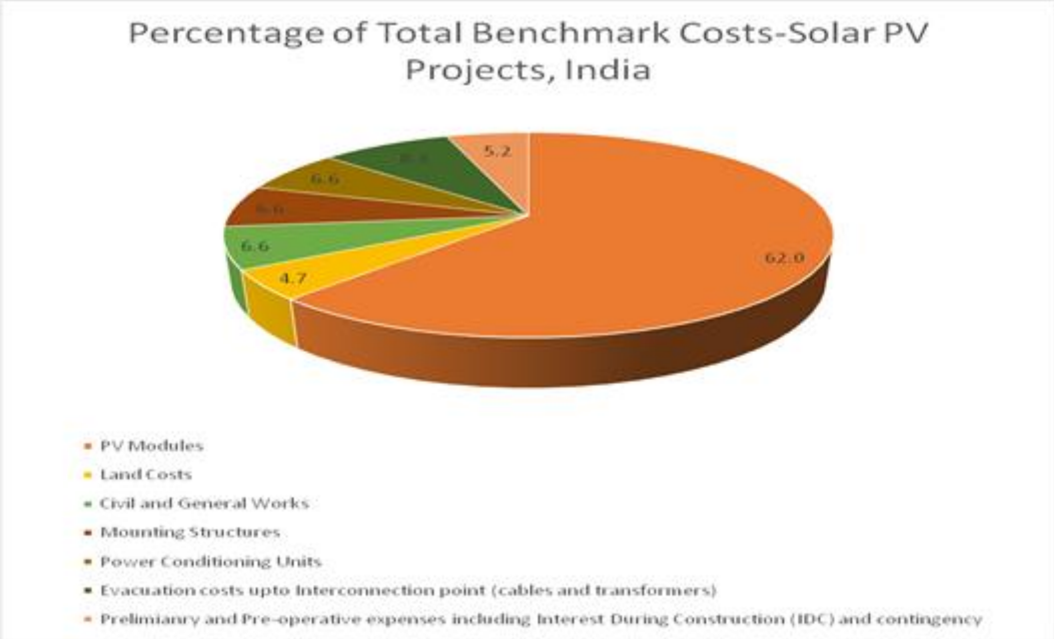


Figure 12: Percentage of Total Benchmark Costs-Solar PV Projects, India 2016-17

Source: CERC, 2016-17

In India, from 2011-12 to 2016-17, the capital costs have declined by 68percent of which 55percent comes from falling PV module costs, 25percent from falling Balance of Systems (BoS) costs and about 19percent from falling soft costs. Land contribution towards total cost, though, has increased from 1percent in 2011-12 to 4.7percent in 2016-17. Land costs themselves increased by 66percent during this period. Land, hence, is becoming an important input, and in the years to come may well pose a challenge for solar energy target achievements.

3.5 Is cost of solar power viable?

Cost efficiency of solar power relative to thermal power is of utmost importance. It is hence important to consider the cost dynamics of solar as compared to the conventional source of energy. The average tariff of power[39] in the country was Rs. 4.80/kwh in 2013-14 (Planning Commission 2013-14)[40] . But the average tariffs have been increasing over the years. From Rs. 1.87/kwh in 1998-1999, it is more than 150percent increase in about 15 years. On the other hand, the generic tariffs as determined by Central Electricity Regulatory Commission (CERC) for solar Photovoltaics (PV) have declined substantially. In 2010-11, levellized tariff (spread across a life of 25 years) stood at Rs. 17.91/kwh without Accelerated Depreciation (AD) and Rs. 14.95/kwh with AD[41] . This fell by 68 percent to Rs. 5.68/kwh without AD and by 66percent to Rs. 5.09/kwh with AD in 2016-17[42] . The average competitive solar bid from projects has come down from Rs. 6.8/kwh in 2014 to Rs. 5.6/kwh in 2015, marking an 18percent fall (ICRA, 2016)[43] . This marks a substantial decline in solar costs since the first phase of Jawaharlal Nehru National Solar Mission (JNNSM) in 2011. The tariff of Rs.

[39] Assuming thermal power, as it accounts for more than 60percent in total.
[40] Planning Commission, http://planningcommission.nic.in/reports/genrep/rep_arpower0306.pdf
[41] http://cercind.gov.in/2010/ORDER/February2010/53-2010_Suo-Motu_RE_Tariff_Order_FY2010-11.pdf
[42] http://cercind.gov.in/2016/orders/sm_3.pdf
[43] http://www.icra.in/Files/ticker/SH-2016-Solarpercent20Energy.pdf

4.34/kwh from a solar plant in Rajasthan is the lowest yet achieved in the country based on competitive bidding and even after accounting for 30percent subsidy (for solar parks) it amounts to Rs. 5.64/kwh. It is to be compared to the cost of thermal power. The cost of thermal power has been rising over the years. From Rs. 2.63/kwh in 1998-99, it has spiraled up to Rs. 5.93/kwh in 2013-14 marking a 125percent jump. Hence, compared with cost of Rs. 5.93/kwh, solar energy definitely has gained much cost efficiency with Rs. 5.68/kwh tariff without AD. Moreover, the commercial and industrial sectors which face the highest tariffs can benefit from solar power at lower costs. The average All India power tariff for Industry was Rs. 6.25/kwh in 2013-14 - this was as high as Rs. 7.71/kwh for Maharashtra, Rs. 7.35/kwh for TN and Rs. 7.36/kwh in UP (Planning Commission 2013-14). Figure 13 represents a comparative picture of thermal power tariffs for different categories of consumers with the tariffs of solar power.

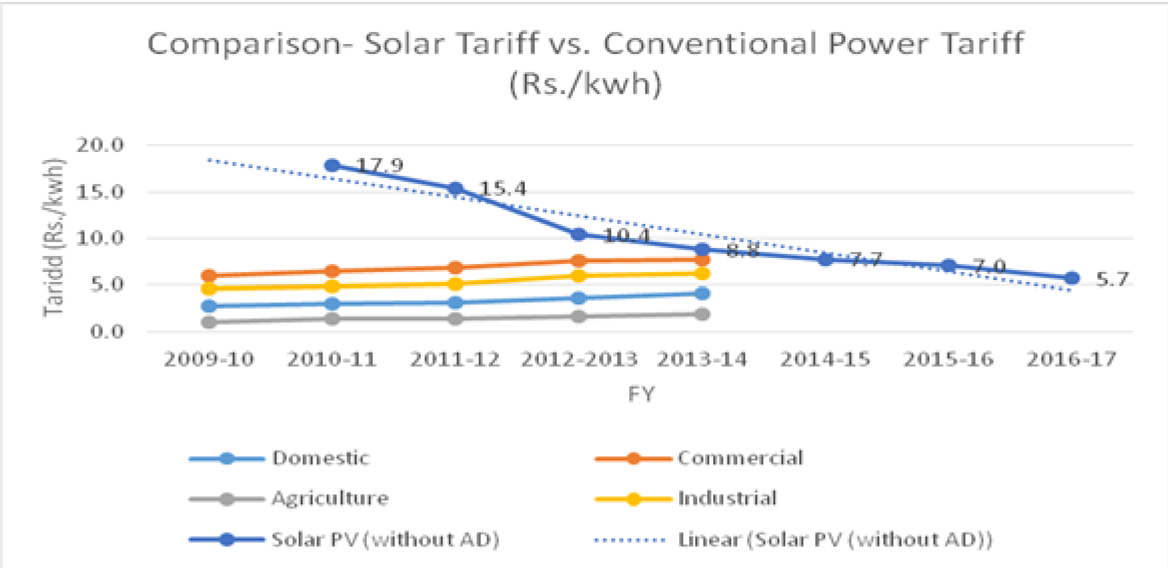


Figure 13: Comparison- Solar Tariff vs. Category wise Conventional Power Tariff (Rs./kwh)

Source: Planning Commission, http://planningcommission.nic.in/reports/genrep/rep_ arpower0306. pdf and various CERC circular notifications

On the other hand, some critics argue that without subsidy the cost of solar power may be much higher and not viable. This is taking into account a number of indirect costs. This includes the cost of distribution and transmission, and stand by cost of alternative sources of energy used as back up in the absence of sun. But on the same lines, it can be argued that cost of conventional coal does not take into account the harmful polluting impact on environment and the cost of depleting resources. Moreover, cost of polluting fossil fuels has been ever increasing as resources get depleted. The government or discoms should buy solar power at marginal costs of coal plus about 15-20percent costs of negative health externalities. The levellised marginal cost of thermal power at pit head is Rs. 4.50/kwh[44] . This would amount to Rs. 5.40/kwh after accounting for 20percent negative externalities. This could indicate that solar power is not far behind in terms of cost viability and has potential to compete with costs of conventional sources, which can materialize soon. And costs of thermal power have been ever increasing. With cost reducing innovations and a hitherto story of drastic decline in costs of solar power in recent years, solar energy definitely looks promising to replace some chunk of thermal power in the near future. This can start from industrial and commercial units which pay the highest tariffs (Figure-13). Moreover, solar power tariffs get fixed for a period of 20 years whereas that of thermal is uncertain and is seen to have been rising in the past.

[44] Collected by authors through personal communication

Also, another issue often raised against feeding surplus solar power into grid is that the DISCOMS are not in a position to take up the system of FITs given their poor financial health. In March 2015, financially depressed DISCOMS had Rs. 4.3 lakh crore worth of outstanding debt, almost 80 per cent up from 2011-12 when it was 2.4 lakh crore[45] . But the incumbent government is undertaking efforts through UDAY scheme to curb this situation in order to strengthen the power sector in the country, which is the backbone of various other development schemes from 'Digital India' to 'Make in India'. Ujjwal DISCOM Assurance Yojna (UDAY) scheme, introduced in 2015, is an initiative aimed at the financial turnaround of state owned power distribution companies (DISCOMS). Under UDAY, 50% of DISCOM debt[46] is to be taken over by states in 2015-16 while 25% is to be taken over in 2016-17, totaling to taking a total of 75 per cent debt of distressed DISCOMS. As of August 10, 2016 a total of 16 states/Union Territories[47] have entered into MoUs for operational and financial turnaround of state DISCOMS. The scheme is optional and not binding on the states. Since solar power is now very cost competitive compared to that from burning coal, this will help the state electricity boards (SEBs) to save on their power subsidy bills for supplying to rural areas, which currently amount to roughly Rs 70,000 crores.

Moreover, FIT mechanism already exists for wind energy. In July 2016, wind energy accounted for 27 GW of installed capacity of Power stations in the country, amounting to 60 per cent of the overall renewable energy capacity of 44 GW. This is also higher than gas and diesel individually which stood at 25 GW and 0.9 GW respectively. The FIT for wind power varies from Rs. 6.61/kwh in Wind Zone-1 (Capacity Utilization Factor- 20 per cent) to Rs. 4.13/kwh in Wind Zone-5 (Capacity Utilization Factor- 32 per cent)[48] . The solar tariff, as determined by CERC, for the same period is Rs. 5.68/kwh which is lower than the tariff that exists for Wind Zones 1 and 2. Hence, with the UDAY scheme to restructure the debts of discoms and falling solar power tariffs, a policy initiative from the Central government can help to trigger the FIT mechanism for solar power, at least starting from the NDA governed states. This would also serve as a platform for a good model of cooperative and competitive federalism in India (PIB, GOI, 2015)[49] .

