DETAILED PROCEDURE

ON

"A STUDY OF SOLAR ENERGY POTENTIAL IN INDIA"

By

(**Alpesh Gedia** & SAP ID: - **500024345**)

Guided By

(Hasnain Rangwala, Deputy Manager, Adani Power Ltd)

A DISSERTATION REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

MBA < POWER MANAGEMENT >

OF

UNIVERSITY OF PETROLEUM & ENERGY STUDIES, INDIA

CENTRE FOR CONTINUING EDUCATION

UNIVERSITY OF PETROLEUM & ENERGY STUDIES, DEHRADUN

ACKNOWLEDGEMENT

This is to acknowledge with thanks the help, guidance and support that I have received during the Dissertation.

I have no words to express a deep sense of gratitude to the management of **Adani Power Ltd** for giving me an opportunity to pursue my Dissertation, and in particular **Hasnain Rangwala**, for his able guidance and support.

I must also thank **Harish Priyani** for his valuable support.

I also place on record my appreciation of the support provided by **Ranjan Kumar** and other staff of **Pandit Dindayal Upadhyay Muni.Library**.

Signature
Name of the Student: **Alpesh Gedia**
Residential Address: 13/18, Laxmiwadi, Rajkot
Telephone/Mobile: 90990 55194.
E-mail: alpesh_gedia2000@yahoo.com

Date: 28-04-2015
Place: Rajkot

adani™

APPENDIX III

DECLARATION BY THE GUIDE

DECLARATION

This is to certify that the **Mr. Alpesh Gedia**, a student of (EMBA Power), Roll No 500024345 of UPES has successfully completed this dissertation report on **"A STUDY OF SOLAR ENERGY POTENTIAL IN INDIA"** under my supervision.

Further, I certify that the work is based on the investigation made, data collected and analysed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfilment for the award of degree of MBA.

Signature

Hasnain

Name and Designation: Hasnain Rangwala – Deputy Manager
Address: Ahmedabad
Mobile: 8980802728
Email Id: hasnain.rangwala@adani.com

Date: 27-02-2015 **Place:** Ahmedabad

Adani Power Ltd
Achalraj
Opp Mayor Bungalow, Law Garden
Ahmedabad 380 006
Gujarat, India
CIN: L40100GJ1996PLC030533

Tel +91 79 2555 7555
Fax +91 79 2555 7177
info@adani.com
www.adani.comz

Registered Office: Shikhar, Nr Mithakhali Circle, Navrangpura, Ahmedabad 380 009, Gujarat, India

Executive Summary / Abstract

It is well known that the rampant increase for the demand of electricity and rapid depletion of the fossil fuels has called for immediate response in the direction of energy sufficiency. To accomplish this, one of the important tasks is to identify the locations of high potential for renewable energy generation. It is a well-established fact that solar energy proved to be the most sought after source for energy generation. Although, solar energy potential maps of India have been prepared based on solar irradiation maps in the earlier studies, the present research study has been carried out with a focused attention directly on solar energy generation considering various parameters. In this work it is shown that solar energy generation does not depend on solar radiation alone at a location. Instead, there are various other factors that influence the energy generation.

Energy is an important input for economic development. Since exhaustible energy sources in the country are limited, there is an urgent need to focus attention on development of renewable energy sources and use of energy efficient technologies. The exploitation and development of various forms of energy and making energy available at affordable rates is one of India's major thrust areas.