[45] Press Information Bureau, Government of India. http://pib.nic.in/newsite/PrintRelease.aspx?relid=130261 (Accessed: August 22, 2016)

[46] Debt as on September 30, 2015

[47] Press Information Bureau, Government of India http://pib.nic.in/newsite/pmreleases.aspx?mincode=52 (Accessed: August 22, 2016)

[48] As per CERC determined Generic tariffs for FY2016-17

[49] Press Information Bureau, Government of India. http://pib.nic.in/newsite/PrintRelease.aspx?relid=130261 (Accessed: August 22, 2016)

4. Solar Power in Agriculture: Challenges, Opportunities and Innovations

4.1 The Challenges

4.1.1 Land Challenges

There are a number of challenges in meeting the solar power capacity targets. First is the requirement of land. Solar energy installations are directly linked to land. The large scale utility projects which constitute 60 percent of the 100 GW target require vast amounts of land. The more sunlight a piece of land receives, the greater its suitability for solar installations. It poses a challenge to have large tracts of land only for solar power generation. MNRE has stipulated and prioritized the use of barren and waste lands for setting up of solar plants so as to not compromise on agriculture land[50] . Also, land area requirement can vary depending upon the technology in use, whereby a decrease in land requirement can be achieved with greater efficiency in technology. As a key input, high land costs and bottlenecks in acquisition of land are important issues that require innovative policies.

Given the 100 GW goal, it would call for large scale as well as large 'space occupying' projects in the country (Philip 2014). Under the JNNSNM, most project initiatives have been ground mounted utilities as of yet. The rising cost of land can be an obstacle in lowering per unit cost of solar energy. Contribution of land in total cost of solar projects has increased from 1percent in 2011-12 to 4.7percent in 2016-17. Land costs have themselves increased by 66 percent from Rs.15 lac/MW in 2011-12 to Rs. 25 lac/MW in 2016-17[51] . Escalating land costs for solar projects have been also worsened by real estate agents and other middle men who arbitrate by buying agriculture land cheap from farmers well in advance only to sell at very high rates later for development of solar projects (CERC)[52] . Given its alternative uses, land has been the bone of contention among various stakeholders. To add, it is subject to political sensitivity owing to the heat around 'Land acquisition bill' pending in the Parliament. This poses impediments in a smooth land acquisition process. That is why 40 percent component of the 100 GW target is also grid connected rooftop installations. But with innovations in policy and processes surrounding solar power generation, farmers' fields can play a critical role. And this can be a powerful tool to transform rural areas where 55percent of total workforce is employed in agriculture (Census 2011).

33 solar parks have potential solar capacity of 19,900 MW in the country (Annexure 1B). Since standard minimum land requirement is approximately about 2ha per MW, this would amount to 39,800 ha land. Figure 14 shows land use, normalized per MW, by various solar parks in the country (for detailed table see Annexure 3). From 2015-16 to 2021 -22 the ground mounted target is 57000 MW including those underway as mentioned above. This in total would need 1,14,000 ha land @2ha/MW. Given the greater need to first use solar energy to provide power accessibility to un-electrified or sparsely electrified rural areas, land based innovations using farmers' fields are very important for India. Such innovations can also help use solar power for irrigation pumps, as discussed in detail below.

[50] http://pib.nic.in/newsite/pmreleases.aspx?mincode=28
[51] CERC benchmark costs
[52] http://www.cercind.gov.in/2014/orders/SO353.pdf

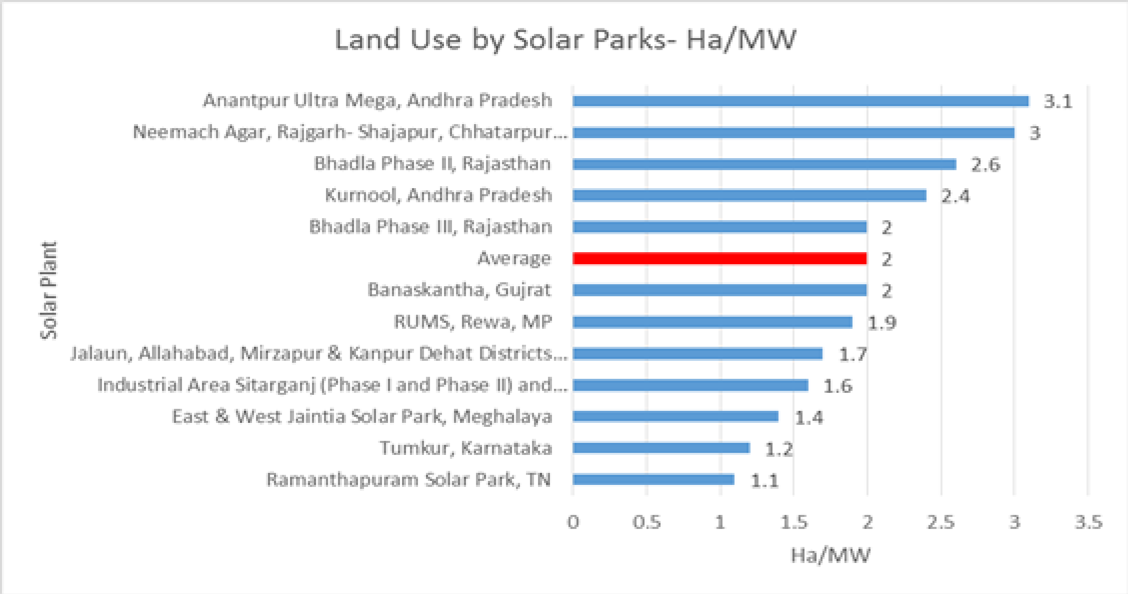


Figure 14: Land Use by Solar Parks

Source: MNRE PPT, http://www.indiaenvironmentportal.org.in/files/file/Solar-Park-Guidelines.pdf and http://www.apspcl.ap.gov.in/landdetails.html

4.1.2 Other Challenges

The other challenge is integrating the variable nature of solar PV to the grid (Kaur 2015). The intermittent nature of solar power means that the gap in supply needs to be filled when sunshine is not available. If the grid operators are required to fill this gap by reserving units for such periods, it cannot be done without prior accurate information on when and how much backup power is required. Moreover, integrating solar power into the grid may not be feasible in all areas, especially where transmission lines are missing. Luckily, such areas are very few and sparse. Also, institutional and residential solar installations for self- consumption of these units would mean greater fluctuations in peak demand for grid operators, something they might not be prepared for.

Solar power cannot be generated during the night or on a cloudy day. And the power sector, so far has not witnessed a breakthrough in large scale storage of electricity in a cost effective manner. Battery storage in case of solar energy is very expensive and not economically viable yet. One of the solutions discussed in literature is Hydro Pumped Storage. It is the most commercially viable solution for storing electricity (Yang 2014). It stores water at two elevation levels such that when there is off peak period, water is pumped from lower to upper reservoir and later generates electricity during peak demand (Swain 2013). In this manner, it helps to tackle the large fluctuations in peak demand. As reported in 2013, there were nine pumped storage plants operational in India with total installed capacity of 4785 MW while the total potential is 96,524 MW across regions in the country (CEA). Globally, Japan has the highest Pumped Hydroelectric Storage (PHES) with 27,438 MW followed by China with 21,545 MW and USA with 20,858 MW (Yang 2014). India can take some lessons from international good practices in this which is a potential area of further study. Thus, pumped storage is today the best tool to tackle the intermittent supply of sunlight. This should be given high priority to match the expected growth in solar power, as otherwise grid stability will become a stumbling block in the quest to reach the target capacity of solar power.

Even if solar energy achieves cost viability at par with thermal or nuclear energy, financing is another challenge. Even to expand transmission lines and integrate solar with the grid, government would have to undertake substantial investments towards such infrastructure. It is also observed that investors are reluctant or may increasingly become so to invest in a sector with rapidly changing technology (Climate Policy Initiative-CPI 2012). This can be a major hurdle together with high cost of borrowing (CPI 2012). Given that solar projects, whether for large scale utility, residential rooftops or for farm installations, require upfront capital costs, both the government and the private sector would have to take up the issue of financing. Institutions like NABARD and other banks can play the facilitating role. Indian Renewable Energy Development Agency Ltd. (IREDA) is also considering converting to a green bank in order to access foreign loans (PHD Chamber Bulletin, 2016). India can also tie up with international organizations like German GTZ and others. India has also signed an agreement with The World Bank by which it would be entitled to a loan of $1billion for solar projects in the country. But foreign loans can be subject to substantial forex risks as well. The government can also raise funds by issuing 8-10 years tax free bonds. In addition, mandatory Corporate Social Responsibility (CSR) requirements towards solar projects can prove to be an important financial boost. Crowd funding can also be used by engaging the private sector.

Box 1: Rooftop Record- Punjab

Dera Baba Jaimal Singh (Radha Soami) in Beas, Punjab has set up a rooftop solar power plant on its campus. Set up by the Radha Soami Satsang Beas (RSSB) Educational and Environmental Society, the plant was inaugurated on 17th May 2016. The state government of Punjab claims it to be the largest rooftop solar plant in the world to be set up on a single roof. Spread across a single roof of 42 acres (17 ha), the plant has a capacity of 11.5 MW. With this, the campus now holds a total rooftop solar capacity of 19.5 MW across multiple roofs totaling 82 acres (33 ha), the largest in India. Advertised as "*From green revolution to green power revolution*", the 139 crore project would help in abatement of 4 lac ton of carbon dioxide emissions in the next 25 years which is equivalent to planting of 2 lac trees. The first phase of 7.5 MW was allotted in September 2013 and connected to grid in April 2014 while the second phase of 12 MW was allotted in February 2015 and synched to the grid in December 2015. It would not only be meeting its own power requirements but has also entered into a 25 year Power Purchase Agreement (PPA) with Punjab State Power Corporation Limited (PSPCD) to feed surplus into the grid at Rs.7.6 per unit.

4.2 Rural Electricity challenges-rooftop installations

From 330 million houses[53] in the country, only 50percent are electrified, 23percent depend upon lighting from kerosene and a meager 1.08 million houses or 0.32percent are already using solar (SECI)[54] . Given this, solar can make inroads in the power sector by making two major contributions. For one, it can introduce a large number of houses and individuals to electricity through solar power and hence become an industry which is inclusive in nature. Secondly, solar power can reduce the carbon footprint created by the use of kerosene. Kerosene is majorly used by poor households as a source of lighting. Solar energy, thus, is faced with a scope of expansion to rural households as well as the farm sector.

[53] According to Census 2011

[54] Solar Energy Corporation of India (SECI), http://seci.gov.in/upload/uploadfiles/files/Shpercent20Rajendrapercent20Nimjepercent20-Febpercent202014.pdf

Out of the 100 GW of solar power capacity target of India, 40percent is to be achieved in the form of grid connected rooftop installations. This comes with both its potential as well as challenges. Currently, rooftop solar has sanctioned capacity of about 2527 MW while achievement is 166 MW of which 11 MW is without subsidy[55] . Rooftop solar addresses the problem of lack of rural electrification (Srivastava and Srivastava, 2013) in the absence of grid or poor supplies of power through the grid. Moreover, in places with grid connection, it can be used to feed surplus power into the grid (See Box 1 for the case of Radha Soami Satsang in Beas, Punjab).

From about 5,97,464 villages in India, Central Electrical Authority (CEA) reports 98percent as electrified and more than 11,000 still waiting electrification[56] . However, the sporadic availability of electricity in most of rural India is an undeniable reality despite the 98percent figure reported as "electrified". This leaves much room for supplying sufficient power to rural areas, and solar power is one such solution. With about 130 million houses with concrete or asbestos roof and with an estimate of 1-3KWp capacity in an average house (SECI 2014)[57] , it poses immense opportunity for rooftop solar. 1 KWp of grid connected rooftop solar requires 10 square meter of area which can be provided by a number of households. So, solar power can potentially play an instrumental role in the power industry through both off grid and grid initiatives. Power supply plays an important role in any economy, to boost agriculture, industry and services. In this regard, decentralized policy initiatives at the state and local level of governance as well as coherent Centre-State efforts are required to promote solar power and contribute to the development of rural economy.

But at the residential unit level, there is a problem of lack of scale economies and high upfront costs. In this scenario, the costs are high for an average consumer. Efficiency of rooftop panels is dependent on how sunny it is to produce electricity and this directly has an impact on cost. On an average a grid connected rooftop solar system costs Rs. 8 crore per MWp[58] . So a 1KWp system would cost around Rs. 80,000. The government provides Central Financial Assistance (CFA) up to 30percent. However, there is no CFA for government buildings, government institutions, private, commercial and industrial sector[59] . But the industrial sector can undertake such upfront capital investments given the high power charges faced by the sector as mentioned previously. Supplying power from single residential units to grid can be costly as it may require additional infrastructure investment in the form of transmission lines and other system requirements where it is to be fed into the grid. Hence for rooftop installations, there is a need for both financing solutions as well as a pooled evacuation to the grid. At the residential level there is a need to have private players for financing investments, technical consulting and those who can help with installations and collective evacuation to the grid. In light of these challenges, more is required to make solar energy a success in the country.

4.3 Solar powering agriculture and rural areas and augmenting farmers' income

Agriculture is where solar power can prove to be largely inclusive. It can help irrigate farmers' fields, build cold storages in rural areas, and augment farmers' incomes by feeding the surplus power generated into the grid. Harvesting solar power on farmers' fields can thus act as harvesting another crop, and can provide a sort of insurance even when rains fail. Rural India faces sparse and sporadic supply of power even where there are grid lines. In many far North and North-East regions, the rocky

[55] http://mnre.gov.in/file-manager/UserFiles/Status-of-Grid-Connected-SPV-Rooftop-Projects-Sanctioned-to_States_UTs_SEC_PSUs_OGA.pdf

[56] CEA report on Electrification, as on 30.04.16

[57] SECI, http://seci.gov.in/upload/uploadfiles/files/Shpercent20Rajendrapercent20Nimjepercent20-Febpercent202014.pdf

[58] http://mnre.gov.in/file-manager/UserFiles/FAQs_Grid-Connected-Solar-Rooftop-Systems.pdf

[59] http://mnre.gov.in/file-manager/UserFiles/gcrt-cfa-notification-04-03-2016.pdf

and mountainous terrains pose a hurdle for laying grid and transmission lines. Solar power can help to bridge this gap in power supply and can be a game changer.

4.3.1 Solar powered irrigation

An important innovation of solar power progress has been solar irrigation pumps which present an immense potential towards growth and development of agriculture. They can be set up in any remote agriculture field where grid is absent or otherwise no other supply of power is available. It just needs the availability of sunshine which can be easily found in rural areas given agriculture is already thriving there (crops cannot grow in the absence of sunlight). Solar Pumps would act as a replacement to electric and diesel pumps. In 2010-11, there were 14.33 million electric pump sets and 6.26 million diesel pump sets in the country[60] . If the electric pump sets are replaced by solar pump sets, it can help to reduce the annual power subsidy bill of the government to the agriculture sector. This could then also be used for financing up front capital costs for solar installations. It also reduces farmer's dependency on sporadic electricity supply which is usually received for a few hours at night. And replacement of diesel pump sets can save the farmer from high priced and polluting diesel source as well save on the government subsidy on diesel. As per a study by Pullenkav (2013), a cost comparison of diesel and solar PV pump sets shows (Table 3 below) solar PV pumps being more cost viable than diesel sets over a ten year period. The total difference exceeds Rs. 1 lakh in favour of solar pumps. This is owing to higher maintenance cost of diesel sets and high prices of diesel fuel itself. An argument against the use of solar pump sets has been overexploitation of groundwater given the free and abundant availability of sunlight. But electric pumps also contribute to groundwater exploitation as power is subsidized to them. Further, there is another incentive model to prevent over use of groundwater. If farmers are given the option of selling surplus power to the grid then they would minimise water pumping and thus conserve water. After meeting their irrigation requirements, excessive solar power would be evacuated to the grid to earn revenue by selling surplus power. Thus, this model would act as an incentive to adopt solar energy in the country, and reduce ground water exploitation and augment farmers' income.

Annexure 5 shows that 19500 solar pumps were installed in the country as part of decentralized/off grid initiatives by end of FY 2014-15. But in 2015-16 alone, 31,472 solar pumps were installed which is greater than the cumulative number so far. This definitely is a boon for remote rural and agriculture areas without any power access as well as sparse electricity supply. But it would be a useful and innovative policy solution to connect such decentralized renewable systems to the grid for additional revenue generation for farmers.

The installation of solar pumps would have two aspects with respect to location. First it would be important to prioritize the distribution of solar pump sets in areas which have sufficient groundwater resource like the Ganga Bramhaputra basin (Shah et al. 2014) and in areas without access to any electricity. This would not pose threat to ground water and supply electricity to areas without power supply. A map categorizing the groundwater resources in Annexure 4 can help to understand and identify such areas that do not face the threat of critical ground water level.

Second, distribution and installations of solar pumps in areas with critical ground water level would have to be accompanied by the 'feed in grid' model to allow farmers to sell surplus power. Dhundi Saur Urja Utapadak Shahakari Mandali (DSUUM) in Gujarat is the first solar irrigation cooperative in the world where farmers are selling surplus solar power to Discom by connecting solar pumps to grid (IWMI)[61] . The solar cooperative, with an installed capacity of 56.4 KW, has entered into a 25 year Power Purchase Agreement (PPA) with Madhya Gujarat Vij Company Ltd. (MGVL) for supplying solar power at Rs. 4.63/kwh. The initiative started as a pilot project by International Water Management

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[60] http://agcensus.nic.in/document/ac1011/reports/AllIndiaTables2010.pdf

[61] http://www.iwmi.cgiar.org/News_Room/Press_Releases/2016/press_release_worlds_first_solar_irrigation_cooperative_receives_award.pdf

Institute (IWMI) with one farmer in January 2015. The farmer replaced diesel pump with solar pump set on his fields and sold surplus power at Rs. 5/kwh to discom. He produces 40-50 units a day and received Rs. 7500 for producing surplus 1500 units in 4 months. According to Tushar Shah[62] , cooperatives of 40-50 such solar pump owners should be formed in each village so as to pool their power and evacuate power to the grid. Solar Irrigation pumps do not require much land as they are mounted at a height and do not hinder crop productivity.

Table 3: Comparing costs for 1HP Diesel and Solar PV Pump over 10 year period

	Capital Cost (Rs.)	Net Present Maintenance cost (Rs.)	Net Present Fuel cost (Rs.)	Total (Rs.)
SPV Pump	200000	3072	0	2,03,072
Diesel Pump	25000	12,289	278,993	3,16,282

Diesel cost at Rs. 50/litre

Source: Pullenkav, T. (2013). Solar water pumping for irrigation: Opportunities in Bihar, India. GIZ (Indo-German Energy Program—IGEN).

Typically the cost of solar pump varies from Rs. 3-5 lakh (MNRE)[63] . Such upfront capital costs pose a challenge. Financing of solar pumps would also need to be addressed through policy solutions discussed previously. Initiatives have been taking place already. Banks have been extending loans to farmers for solar pumps. For instance, the loan amount for Rs. 3-5 lakh for a set is about Rs. 2.7- 4.5 lakh including the subsidy component in which subsidy amount is Rs. 1.3-2 lakh (about 40-43percent subsidy). Thus, net loan amount of Rs. 1.4-2.5 lakhs accounts for 46-50percent of the total cost. In this, mortgage of land as collateral has been a major challenge other than hypothecation of equipment[64] . MNRE, by way of a circular dated 21st May 2016, has requested banks to follow the example of Syndicate Bank and waive off this additional collateral of land (for loans amounting Rs. 2 to 5 lakhs) to encourage more farmers to avail loans for solar pumps. Also, it would be important to organize the farmers into cooperatives as seen in the case of Gujarat or Farmer Producer Organisations (FPOs). The successful model of Amul cooperatives can be a guiding light for organizing the farmers at a large scale. With monitored and effective implementation, this innovation can become a boon both for the agriculture and power sector of the country.

The importance of solar irrigation does not seem to have been fully appreciated. It is necessary to go into these questions in greater detail. This is perhaps the most important initiative that can link the two goals of doubling famers' incomes and reaching 100 GW of solar capacity by 2022.

4.3.2 Leasing farmers' fields for solar power

The second solar power application in agriculture is planting solar panels (crop) in fields. Solar panels can be set up over entire farmer fields to harvest crops as well as power. It is like having a second crop of solar power at a height of 15-20 feet with the food crop below on the field. Studies across the globe have proved that shade of solar panels have no negative impact on crop growth, if arranged in a particular configuration that allows sufficient sunlight and wind to pass through to the plants. This has also been observed in experiments in Gujarat, when solar panels are arranged like a chess board with gaps and at about 15 feet above the field (GERMI)[65] to allow sufficient sunlight for

[62] https://www.youtube.com/watch?v=evPKkIQbXR4

[63] http://mnre.gov.in/file-manager/UserFiles/DO-letter-to-all-Banks-financing-solar-pump-sets.pdf

[64] MNRE

[65] Gujarat Energy Research and Management Institute (GERMI) http://www.germi.org/downloads/News-Nature-India.pdf

crops. This prototype method called ‘solar sharing’ was first adopted in Japan. Introduced by Akira Nagashima in 2004, the method entails installation of solar panels on agricultural land as a shade-roof like structure, but with gaps for air flow and sunlight passage for the crops beneath (see Picture below). The idea is based on the fact that beyond a certain optimal level, sunlight does not contribute to photosynthesis. Hence, excess sunlight can be tapped for generating power. This is particularly applicable for fruits and vegetables that do not require much sunlight. It has additional utility as shade and also helps to reduce irrigation requirements owing to increased retention of soil moisture levels. The farmer can meet his electricity needs as well as sell the surplus power to a discom by feeding into the grid at a pre-determined tariff and earn revenue. The tariff should be equated to marginal cost of thermal power plus transmission cost to remote and rural areas as well as a 10-20percent premium accounting for negative externalities. This would amount to a tariff of around Rs.6 to 6.5/kwh. The cost of solar power currently varies between Rs. 4.5 to 6/kwh and this would be an important boost to the farmers’ incomes. Thus, solar power by itself acts like risk insurance by diversifying the sources of farmers' incomes. Food crops are very prone to natural calamities, pests and irregularity of monsoons. It reduces the farmers’ sole dependence on incomes from food crops and reduces the risk factor in earnings.