CONTENTS

Chapter-1 Itroduction..1 to 9

1.1 Introduction 1

1.2 Objective 2

Chapter-2 Solar Energy..10 to 21

2.1 Solar-the centre stage of renewable energy 10

2.2 Advantages of Solar Energy 11

2.3 Solar Photovoltaic 13

2.4 Standards of SPV 15

2.5 Advantage of SPV systems 15

2.6 SPV Lighting systems 16

2.7 SPV power plants 17

2.8 Solar Generators 18

2.9 Building integrated PV systems 18

2.10 SPV Pumping systems 19

2.11 Solar energy inIndia 20

Chapter-3 Policy framework in India................................22 to 49

3.1 Solar 22

3.2 Development of solar energy 28

3.3 State solar policies 41

3.4 challenges and constraints 47

Chapter-4 Challenges in solar power Development in India......50 to 68

4.1 Introduction/Background 50

4.2 Key industry risks and suggested interventions 55

4.3 Conclusion 59

Chapter-5 Conclusion Observation.................................69 to 73

5.1 Solution 69

5.2 An open Market 72

LIST OF FIGURES

Sr. No.	Title of the Figure	Page No.
Fig 1	India's DNI	3
Fig 2.1	SPV Technology	12
Fig 2.2	SPV Module	14
Fig 2.3	Solar street plant	16
Fig 2.4	SPV power plant	17
Fig 2.5	SPV pumping systems	20
Fig 2.6	Solar Radiation in India	21
Fig	Installed capacity by state	61
Fig	Solar Parks	62
Fig	Rooftop solar	63
Fig	Rooftop policy by state	64
Fig	Financial viability	64
Fig	Open access regulations	65
Fig	Off grid solar	66

LIST OF TABLES

Sr. No.	Title of Table	Page No
1.1	India's estimated land area suitable for CSP development potential	4
1.2	Sector wise energy consumption in India	7
1.3	Significance of Renewable energy	8
1.4	Renewable energy-estimated potential and cumulative achievements	9
3.1	State-wise solar RPO	28
3.2	Expected solar RPO requirement and compliance for 2012-2013	30
3.3	Solar power capacity requirement by 2022	31
3.4	State-wise distribution	32
3.5	Policy wise distribution	33
3.6	JNNSM targets with timeline	34
3.7	Technology wise capacity targets under JNNSM phase III	34
3.8	Floor and florbearance prices for RECs	35
3.9	Solar REC trading details from IEX	36
3.10	Compilation of recently declared preferential tariffs for solar PV and solar thermal technologies	37

CHAPTER-1

1.3 Introduction

The Sun is a reliable, non-polluting and inexhaustible source of energy. Since the beginning of life on earth, the energy that was received by all living forms was radiated from the sun. It is the time now when the mankind is on a standpoint to again depend and rely upon the sun as the main source of energy.

With rapid rise in energy prices, concern over pollution, depletion of resources and environment degradation the awareness for limited resources around the world has increased dramatically. Use of fossil fuels which causes greenhouse emissions, inefficient use of energy and release of harmful pollutants to the atmosphere causing threat such as acid rain must be addressed seriously in new buildings. Governments with vision have come to realise that generation of electrical power through non-renewable sources of energy is not enough. The power of the future must be environmentally friendly as well.

To alleviate the concern, policy makers across the world have been looking for some sustainable and feasible alternative input energy sources for electricity generation. They found many options like nuclear, wind, solar, hydro, biomass, tidal, geothermal, and so forth. However, literature supports solar energy as it is the most ready and green option available across the world [5]. The report published by Indian Meteorological Department (IMD), Ministry of Earth Sciences, Government of India (GoI) states that

The solar energy received by the earth is more than 15,000 times the world's commercial energy consumption and over 100 times the world's known coal, gas and oil reserves. And this energy is readily available during the day for anyone to tap and that too free and without any constraint.

Initially used to supply electricity to satellites due to its high generation cost, solar technologies and its potential have improved enough to supply electricity not only to remote locations but also to supplement the national grid power at multi megawatt levels.

In India, wind- and solar-based systems have been getting good response under the conducive environment created through different policy measures. In this paper, our focus is only on the development of solar-based electricity supply systems. There are different kinds of support measures to promote grid connected and off-grid solar systems. We discuss these in detail in the subsequent sections.

1.2 Objective

The objectives of this thesis work is to

- Study the significance of Solar Power as renewable energy
- Study the Solar Energy Potential in India
- Find solutions for the problems faced for solar energy sector in India
- To check various feasibility study

A. Background

India is located in the northern hemisphere, lying between latitudes 8°4′N and 37°6′N and longitudes 68°7′E and 97°25′E; the country is divided into almost two equal halves by the Tropic of Cancer (23°30′N). The southern half which coincides with peninsular India lies in the tropical zone, while the northern half belongs to the subtropical zone.