Solar Panels on an agriculture field in Japan

There are some initiatives being already undertaken to introduce solar power plants in agriculture fields. Experiments have been conducted in state agriculture universities in Gujarat[66] . If implemented at a large scale, this would entail farmers leasing out land to discoms for solar panel installations and also earn about 30-40 percent profit sharing in power generation revenue. Also various Indian Council of Agricultural Research (ICAR) institutions have large tracts of land where they can carry out a number of such experiments and initiate solar installations. Other than solar plant on agriculture fields, Gujarat Energy Research and Management Institute (GERMI) is also awaiting large scale implementation of another proposal that would involve putting a layer of solar panels over one another which would generate 70 percent more energy than a single layer panel.

Solar harvesting would play a crucial role in regions which are single cropped as solar power would act like another perennial crop that can be harvested with gains from feeding power into the grid. Figure 15 below shows the cropping intensity (gross cropped area as a proportion of net cropped area) of some selected states. The much below 200 percent cropping intensity shows scope for planting such ‘solar trees’ on fields. Supplementing farmers income and increasing cropping intensity through better solar powered irrigation is of relevance particularly in Eastern states of Bihar,

[66] http://www.germi.org/news/economictimes-2-9-15.pdf

Jharkhand, Odisha where power supply to rural areas is very low, and in far off North eastern states where grid lines have not reached. Benefits would particularly be realized in regions like Marathwara in Maharashtra and Bundelkhand across UP and MP with low cropping intensity where the land lies fallow after one cropping cycle. Solar panels can be planted over the entire field and solar power can be reaped in the remaining parts of the year particularly when food crop is not sown at all.

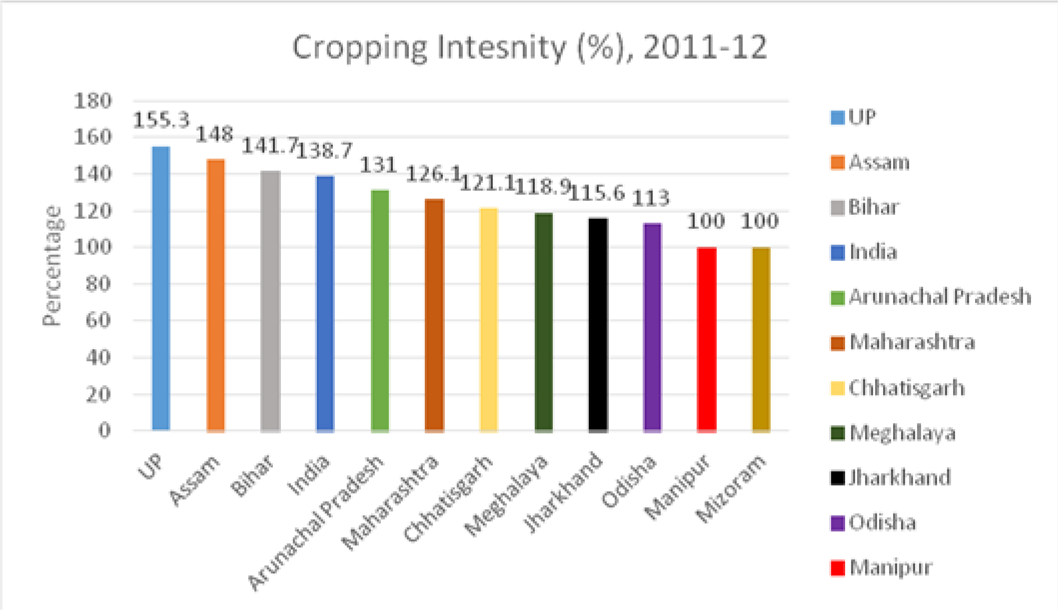

Figure 15: Cropping Intensity in Selected States

Source: Agricultural Statistics at a Glance 2014, Directorate of Economics & Statistics

4.3.3 *Cold storage- agriculture value chains*

An area that may deserve attention by way of solar energy application is agri-value chain, starting with solar irrigated farms, solar powered cold storages/chillers in rural areas for fast perishable products like fruits, vegetables, milk etc, solar powered transport logistics (like reefer vans) and finally solar powered retail outlets, including solar powered push carts of small vendors . India is the second largest producer of horticulture in the world and faces substantial post- harvest losses. Cold storage is an important infrastructure for farmers and suppliers who face risk of crop losses due to perishable nature of the produce. Lack of power supply in remote rural areas as well its erratic supply make cold storage solutions even more critical. Use of diesel for power supply is neither sustainable nor cost effective. Installation of solar panels on roofs of storage units/warehouses where grid lines are practically absent can prove to be an important solution. Central Institute for Agricultural Engineering (CIAE)[67] , Bhopal, developed a 5x4.4x3 m and 20kwp plant with power storage at a cost of Rs, 20,00,000 for 15 years. For mangoes, it was found that there was an increase in the shelf life, reduction in weight loss and an improvement in quality. A visual image of the cold storage set up by CIAE can be seen in Annexure 6. Such prevention of losses in food crops can reduce income loss to farmers. In a country with storage capacity of about 31 million metric tons[68] which is less than 10percent of total production (NCCD) and where storage infrastructure highly falls short, it is an important technological innovation in agri-value chains.

[67] http://mnre.gov.in/file-manager/akshay-urja/january-february-2016/EN/37-39.pdf

[68] National Centre for Cold Chain Development, http://www.nccd.gov.in/PDF/Mofpi.pdf

Technology Entrepreneurship Park (STEP), IIT Kharagpur, had designed a portable cold storage system for marginal farmers lacking access to electricity[69] . The students are selling it through a company called 'Ecozen'. Their products include a micro cold storage of 5 tons priced at Rs. 5-6 lakhs[70] . There are other ideas that can also be implemented. Introducing solar powered reefer vans can minimize transit based losses. Similarly, solar powered push carts can be an innovation that can help to reduce income losses to the vegetable/fruit vendor. With solar shade, it can help to increase the shelf life of the produce and a solar powered refrigerator beneath the cart can allow him to store the unsold produce for longer durations by reducing the losses due to warm and humid weather.

Given the speed and targets, and India's current solar standing, two factors will play an important role in achieving its solar targets. Firstly, a well-designed policy framework will decide how efficiently, speedily and sustainably India achieves this target through effective and timely implementation. And secondly, India's ability to realize this goal hinges on technological, process and product innovation.

4.3.4 Improving power reliability

As per CEA, 98 percent of villages stand electrified in India, out of a total of 5,97,464 villages in the country. But this figure doesn't translate into regular and sufficient power supplies to villages. Even villages that satisfy the following four criteria are counted as electrified- a) basic distribution transformer and distribution lines are present in the inhabited area b) Public spaces like schools, Panchayat Office, Health Centre, Community Centres, etc. receive electricity c) at least 10percent of the total households in the village are electrified and d) Gram panchayat gives a certification of completion of village electrification. Thus, this does not amount to supplying power to 100percent households even in all of the 98 percent villages stated as electrified. This only indicates that there are substantial gaps in supplying power to rural households. Having 24x7 power supplies in rural areas is still a far cry. Solar power can fill this gap.

Moreover, farmers who do receive power, receive erratic electricity supply at odd hours, mostly in the night. Solar power can help to overcome the problem of lack of electricity supply to agriculture and rural areas. This would enhance the productivity of the farmers as well as provide a boost to non-farm sector in rural areas. It can contribute to the development of cottage and other rural industries as power is one of the key inputs for the development of any industry. This will help create non-farm employment in rural areas, which is the need of the hour.

[69] http://zeenews.india.com/news/sci-tech/solar-power-driven-portable-cold-storage-to-prevent-food-wastage_1473116.html

[70] http://ecozensolutions.com/innovation/micro-cold-storage

5. More in the Pipeline: Innovations and Practices around the Globe

As an address to the challenges faced by solar energy, particularly in competition with other sources, a closer look at innovations in the industry can bring optimism about the future of solar (For instance, Box 2 below gives the case of solar paneled roads). In order to cross the bridge between where we are and where we have to go, innovations at various levels will play a crucial role. There are two types of innovation: entrepreneurial which is science based and others are in the nature of a routine, which is based on cumulative learning by doing (Cefis and Marsili, 2005). Both have contributed and continue to play a role for progress of solar energy, and will drive the future of solar power industry.

Within the solar power sector, PV technology has been attracting a lot of research, given the huge funds that are flowing in and wide scope that exists. An important trend in the industry has been reduced dependence on silicon and hence panel's increased financial viability. As the use of silicon and its contribution towards total cost have come down over the years, there are further efforts taking place in this direction. Gibson and Martinsen from Norwegian University of Science and Technology have found a way to reduce the use of silicon by 90 per cent per unit area[71] . This innovation in technology and process is aimed at reducing the use of silicon by using 'dirty' and hence cheaper silicon. It is also stated to reduce factor cost by being less labour intensive as well as being subject to less processing. The team is also attempting to replace silicon by 50-90 percent and replacing it with glass. They are still working towards increased efficiency before it is introduced in the market.

A large part of innovations come from private sector innovators in solar PV, which is indicative of the scope and potential that exists in the industry. Private sector puts its money in any basket based on the financial returns it expects from it. Substantial amounts of financial investments are thus indicative of positive signs. Among the four 'Climate Change Mitigation Technologies' (CCMT) consisting of: PV solar, PV thermal, bio-fuels and wind, solar PV had the highest volume of patent filings from 2006-11 (Helm, Tannock and Iliev, WIPO, 2014)[72] . In 2012, investments in solar were the highest- both solar thermal and solar PV- at $140 million (Helm, Tannock and Iliev, WIPO, 2014). In response to its severely low and further deteriorating air quality, China is attempting major innovations in solar technology. At 36000 kms above the ground, China is attempting a solar power station[73] , which will be able to tap solar energy 99 percent of the time unlike those on earth which are constrained at night time. But challenges remain in its thin design and light weight so as to enable it to be carried by rockets. It can be a breakthrough if it works out, because space solar station can generate electricity ten times more than that on ground.

The UK Government is planning to help schools crowd source funds to install solar panels on rooftop in a bid to promote 'community energy'[74] . This is also being suggested as a source to raise revenues by supplying surplus into the grid. This is an important step as, in addition to saving on land, it holds practical viability for schools. Schools operate for fewer hours per day as well as lesser number of working days annually, thereby having lower energy needs. So their energy needs can be met through solar rooftop installations. It would thus be a good idea if a number of private schools and universities with ample space both on rooftop and open land can install solar plants. A similar suggestion is being made by IHC authorities for the adjoining school in the neighborhood. Initiatives taken by IHC are discussed in Box 3 below.

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[71] http://www.gizmag.com/solar-cells-cheaper-silicon-ntnu/34554/

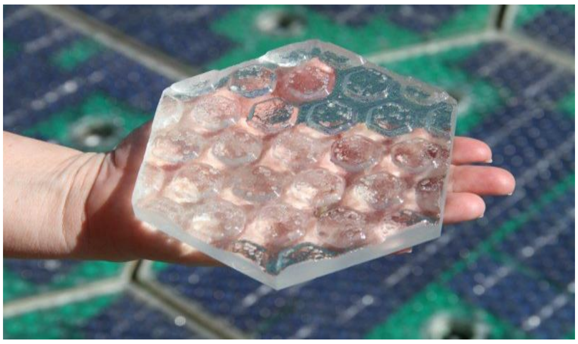
[72] http://www.wipo.int/edocs/pubdocs/en/wipo_pub_gc_3.pdf

[73] http://articles.economictimes.indiatimes.com/2015-03-30/news/60644068_1_power-station-international-space-station-energy-crisis

[74] http://www.theguardian.com/environment/2015/apr/05/solar-panels-school-energy

Box 2: SOLAR PANELLED ROADS

Route 66 in Missouri, USA is underway construction of solar paneled roads that would also produce energy. It is being developed by *Solar Roadways,* a company which raised funds through crowdfunding and is dedicated to construction of solar roads and parking lots. The roads would be covered with tempered glass such that cars can drive on them. The hexagonal panels also have LED lights that would perform the task of signage eliminating the need of paint markers. Also, they would have heating features to prevent the accumulation of snow on the road which is a common problem in USA. Other than USA, France is also looking to make 600 miles of solar paneled roads.



In February 2016, Pakistan Parliament (Picture below) became the first in the world to use solar energy to entirely meet its power requirements[75] . This has been financially supported by the Chinese government. The Parliament would also be evacuating surplus power to the grid.

The Indian government and its ministries, private sector, agriculture, industry, services, schools and colleges, malls and hotels, etc. can take clue from these innovations happening around the world and scale up to contribute to India's solar power capacity target of 100 GW by 2022.

Similarly, Innovations to tackle many problems with maintenance of solar systems are also being attempted. With greater installations, there would be a rising need for cleaning of solar panels to maintain their efficiency. Cleaning also calls for time, labour and scarce resource like water. As a first time ever, Kibbutz solar park in Israel has been using robots to clean panels[76] . Additionally, they do not employ water. Instead they use microfibers to clean and for each minute a robot cleans about 100 sq feet panel area. According to a media report, Israel based company Ecoppia[77] is setting up a robotic solar cleaner manufacturing unit in Chennai in foresight of the cleaning requirements that would arise with rapid solar installations.

Knowledge and information moves freely from one place to another given the ephemeral nature of borders in a globalized world. Policy ideas and lessons in implementation can be adopted in India by learning from good practices from around the world. Given the time bound need for policy initiatives in order to meet the 2022 goal, many innovative ideas need to be put to implementation. India is also an active participant in the initiatives taking place in the world of solar energy. Cochin International Airport has achieved the feat of becoming the first airport in the world to go completely

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75 http://timesofindia.indiatimes.com/world/pakistan/Pak-parliament-becomes-first-in-world-to-run-entirely-on-solar-power/articleshow/51105590.cms

76 http://www.israel21c.org/robots-clean-israeli-solar-panels-without-water/

77 http://www.timesofisrael.com/israeli-solar-panel-robot-cleaners-outsourced-to-india/

solar in August 2015[78] . The 12 MWp plant spread across 18 ha together with previously installed 1.10 MWp plant produces about 48000-50000 units every day. This is an important contribution in the direction of MoU signed between Airport Authority of India (AAI) and SECI[79] who have identified 30 airports for solar installations.

PAKISTAN PARLIAMENT

Source: http://www.newsx.com/world/21504-pakistans-parliament-becomes-worlds-first-completely-solar-parliament

To save on land, another innovation has been floating solar plants. The first floating solar plant of 10KW was set up in Rajarhat, Kolkata in 2015 and occupies a mere 0.01 ha of land[80] . SECI has initiated a hybrid solar-wind project with 300 MW capacity in Andhra Pradesh where World Bank is expected to fund half the project[81] . SECI has also announced floating solar projects of 10 MW each in Andhra and Kerala and 5MW in Lakshadweep[82] . This innovation can help to electrify the very remote rural areas and villages that still await power supply. The presence of water bodies in rural areas can hence be utilized for the same.

In Haryana, solar power plant installation of 3-5percent of connected load has been made mandatory for all residential buildings with plot size of 500 square yards (0.04 ha) and more, for all government and private educational institutions and offices with connected load of 30 KW and above and for private hospitals and nursing homes, malls, industrial and commercial establishments, hotels, banquet halls and tourist complexes of 50 KW and above[83] . This is on lines of San Francisco which has also passed legislation for mandatory rooftop solar installations for all commercial and

[78] http://cial.aero/Pressroom/newsdetails.aspx?news_id=360
[79] http://pib.nic.in/newsite/PrintRelease.aspx?relid=105253
[80] http://www.vikramsolar.com/projects-and-services/pdf/wb-india.pdf
[81] http://seci.gov.in/upload/files/what_new/press_release/572ae6f5a465eIndSECIplans325MwofhybridfloatingsolarprojectsreportSeeNewsRenewables.pdf
[82] http://seci.gov.in/upload/files/what_new/press_release/57284c2ebff64SolarEnergyCorporationofIndiaplanstosetupmoresolarplantsTheEconomicTimes.pdf
[83] http://hareda.gov.in//writereaddata/document/hareda810524221.pdf

residential buildings up to ten stories[84] . Politically as well, much initiative is moving in the direction of achieving solar power goal. There were 26 pacts (valued at $22 billion[85]) signed with China during Prime Minister Narendra Modi's visit to China in May 2015, and 4 out of these 26 are in the area of solar energy.

Box 3: INDIA HABITAT CENTRE, NEW DELHI

India Habitat Centre (IHC) has installed a 250 KW rooftop solar system as a prototype to demonstrate effective tapping of solar energy and efficient use of available space. From terrace rooftop area of 4600 square meter, about 2700 square meter or about 58percent has been employed for installation of solar panels. Power generation in 2015-16 was three lakh and fifteen thousand units which amounts to saving of Rs. 16 lakhs.

Bids were invited for hiring of both consultants and vendors for the twenty year tenure project. Solar modules imported from China have been installed on a number of terraces at IHC. This includes 12 locations with sizes varying from 5 KW to 63 KW. Different input equipments have been procured from different suppliers like modules from Trina, Invertors from Delta and structures from S&S Corp. In line with its objective of creating awareness about adoption of solar energy, live display screens have also been installed at locations within the centre's premises for public viewing of data and information.

The project that took about a year to complete from March 2014 to March 2015 is a twenty years Power Purchase Agreement (PPA) between JBM Group and IHC. With CSR grant of Rs. 50 lakh from IFFCL and ILFS leading to initial upfront payment to the vendor, it has meant fixed (for 20 years) cost of Rs. 4.99/ unit for electricity generated from solar energy. This is a lead in terms of cost as it is almost 50percent less than the variable tariff paid to BSES in 2015 @ Rs.10

During 2005 to 2015, BSES tariff jumped by 79percent and escalated from Rs. 5.6 to Rs 10 per unit. Evidently, these tariffs will go up further as and when s BSES revises them. Clearly, over the years, the gap between solar power tariff and BSES tariffs from other sources of energy would widen to make solar power even more attractive than what it is today. With each passing year, therefore, it is likely to attract more users to go for solar energy.

Some challenges were also faced in installation. The panels were installed at low heights on the terrace so as to avoid any visibility from the ground floor. This was to keep the artistic and heritage visual beauty of IHC as it is. This meant installations at certain lower angles of inclination. To maximize efficiency of solar cells in converting energy to electricity, concrete structures were constructed on which the panels were mounted to achieve the desired angle. Also, space imposed some constraints as certain parts of terrace do not receive ample sunlight owing to construction design and other factors.

Even though the plant is currently serving only 4percent of IHC's total power consumption, yet it is an important step towards a larger goal. Overall, it has been a successful attempt to showcase the benefits of solar energy and create wider acceptability.

[84] http://www.sfexaminer.com/san-francisco-require-rooftop-solar-installations-new-buildings/

[85] http://mea.gov.in/bilateral-documents.htm?dtl/25248/Business+MoU+Agreements+signed+at+India+China+Business+Forum+during+PMs+visit+to+Shanghai+May+16+2015

These examples bear the testimony that policy initiatives are being undertaken towards the attainment of the solar energy target. The solar industry is charged and is coming up with several innovative solutions. For India, these international technology transfers are a source not only for innovation adoption but also for further cumulative ‘learning by doing’. Overall, it is also dependent upon our absorptive capacity to identify, decode and put new knowledge to use in a localized context (Cohen and Levinthal, 1990).

6. Conclusion

Prime Minister Narenda Modi has set two ambitious targets to be achieved by 2022: installing 100 GW solar power capacity and doubling farmers' incomes. This paper reviews the developments in solar power arena, especially how its costs have been declining so dramatically since 2008-09, and how different countries are innovating in policies, technologies, processes, and products, to make the best use of clean energy. India has a lot to learn from these best practices around the world, but also become a pioneer by mainstreaming it on farmers' fields like a "chess board" at a height of about 15-20 feet, improving agri-value chains and generating non-farm activities in rural areas. This will make the solar mission more inclusive and it would contribute in a significant way to achieving the Prime Minster Modi's twin goals set out for 2022. For pursuing the two in unison, both Ministry of Agriculture and the Ministriess of Power and New & Renewable Energy Resources will have to work closely, generating synergy to achieve these goals.

With a growing population and a rapid shift towards energy intensive lifestyles, the demand for energy will keep increasing. Today, about 60 percent of India’s power requirements are met by burning coal, which is damaging the environment. So, India needs to reduce its dependence on fossil fuels for a better future. Around the world, there is a greater acknowledgement and shift towards the use of renewable forms of energy. Solar energy is one form of energy that can be an alternative source of power supply. The merit of solar power is based on 4 important characteristics namely CISS, defined as: C- Cost Competitiveness, I- Inclusiveness, S- Scalability, and S- Sustainability, both environmental and financial. Cost competitiveness includes cost viability of solar with respect to conventional sources of energy, typically coal based thermal power. Given the imbalance of power distribution between cities and remote & rural areas, ability of solar energy to provide electricity to those excluded from its benefits would play a very crucial role in defining its inclusive nature. The large scale at which it can be viably adopted across sectors- industry to agriculture as well as across regions- both urban and rural, would define its scalability. On account of sustainability, it is a non-polluting and freely available source of energy derived from sunshine. Through this work, a case for solar energy is made based on these four defining features.

Rise of solar power is a global phenomenon. In 2014, the cumulative installed solar power capacity in the world was 178 GW. The global capacity added in the year 2014 was 40 GW, the same amount which was the cumulative capacity in 2010. In this global quest for solar energy, Germany has emerged as a leader with 21percent of the 178 GW solar capacity installations. The centerpiece of Germany’s successful model hinges on two key features- guaranteed grid access to renewable energy producers and Feed-in-Tariffs (FITs). FIT can be an important instrument to augment farmers’ income in India and hence is an important policy lesson for us. India which accounted for 3 GW of 178 GW in 2014 had a capacity as low as 3 MW in 2008-09. India has touched 8 GW solar capacity by July end, 2016. These figures are testimony to the fact that solar industry has gained much traction in the last few years both nationally and globally. But we have a long road ahead. Setting a target of 100 GW by 2022, we are faced with the challenge of adding more than 90 GW of capacity in six years. This could mean adding 15 GW every year for the next six years.

The prime reason for widespread adoption of solar power, other than its sustainable nature, has been falling costs. Falling polysilicon prices, cost reducing innovations, improvement in design and engineering and falling costs of Balance of System, have all contributed to bringing down the costs of solar power globally. It is reflected in the fact that as a key input, solar module costs have declined by more than 80 percent since 2008. In India, the capital cost of solar PV projects has also reduced by 68 percent since 2010-11. However, the cost of land has been rising and its contribution to total cost in projects has increased from 1percent in 2011-12 to 4.7percent in 2016-17. The rising land cost, hence, is a challenge to which this paper has suggested some solutions in terms of using farmers' fields for setting up solar power plants. Also, a number of private schools, colleges, universities and ICAR institutions have tracts of land as well as rooftops that can be deployed for solar power installations. To encourage FIT model for such institutions as well as for farmers, Central govt. can draft a model Power Purchase Agreement that can be a guide for states which should also ensure timely payments.