Due to its locational advantage, on average, the country experiences 250 to 300 sunny days per year and receives an average hourly radiation of 200 MW/km2. The annual global radiation varies from 1600 to 2200 kWh/m2 , which is typical of the tropical and subtropical regions. NREL recently released 10 km resolution solar resource maps for India based on the SUNY satellite. Figure 1 shows the annual average direct normal irradiance (DNI) across India, which illustrates that most areas of the country have greater than 5 kWh/m2/day of direct normal irradiance (DNI). This image shows the areas of highest resource occurring in the state of Gujarat, Rajasthan, and the high-elevation Himalayan region. Figure 1 also shows large areas with annual average direct normal irradiance (DNI) greater than 5.5 kWh/m2/day in the state of Madhya Pradesh, Chhattisgarh, and Maharashtra and smaller land areas with similar resources in several other states. This area could be further increased by the use of building-integrated Photovoltaic (PV). Though large-scale concentrated solar power (CSP) has not yet been deployed in India; one study has estimated that this technology alone could generate 11,000 TWh per year for India (Table 1). In addition, it also offers huge potential for decentralized distributed electricity supply system, which can address the problem of electricity to a remote location with less/lower transmission losses.

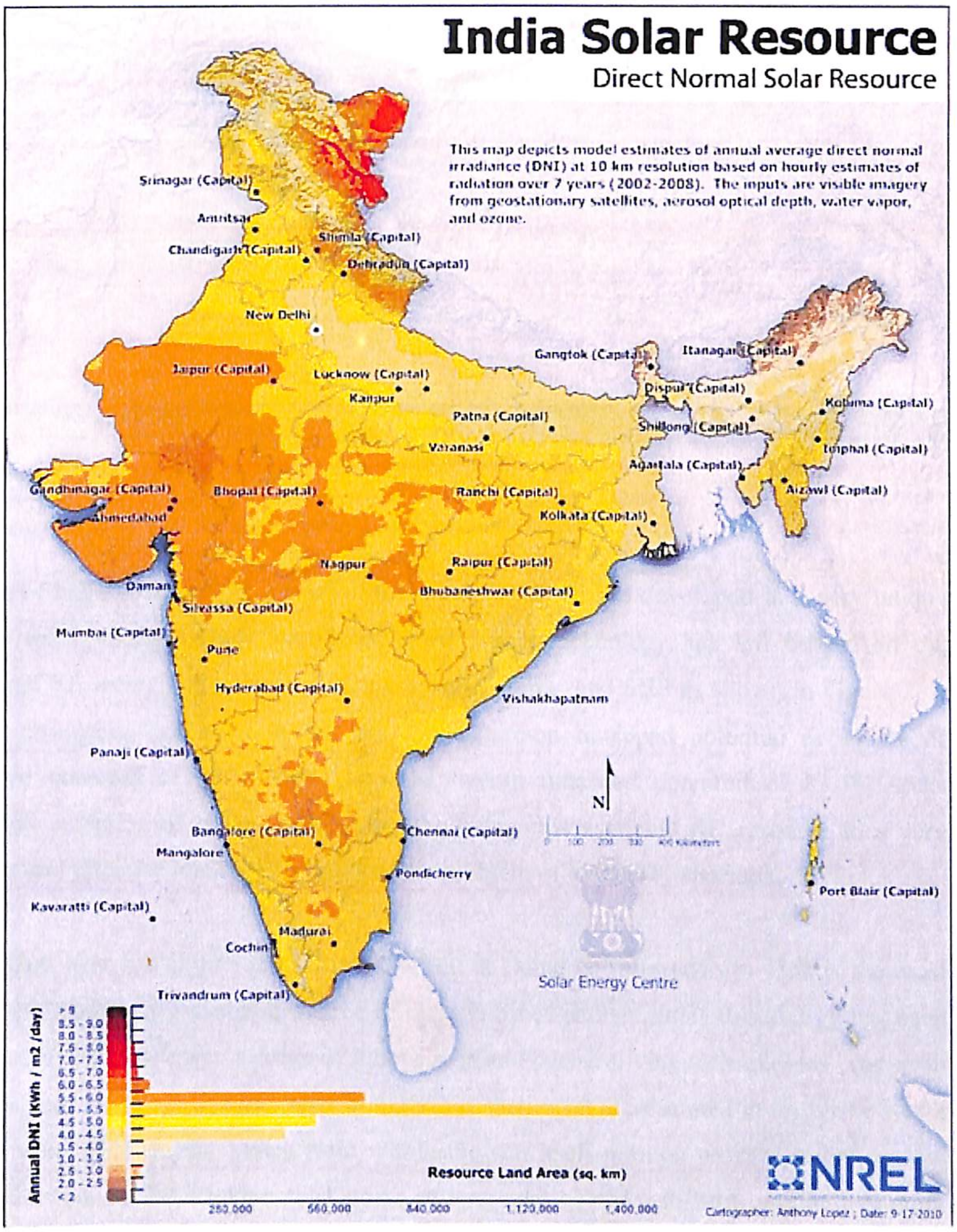


Figure 1: India's DNI resource at 10 km resolution (source: NREL)

Table 1: India's estimated land area suitable for CSP development and generation potential [28].

DNI class ($kWh/m^2/year$)	Land area suitable for CSP development (km^2)	CSP generating potential (TWh/year)
2,000–2,099	83,522	7,893
2,100–2,199	11,510	1,140
2,200–2,299	5,310	550
2,300–2,399	7,169	774
2,400–2,499	3,783	426
2,500–2,599	107	13
2,600–2,699	976	119
2,700–2,800+	120	15
Total	112,497	10,930

In spite of huge solar energy potential, the portfolio of RE has developed in a very unique way in India, though, lately introduced wind power technology has left behind all the traditional RE technologies such as biomass, solar power, and SHP as shown in Figure 2. It also demonstrates that solar power has the maximum untapped potential as 97.9% of estimated potential of 50000 MW. And the overall untapped potential of 81.3% seeks immediate attention of policy makers for exploiting this available RE resource in a very efficient and effective manner to overcome the problem of electricity shortage.

The radiant heat and light energy from the Sun is called as solar energy. This is the most readily and abundantly available source of energy. Since ancient times this energy has been harnessed by humans using a range of innovations and ever-evolving technologies. The earth receives more energy in just one hour from the sun than what is consumed in the whole world for one year. This energy comes from within the sun itself through process called nuclear fusion reaction. In this reaction four atoms of hydrogen combine to form one helium atom with loss of matter. This matter is emitted as radiant energy. India is a tropical country with sunshine in plenty and long days. About 301 clear sunny days are available in a year. Theoretically, India receives solar power of about 5000 trillionkWh/ yr (600TW approx.) on its land area. On an average, daily solar energy incident over India ranges from 4 to 7 kWh/m^2. Depending on the location sunshine hours varies from 2,300-3,200 hours in a year. This is far more than current total energy consumption. For instance, assuming conversion efficiency of 10% for PV modules, it will still be thousand times greater than the likely electricity demand in India by the year 2015.This energy from the sun is used as solar thermal and solar power applications. Solar thermal energy, through various technologies, is utilised for various purposes which includes Heating, Drying, Cooking, seasoning of timber, water treatment (Distillation and disinfection), Cooling (Refrigeration and Cold storage), High temperature process heat for industrial purposes.

Solar energy is not only about present but it also about future. The unlimited potential of Solar is visible in its varied applications of energy generation. One such power of solar can be seen today with homes being energised by solar panels. This energy accelerates cost saving as electricity bill is reduced to about 30% with incorporation of solar power.

Buildings are the largest consumers of electricity using over 40% of the world electricity. The developers, consultants, architects, investors and contractors are opting for alternative forms of energy without damaging the environment as we incline towards passive energy buildings. Solar technology in form of solar Photovoltaic is a proving to be a reliable solution for electricity generation.

Photovoltaic literally stands for 'electricity from light'. A photovoltaic cell, also called as Photovoltaic (PV) cell, is a special semi-conductor diode that converts visible light into DC (direct current). Certain PV cells are able to transform in-frared(IR)or ultraviolet (UV) rays into DC power. Solar powered toys, calculators and telephone call boxes are some common application of solar electricity. Photovoltaic cell forms an integral part of solar-electric energy systems, which presently are finding increasingly important place as an alternative utility power source.

The Photovoltaic (PV) technology in use today is not very complex. Photovoltaic cell comprises of thin layers (two or more) of semi-conducting material, usually silicon. When this silicon is exposed to light it generates electrical charges and with the use of metal contacts this can be conducted away as direct current (DC). A single cell has small electrical output, so multiple cells are combined together and encapsulated to form a Photovoltaic (PV) module (also called "panel"). This module is the principle and basic building block of entire Photovoltaic (PV) system and numerous modules can be put together to give the desired electrical output. Contemporary Photovoltaic (PV) cells are able to convert 10 to 20 percent of radiant energy into electrical energy. In years to come, this efficiency will be improved to produce even better results.

The different types of Photovoltaic (PV) systems are multi-crystalline Silicon Cells, Mono-crystalline Silicon Cells, Amorphous Silicon, Thick-Film Silicon, Other Thin films. Today the grid connected Photovoltaic (PV) systems are the main area of interest. As these systems are connected to the local electricity network, the electricity produced during the day time can either be used immediately or can be sold to the utility. Also as the sun goes down, power can be bought back from the network. Thus the grid is acting as system for energy storage, i.e. the battery storage need not be included in the PV systems. Stand-alone photovoltaic systems are used where grid power supplies are difficult to connect or unavailable. Applications are in monitoring stations, radio repeater stations and street lighting.