The falling capital costs are reflected in declining tariff of solar power. In the country, tariff of solar power has decreased by 68 percent since 2010-11 to Rs. 5.68/kwh without Accelerated Depreciation (AD). This is lower the cost of supply of thermal power of Rs. 5.93/kwh for 2013-14 as discoms have been running in losses. The lowest bid for solar park in 2016 so far is at Rs.4.34/kwh, which is much lower than the cost of supply of thermal power. And a number of indirect costs in case of thermal power are not accounted for. This includes cost of transporting coal from place of mining to load station as well as the health hazard created by use of fossil fuels. Solar power should be priced at marginal cost of thermal power plus a 15-20 percent cost premium to account for negative health externalities created by use of coal. This feed in tariff would amount to Rs. 6 to 6.5/kwh which would contribute to a revolution in solar power as well in agriculture sector.

Given solar energy's sustainability and cost efficiency, its inclusiveness and scalability is going to be the fulcrum on which its wider acceptance as a source of power is going to be based. India's initiatives and huge targets in solar energy would receive a further momentum if additional gains are realized other than just as an initiative to switch to greater use of renewable energy. The use of solar energy in agriculture is one such potential area given the important role of agriculture in the country as well as the vast scope in the sector to make substantial contributions. The GOI has a target of doubling farmers' incomes by 2022. Sharing the same operational period, the two targets of 100 GW and doubling farmer income are very much in tandem with another.

As has been seen in section 4.1.1 solar power requires huge amounts of land. The costs of these are growing. With proper intervention by the State Governments it should be possible to ensure that the benefits of such escalation flow to the farmers. If there can be model leasing agreements and proper education of farmers this can provide a steady and increasing source of income. Further such income need not come only from the barren lands but also from land being cultivated. This idea has been discussed in section 4.3.2 whereby solar panels can be mounted on entire agriculture fields and act as a second crop at a height of about 15 feet along with food crops below. This would serve as additional income if planted along with a food crop and as an insurance cover in case of a drought.

There is also a growing interest in solar powered irrigation. This can be seen from the rapid increase in the pace of installations that has been brought out earlier. What is even more exciting is the possibility that farmers can increase their incomes by selling surplus power to the grid. This would mean a direct increase in the income of the farmer as they do not need all the solar energy that they get. Further, as is well known, the water tables have been generally falling all across India. While there are many causes for this one contributory cause has been the provision of unmetered, close to free power. This has meant that the farmers can use the electric driven pump sets without any direct costs. Replacement by solar pumps would also help to save on power subsidies to the agriculture sector which can be used to provide subsidies for up front capital costs for solar pumps. If the solar pump sets can be connected to the grid with a provision for buy back of surplus power it can provide a direct incentive to the farmers to use the pump sets only when required. This in turn will provide some income to the farmers immediately and protect water tables. Obviously, such a policy will also help to improve long term sustainability of water as well as incomes of farmers. A liberal subsidy scheme for solar powered pump sets with help to farmers to organize themselves and enter into arrangements with the Discoms to buy surplus power needs to be made a priority policy for both the solar and the doubling of farmers' incomes initiatives. It would also be imperative to organize farmers on the lines of Amul cooperative to ensure large scale participation and inclusion of farmers.

Much has been written about the farm to home wastages in horticulture and dairy sectors. The GOI has many schemes for promotion of cold chains. One problem of course is the lack of secure power supply in both villages and towns. The traditional response has been to use diesel powered back up supply. This again is costly in both financial and economic terms. Use of solar power, with wind/biomass to supplement this source, can be an answer to this problem. Therefore in the cold chain schemes also a portion of the subsidy should be kept aside for solar powered cold chains.

While rural India is getting better connected to the grid what is yet to happen is assuring 24X7 power supply to them. Typically power is supplied at odd hours in the night for farm operations and rural homes still have erratic power supply. Solar plants can be set up even in the most remote areas. Quite clearly having dedicated solar power can overcome these problems, improve productivity, enable farmers to get into non- farm activities apart from an improvement in the quality of their lives. It would also help in developing the rural health and education infrastructure with a greater control over power supply.

There are still some challenges that need to be addressed. Financing of upfront capital costs is one limitation that needs foremost attention. The current provision of subsidies, though a short to mid-term boost, is not a long term answer. The role of NABARD and likewise banks and international financial institutions in facilitating credit at moderate rates is one solution. Tax free government bonds can also help to raise capital. Crowdfunding can also help to mobilize funds effectively. Corporate Social Responsibility can provide the large funds required to finance up front capital costs by engaging the private sector.

As the size of the solar source increases the problem of its intermittent nature will cause problems for the grid. One way of combating this problem is to ensure better transmission links so that surplus power in one region can be transmitted to other deficit areas. With the large size of India this provides some scope of managing the temporary spurts of generation. Better forecasting techniques can also help to address this problem. The other method is to invest in power storage. Batteries are still expensive but could provide an answer if their costs come down. The other way is to use pumped storage in a much bigger way than has been done hitherto. Investment in pumped storage is today the best way to address this problem. Many sites have been identified by CEA. In 2013, there were 9 sites with total installed capacity of 4786 MW.

Concentrated efforts are being undertaken to make the world more green and energy efficient and India is a pro-active participant in this endeavor. Indian PM Narendra Modi together with French President Francois Hollande laid the foundation of International Solar Alliance[86] during Paris Climate Conference held in November –December 2015. This is the first inter-governmental organization with its headquarters in India and it shall be working to promote solar energy. With this, and India's ambitious targets and energetic endeavors, India has become a key player in the global initiative towards solar power. The solar industry has witnessed a tremendous growth and is fast moving towards wide acceptability and viability. This is the right time to use these advances in technology to meet the fundamental challenge of sustainable energy supply and use it in an equally large measure to support farmers and double their incomes by 2022.

[86] http://pib.nic.in/newsite/PrintRelease.aspx?relid=135794

References:

Andhra Pradesh Solar Power Corporation Private Limited. [Online]. Available from: http://www.apspcl.ap.gov.in/landdetails.html

Birol, F. (2015). India energy outlook 2015. International Energy Agency, http://www.worldenergyoutlook.org/media/weowebsite/2015/IndiaEnergyOutlook_WEO2015.pdf

Cefis, E., & Marsili, O. (2005). A matter of life and death: innovation and firm survival. Industrial and Corporate change, 14(6), 1167-1192.

Central Ground Water Board, Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India (2014), Dynamic Ground Water Resources of India (as of 31st March 2011). [Online]. Available from: http://www.cgwb.gov.in/documents/Dynamic-GW-Resources-2011.pdf

Cohen, W. M. and Levinthal, D.A. (1990). Absorptive capacity: A new perspective on learning and innovation. Administrative science quarterly, 128-152.

Department of Agriculture and Cooperation, Government of India, All India Report on Agricultural Census 2010-2011. [Online]. Available from: http://agcensus.nic.in/document/ac1011/reports/AllIndiaTables2010.pdf

European Photovoltaic Industry Association (EPIA), Global Market Outlook for Photovoltaics 2014-2018. Available from: http://www.cleanenergy businesscouncil.com/site/resources/files/reports/EPIA_Global_Market_Outlook_for_Photovoltaics_2014-2018_-_Medium_Res.pdf

Fraunhofer Institute for Solar Energy Systems (Fraunhofer ISE), Photovoltaics Report, (2016). [Online]. Available from: https://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles /photovoltaics-report-in-englischer-sprache.pdf

International Energy Agency (IEA), Technology Roadmap Solar Photovoltaic Energy, (2014). Available from: https://www.iea.org/publications/freepublications /publication/ TechnologyRoadmap Solar PhotovoltaicEnergy2014edition.pdf

International Water Management Institute (IWMI). (2015). Payday for India's first ever "sunshine farmer".12 June. Available from: http://www.iwmi.cgiar.org /News_Room/Press_Releases/2015/press_releaseindian_farmer_harvests_solar_crop.pdf

Investment Information and Credit Rating Agency (ICRA). (2016), Solar Energy Sector: Capacity addition estimated at 5.7 GW in FY 2017 aided by strong pipeline of projects, but concerns persist over aggressive competitively bid tariffs & regulatory challenges. [Online]. Available from: http://www.icra.in/Files/ticker/SH-2016-Solarpercent20Energy.pdf

Jayaraman, K. (2015). Indian farmers could grow power, not just crops. GERMI [Online] 8 May. Available from: http://www.germi.org/downloads/News-Nature-India.pdf

Kaur T. (2015). Solar PV Integration in Smart Grid- Issues and Challenges. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol 4, Issue 7

Nair N. (2016). World's First Solar Irrigation Cooperative Receives Award. International Water Management Institute [Online] 9 May. Available from: http://www.iwmi.cgiar.o rg/News_Room / Press _Releases / 2016/press_release_ worlds_first_solar_irrigation _cooperative _receives_award .pdf

Nelson, D., Shrimali, G., Goel, S., Konda, C., & Kumar, R. (2012). Meeting India's renewable energy targets: The financing challenge. CPI-ISB Report, Climate Policy Initiative (www. climatepolicyinitiative. org).

PHD Chamber Bulletin (June 2016), Vol. No. XXXVIII No. 6

Philip, A. (2014). Filling the Gaps: Rooftop Solar Projects in India. Economic and Political Weekly, 49(10).

Planning Commission, Government of India. (2014). The working of state power utilities & Electricity departments, Annual Report (2013-2014).[Online]. Available from: http://planningcommission.nic.in/r eports/genrep /rep_ arpower0306.pdf

Pullenkav, T. (2013). Solar water pumping for irrigation: Opportunities in Bihar, India. GIZ (Indo-German Energy Program—IGEN).

Puttaswamy, N. and Ali, M. (2015), How Did China become the largest Solar PV Manufacturing Country. Centre for Study of Science, Technology & Policy [Online]. Available from: http://www.cstep.in/uploads/default/files/publications/stuff/dc6ff09 f580c30a0a6fc0d1a90ed813f.pdf

Renewable Energy Consumer Code-RECC. (2015). Feed-in Tariff Scheme. [Online]. Available from: https://www .recc.org.uk/pdf/feed-in-tariff-scheme-guidance-for-consumers.pdf

Renewable Energy Policy Network for the 21st Century (REN21). (2015). Renewables 2015 Global Status Report. Available from: http://www.ren21.net/wp-content /uploads/2015/07/REN12-GSR2015 _ Onlinebook_low1.pdf

Shah, T., Verma, S. and Durga, N. (2014). Karnataka's Smart, New Solar Pump Policy for Irrigation. Economic and Political weekly. 49(48). Pg 11

Shumkov, I. (2016). India's SECI plans 325 MW of hybrid & floating solar projects ¬ report. Solar Energy Corporation of India Limited [Online] 4 May. Available from: http://seci.gov.in/upload/files/what_new/press_release/572ae6f5a465eIndSECIplans325MWofhybridfloatingsolarprojectsreportSeeNewsRenewables.pdf

Solar Energy Corporation of India Limited (SECI) Government of India, State-wise Solar Parks. [Online]. Available from: http://seci.gov.in/content/innerpage/statewise-solar-parks.php

Solar Energy Corporation of India Limited (SECI), Government of India. (2014). Pilot Scheme on Grid - Connected Rooftop PV Systems. [Online] 18 February. http://seci.gov.in/upload/uploadfiles /files/Shpercent20Rajendra percent20 Nimjepercent20-Febpercent202014.pdf

Solar Power Europe, Global Market Outlook for Solar Power. 2015-2019. Available from: http:// helap co.gr/pdf/Global_Market_Outlook_2015_-2019_lr_v23.pdf

Srivastava, S. P., & Srivastava, S. P. (2013). Solar energy and its future role in Indian economy. International Journal of Environmental Science: Development and Monitoring, 4(3), 81-88.

Swain, M (2013). Pumped Storage Hydro Power Plant. Electrical India. November 2013.Available from: http://npti.in/Download/Hydro/Pumpedpercent20Storagepercent20Hydropercent20Powerpercent20Plant,percent20Electricalpercent20India,percent20Nov,percent202013.pdf

Weisss, Jurgen. (2014). Solar Energy Support in Germany. Prepared for NARUC Annual Meeting. The Brattle Group [Online]. Available from: http://www.brattle.com/system/publications/pdfs/000/005/060/original/Solar_Energy_Support_in_Germany_-_A_Closer_Look.pdf?1406753962

World Intellectual Property Organization (WIPO). Renewable Energy Technology: Evolution and Policy Implications— Evidence from Patent Literature. [online]. Available from: http://www.wipo.int/edocs /pubdocs/en/wipo_pub_gc_3.pdf

Yang, C. J. (2014). Pumped hydroelectric storage. http://people.duke.edu/~cy42/phs.pdf

Online Resources:

Anderson, J. (2014). Using 'dirty silicon' to cut the cost of solar cells. Gizmag [Online] 5 November. Available from: http://www.gizmag.com/solar-cells-cheaper-silicon-ntnu/34554/

Bera, S. (2016). States to prepare weekly action plans to deal with drought: Radha Mohan Singh. LiveMint [Online] 18 May. Available from: http://www.livemint.com/Politics/POTd7T1QFEnCPnRRhsaHgI/States-to-prepare-weekly-action-plans-to-deal-with-drought.html

Bhat, S. (2016) India's solar power punt. Forbes India [Online] 14 June. Available from: http://forbesi ndia.com/article/real-issue/indias-solar-power-punt/40047/1

Boffey, D. (2015). Crowdsourcing funds will put solar panels on every school roof. The Guardian [Online] 5 April. Available from: https://www.theguardian.com/environment /2015/apr/05/solar-panels-school-energy

Cabinet, Government of India. (2015). UDAY (Ujwal DISCOM Assurance Yojana) for financial turnaround of Power Distribution Companies. [Online] 5 November. Available from: http://pib.nic.in/newsite/PrintRelease.aspx?relid=130261

Central Electricity Authority (CEA). http://www.cea.nic.in/

Central Electricity Regulatory Commission (CERC), Government of India. (various circulars)

Chandrasekaran, K. (2016). Solar Energy Corporation of India plans to set up more solar plants. The Economic Times [Online] 3 May. Available from: http://seci.gov.in/upload/files/what_new/pressrelease/57284c2ebff64SolarEnergyCorporationofIndiaplanstosetupmoresolarplantsTheEconomicTimes.pdf

Cochin International Airport Limited, Kochi airport becomes world's first to completely operate on solar power. [Online]. Available from: http://cial.aero/Pressroom/newsdetails.aspx?news_id=360

Coren, M. (2016). Germany had so much renewable energy on Sunday that it had to pay people to use electricity. Quartz [Online] 10 May. Available from: http://qz.com/680661/germany-had-so-much-renewable-energy-on-sunday-that-it-had-to-pay-people-to-use-electricity/

Ecozen Solutions. Available from: http://ecozensolutions.com/innovation/micro-cold-storage

Eldredge B. (2016). US’s First Public Solar Road Will Roll Out On Route 66. Curbed. [Online]. 21 June. Available from: http://www.curbed.com/2016/6/21/11976224/solar-panel-street-pavers-missouri-energy-route-66

Energy and Petrochemical Department, Government of Gujarat. (2015). Gujarat solar power policy-2015. GEDA [Online] 13 August. Available from: http://geda.gujarat.gov.in/policy_ files/gujarat_solar_ power_policy_2015.pdf

Ghosh,A. (2015). Arunabha Ghosh: Speed, scale, skill... solar?. Business standard [Online] 16 February. Available from: http://www.business-standard.com/article/opinion/arunabha-ghosh-speed-scale-skill-solar-115021601820_1.html

Green Rhino Energy, The Solar value chain. [Online]. Available from: http://www.greenrhinoenergy .com /solar/industry/ind_valuechain.php

Gulati, A. and Saini, S. (2016). Farm Incomes: Dreaming to Double. The Indian Express. [Online]. 28 July. Available from: http://indianexpress.com/article/india/india-news-india/farm-incomes-dreaming-to-double-2939405/

Hanley, S. (2016). Solar Roadways Coming to Route 66 in Missouri. CleanTechnica. [Online]. 28 June. Available from: http://cleantechnica.com/2016/06/28/solar-roadways-coming-route-66-missouri/

Haryana Government Renewable Energy Department, Government of Haryana (2016). Haryana Solar Power Policy, 2016. [Online] 14 March. Available from: http://hareda.gov.in//writereadd ata/document / hare da810524221.pdf

Indiatoday. (2015). Gujarat becomes the first state to implement Agro-Solar Policy. [Online] 24 August. Available from: http://indiatoday.intoday.in/education/story/gujarat-first-state-to-implement-agro-solar-policy/1/460625.html

IWMI. SPaRC'ing a Revolution. (2016). [Video]India: International water Management Institute. Available from: https://www.youtube.com/watch?v=evPKkIQbXR4

Jena, M. (2015). India builds solar plants atop canals to save land, water. REUTERS [Online] 16 Jan. Available from: http://in.reuters.com/article/india-solar-idINKBN0KP0ZO20150116

Kloosterman, K. (2014). Robots clean Israeli solar panels without water. Israel21c [Online] 14 June. Available from: http://www.israel21c.org/robots-clean-israeli-solar-panels-without-water/

Mehta, S. (2014). The Shifting Relationship Between Solar and Silicon in Charts. Greentechmedia [Online] 03 February. Available from: http://www.greentechmedia.com/articles/read/Solar-and-Silicons-Shifting-Relationship-in-Charts

Ministry of Civil Aviation, Government of India. (2014). MoU for Tapping Solar Energy at AAI Airports. [Online] 28 May. Available from: http://pib.nic.in/newsite/PrintRelease.aspx?relid=105253

Ministry of External Affairs, Government of India. (2015). Business MoU/ Agreements signed at India-China Business Forum during PM's visit to Shanghai. [Online] 16 May. Available from: http://mea.gov.in/bilateral-documents.htm?dtl/25248/Business+MoU+Agreements+signed+at+India +China+Business+Forum+durin g+PMs +visit+to+Shanghai+May+16+2015

Ministry of External Affairs, Government of India. (2015). India-France Joint Statement during the visit of Prime Minister to France. [Online] 10 April. Available from: http://www.mea.gov.in/bilateral-documents.htm?dtl/25053/IndiaFranceJoint_Statementduring_the_visit_of_Prime_Minister_to_France_April_911_2015

Ministry of Food Processing Industries, Government of India. (2014). Government support & initiative to build a robust cold chain. NCCD. [Online] 9 May. Available from: http://www.nccd. gov.in/PDF/Mofpi.pdf

Ministry of New and Renewable Energy. http://mnre.gov.in/

Ministry of Power, Government of India. (2016). Puducherry joins "UDAY" scheme; would derive an overall net benefit of Rs 378 crore through "UDAY". [Online] 10 August. Available from: http://pib.nic.in/newsite/pmreleases.aspx?mincode=52

Ministry of Statistics and Programme Implementation, Government of India http://mospi.nic.in/Mospi_New/site/home.aspx

Munsell, M. (2016). Solar Module Prices reached 57 cents per Watt in 2015, Will continue to fall through 2020. Greentechmedia [Online] 10 March. Available from: http://www.greentechmedia.com/articles/read/solar-pv-module-price-reach-57-cents-per-watt-in-2015-continue-to-fall-thro

Nelson, A. (2016). Portugal runs for four days straight on renewable energy alone. The Guardian [Online] 18 May. Available from: http://www.theguardian.com /environment /2016/may/18/portugal-runs-for-four-days-straight-on-renewable-energy alone?utm _source=facebook&utm _medium=post&utm_ term=renewable, Portugal&utm _campaign=Climate &__surl__=IgNYa&__ots_ _=1463716048252 & _step__=1

Parnell, J. (2013). Technology not materials to drive down Chinese solar costs: GTM. PV-TECH [Online] 27 August. Available from: http://www.pv-tech.org/news/technology_not _materials_to_drive _down _chinese_solar_costs_gtm

Press Information Bureau (PIB), Government of India. (2016). Solar Power Capacity Crosses Milestone of 5,000 MW in India. [Online] 16 January. Available from: http://pib.nic.in/newsite/printrelease.aspx?relid=134497

Sabatini, J. (2016). SF to require rooftop solar installations on new buildings. San Francisco Examiner. [Online] 19 April. Available from: http://www.sfexaminer.com/san-francisco-require-rooftop-solar-installations-new-buildings/

Sontakke, M. (2015). German Rooftops dominates global photovoltaic capacity. Market Realist [Online] 02 February. Available from: http://marketrealist.com/ 2015/02/german-rooftops-domniate-global-photovoltaic-capacity/

The Economic Times. (2015). Gujarat farmers to be roped in to tap solar energy. [Online] 17 August. Available from: http://www.germi.org/news/economictimes-2-9-15.pdf

The Economics Times. (2015). China plans to build huge space solar power station. [Online] 30 March. Available from: http://articles.economictimes.indiatimes.com/2015-03-30/news/60644068_1_power-station-international-space-station-energy-crisis

The Times of India. (2015). Radha Soami Satsang Beas. World’s Largest Single Rooftop Solar Power Plant in Punjab. [Online].

The Times of India. (2016). Beas has world's largest rooftop solar plant. Radha Soami Satsang Beas [Online] 18 May. Available from: http://www.rssb.org /files/pdf/Timespercent20ofpercent20Indiapercent20Article-May-18-2016.pdf

The Times of India. (2016). Pak parliament becomes first in world to run entirely on solar power. [Online] 23 February. Available from: http://timesofindia.indiatimes.com/ world/pakistan/Pak-parliament-becomes-first-in-world-to-run-entirely-on-solar-power/articleshow/51105590.cms

The Times of Israel. (2016). Israeli solar panel robot cleaners ‘outsourced’ to India. [Online] 6 May. Available from: http://www.timesofisrael.com/israeli-solar-panel-robot-cleaners-outsourced-to-india/

U.S. Department of Energy. The falling Price of Utility-scale Solar Photovoltaic (PV) Projects. [Online]. Available from: http://energy.gov/maps/falling-price-utility-scale-solar-photovoltaic-pv-projects

Vaughan, A. (2016). Solar power sets new British record by beating coal for a day. The Guardian [Online] 13 April. Available from: http://www.theguardian.com/ environment/2016/apr/13/solar-power-sets-new-british-record-by-beating-coal-for-a-day

Vikramsolar. Floating solar power plant in West Bengal, India. [Online]. Available from: http:// www. vikramsolar.com/projects-and-services/pdf/wb-india.pdf

Z News. (2014). Solar power-driven portable cold storage to prevent food wastage. [Online] 20 September. Available from: http://zeenews.india.com/news/sci-tech/solar-power-driven-portable-cold-storage-to-prevent-food-wastage_1473116.html

Annexure

ANNEXURE 1A- STATE WISE SOLAR TARGETS AND CAPAPCITY ACHIEVED

S. NO.	STATE	SOLAR ENERGY TARGET BY 2022*1 (MW)	SOLAR ENERGY COMMISSIONED AS OF 14.01.2016*2 (MW)	TOTAL COMMISSIONED (MW) AS OF 31.03.2016*3	Target achieved by 31.03.2016 (Percentage percent)
	Andhra Pradesh	9834	357.34	572.966	5.83
	Arunachal Pradesh	39	0.265	0.265	0.68
	Assam	663	-		0
	Bihar	2493	-	5.100	0.20
	Chhattisgarh	1783	73.18	93.580	5.24
	Gujarat	8020	1024.15	1119.173	13.95
	Goa		-		0
	Haryana	4142	12.8	15.387	0.37
	HP	776	-	0.201	0.03
	Jharkhand	1995	16	16.186	0.81
	J&K	1155	-	1	0.09
	Karnataka	5697	104.44	145.462	2.55
	Kerala	1870	12.025	13.045	0.70
	MP	5675	678.58	776.370	13.68
	Maharashtra	11926	378.7	385.756	3.23
	Manipur	105	-		0
	Meghalaya	161	-		0
	Mizoram	72	-	0.100	0.14
	Nagaland	61	-		0
	Odisha	2377	66.92	66.920	2.82
	Punjab	4772	200.32	405.063	8.49
	Rajasthan	5762	1254.35	1269.932	22.04
	Sikkim	36	-		0
	TN	8884	418.945	1061.820	11.95
	Telangana		342.39	527.843	-
	Tripura	105	5	5	4.76
	UP	10697	140	143.495	1.34
	Uttarakhand	900	5	41.145	4.57
	WB	5336	7.21	7.772	0.15
	A&N	27	5.1	5.100	18.89
	Delhi	2762	6.712	14.28	0.52
	Lakshadweep	4	0.75	0.750	18.75
	Puducherry	246	0.025	0.025	0.01
	Chandigarh	153	5.041	6.806	4.45
	Daman & Diu	199	4	4	2.01
	Dadar& Nagar Haveli	449	-		0
	Others		0.79		
	TOTAL	99533	5129.813	6762.853	6.79

ANNEXURE 1B- STATE WISE SOLAR PARKS

S. No.	STATE	CAPACITY APPROVED (MW)
1	Andhra Pradesh*1	4000
2	Rajasthan*2	3251
3	MP*3	2750
4	Karnataka	2000
5	Maharashtra*4	1500
6	HP	1000
7	Odisha	1000
8	Gujarat	700
9	UP	600
10	Chhattisgarh	500
11	Haryana	500
12	TN	500
13	Telangana	500
14	WB	500
15	Kerala	200
16	Arunachal	100
17	J&K	100
18	Assam	69
19	Nagaland	60
20	Uttarakhand	50
21	Meghalaya	20
	TOTAL	**19,900**

Source: SECI, http://seci.gov.in/content/innerpage/statewise-solar-parks.php [accessed: 4th May 2016]

*1 (4 projects: 1500, 1000, 1000, 500)

*2 (5 projects: 680, 1000, 750, 500, 321)

*3 (4 projects: 750, 1000, 500, 500)

*4 (3 projects: 500, 500, 500)

ANNEXURE 2- PROJECT BENCHMARK COSTS, 2016-17

Particular	Project cost norm for solar PV project (Rs. Lakh/mw)	percent of total cost
PV Modules	328.39	61.96
Land cost	25	4.7
Civil and General works	35	6.6
Mounting structures	35	6.6
Power conditioning units	35	6.6
Evacuation cost up to Interconnection point (cables and transformers)	44	8.3
Preliminary and Pre-operative expenses including IDC and contingency	27.63	5.21
Total capital cost	**530.02**	**100percent**

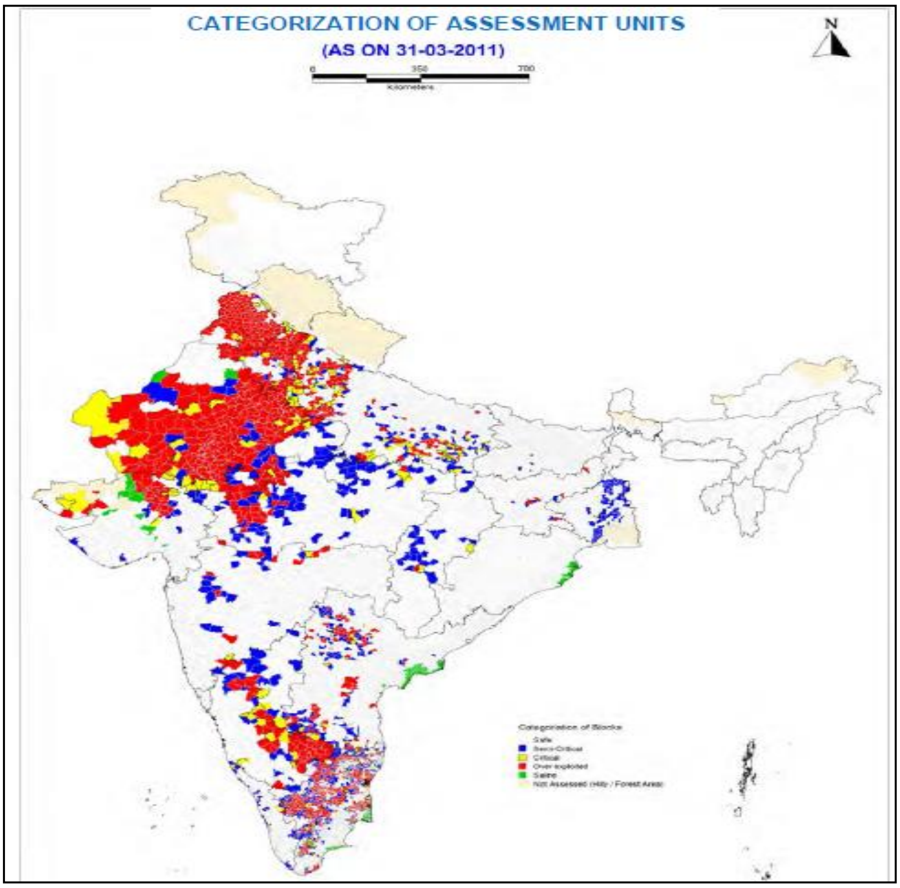
Source: CERC

ANNEXURE 3- LAND USE IN SOLAR UTILITY PROJECTS

Plant	Capacity	Land (ha)	Ha/MW
Anantpur Ultra Mega, Andhra Pradesh	1500	4665.39	3.11
Kurnool, Andhra Pradesh	1000	2400.72	2.4
Lohit, Arunachal Pradesh	100	1092	10.92
Banaskantha, Gujarat	700	1407	2.01
Tumkur, Karnataka	2000	2429	1.2
RUMS, Rewa, MP	750	1400	1.86
Neemach Agar, Rajasthan Rajgarh- Shajapur, Rajasthan Chhatarpur Morena, Rajasthan	2000	6000	3
East & West Jaintia Solar Park, Meghalaya	20	27	1.35
Bhadla Phase II	680	1797.45	2.64
Bhadla Phase III	1000	2000	2
Ramanthapuram Solar Park, TN	500	568	1.13
Industrial Area Sitarganj (Phase I and Phase II) and Industrial Area Kashipur, Uttarakhand	50	77.853	1.55
Jalaun, Allahabad, Mirzapur & Kanpur Dehat Districts of Uttar Pradesh	600	1038	1.73

Source: http://www.indiaenvironmentportal.org.in/files/file/Solar-Park-Guidelines.pdf and http://www.apspcl.ap.gov.in/landdetails.html

ANNEXURE 4- GROUNDWATER ASSESSMENT



Source: Dynamic Groundwater Resources of India. As on 31st March 2011. Central Groundwater Report, 2014

White- *Safe*

Blue- *Semi Critical*

Yellow- *Critical*

Red- *Over Exploited*

Green- *Saline*

ANNEXURE 5- OFF GRID SOLAR PUMPS

State/UT	SPV Pumps (Nos.)					
	2009-10	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**
Andhra Pradesh	613.0	613.0	613.0	613.0	613.0	613.0
Arunachal Pradesh	15.0	15.0	18.0	18.0	18.0	18.0
Assam	45.0	45.0	45.0	45.0	45.0	45.0
Bihar	139.0	139.0	139.0	139.0	139.0	139.0
Chhattisgarh	166.0	222.0	240.0	240.0	240.0	240.0
Goa	15.0	15.0	15.0	15.0	15.0	15.0
Gujarat	85.0	85.0	85.0	85.0	85.0	85.0
Haryana	469.0	469.0	469.0	469.0	469.0	469.0
Himachal Pradesh	6.0	6.0	6.0	6.0	6.0	6.0
Jammu & Kashmir	39.0	39.0	39.0	39.0	39.0	39.0
Jharkhand	-	-	-	-	0.0	0.0
Karnataka	551.0	551.0	551.0	551.0	551.0	551.0
Kerala	810.0	810.0	810.0	810.0	810.0	810.0
Madhya Pradesh	87.0	87.0	87.0	87.0	87.0	87.0
Maharashtra	228.0	228.0	239.0	239.0	239.0	239.0
Manipur	12.0	40.0	40.0	40.0	40.0	40.0
Meghalaya	19.0	19.0	19.0	19.0	19.0	19.0
Mizoram	37.0	37.0	37.0	37.0	37.0	37.0
Nagaland	3.0	3.0	3.0	3.0	3.0	3.0
Odisha	56.0	56.0	56.0	56.0	56.0	56.0
Punjab	1850.0	1857.0	1857.0	1857.0	1857.0	1857.0
Rajas than	283.0	283.0	1667.0	4501.0	4501.0	11603.0
Sikkim	-	-	-	-	0.0	0.0
Tamil Nadu	829.0	829.0	829.0	829.0	829.0	829.0
Telengana						0.0
Tripura	25.0	151.0	151.0	151.0	151.0	151.0
Uttar Pradesh	751.0	573.0	575.0	575.0	575.0	1348.0
Uttaranchal	26.0	26.0	26.0	26.0	26.0	26.0
West Bengal	48.0	48.0	48.0	48.0	48.0	48.0
Andaman & Nicobar	5.0	5.0	5.0	5.0	5.0	5.0
Chandigarh	12.0	12.0	12.0	12.0	12.0	12.0
Dadar & Nagar Haveli	-	-	-	-	0.0	0.0
Daman & Diu	-	-	-	-	0.0	0.0
Delhi	89.0	89.0	90.0	90.0	90.0	90.0
Laks hadweep	-	-	-	-	0.0	0.0
Puducherry	21.0	21.0	21.0	21.0	21.0	21.0
Others *	-	-	-	-	0.0	0.0
Total	**7334.0**	**7373.0**	**8792.0**	**11626.0**	**11626.0**	**19501.0**

Source: MOSPI, http://mospi.nic.in/Mospi_New/upload/SYB2016/ch16.html

ANNEXURE 6- COLD STORAGE IN CENTRAL INSTITUTE FOR AGRICULTURAL ENGINEERING, BHOPAL

Solar powered cold storage system

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