Photovoltaic (PV) technology is most widely used in the developing world. The system finds itself the best place where the problems of remote locations and fact of unreliable or non-existent electricity grids are dominant. Here, PV power supply serves as the most economic option. Building Integrated Photovoltaic (BIPV) is a multifunctional solar product that not only generates electricity but also serve as materials for construction. Building Integrated Photovoltaic is where the building envelope is incorporated with PV cells instead of conventional materials of construction. BIPV gives buildings the opportunity to become more self-sufficient by allowing them to generate their own electricity rather than merely consume energy. PV integrated into a building can, as a second function, also provide shade, insulation and help to control the interior climate.

A. Need of Renewable Energy

The various activities (such as industrialization) which involve energy consumption that consequently leads to depletion of energy sources and degradation of environment are stretching the resources of our planet to breaking point. When it comes to the future of energy, the world needs a reality check.

The economic growth and prosperity of any country or region in the world is related to the level of its consumption of energy. With the various developments, particularly with the Industrial Revolution, there has been a quantum leap towards the tremendous consumption energy which is supplied through fossil fuels such as gas, petroleum and coal. During 1920s, coal accounted for the maximum part of total energy supply of the world. Later in early 1990s, its share dropped to only 26%, while 40% of the world's energy needs was taken by oil. Now the depletion rate of fossil fuels has reached to 100,000 times faster than its formation rate.

When the resource under consideration is non-renewable energy source, the problem of depletion is an obvious addition to its consumption. At present, non-renewable fossil fuels (natural gas, coal and petroleum) contribute to 90% of world commercial energy production. The remaining 10% generated from non-conventional form of energy (nuclear, hydropower, geothermal, wind, solar, etc.). Even if the present reserves of fossil fuels may be sufficient enough to meet the global energy demand for years in future, any consumption of such resources represents an absolute loss in its finite supply.

Projections on the energy demand in the early years of 21st century are alarming. The estimates are about100 million tonnes per year for petroleum, 400 million tonnes per year for coal and 100,000 MW per year for power. This energy scenario poses a great challenge for our technology, and also to our environment, which is suffering a tremendous pressure.

sector	Percentage power consumption
industry	49%
Transport	22%
Residential	10%
Agriculture	5%
others	14%

Table 1.2: Sector wise energy consumption in India

The present total installed capacity of electrical power generation in India is 1, 44,912 MW (as on June 2008), produced from various resources as given in table

Resources	production	Percentage Share
Thermal		

Coal Gas Diesel	76648 147116 1119 Total = 92563	52.8 10 0.8 Total=63.6
Nuclear	4120	2.8
Hydro	36033	24.8
Renewable energy sources (Excluding hydro)	12194	8.4
Total	144910	100

Table 1.3: significance of Renewable Energy

In modern world the demand for energy has increased dramatically in the past century and it will grow even further in the near future than ever before. Renewable energy is that energy which comes from the natural energy flows on earth. Unlike conventional forms of energy, renewable energy will not get exhausted. Renewable energy is also termed as „green energy", „clean energy", „sustainable energy" and „alternative energy".

Merits:

- Renewable energy sources are available in nature free of cost
- They produce no or very little pollution
- They are inexhaustible
- They have low gestation period

Demerits

- In general , the energy is available in dilute form from these sources
- Though available freely in nature, the cost of harnessing energy from non-conventional source is generally high
- Availability is uncertain; the energy flow depends on various natural phenomena beyond human control

Located in tropical region, India is endowed with abundant renewable energy resources i.e. solar, wind and biomass including agriculture residue which are perennial in nature. Harnessing these resources is best suited to meet the energy requirement in rural areas in a decentralised manner.

India has the potential of generating more than 100000 MW from non-conventional resources. Up to June 30 2008, the electrical power generation by conventional resources has reached 12,194 MW, which is about 8.4% of total installed electrical power generation capacity. The government plans to increase this share to 10% by 2012. The current status of various resources is given in table.

SL No.	Source/System	Estimated Potential	Cumulative Achievement
Rural and Decentralised Energy Systems			
1	Family type biogas plant	120 lakhs	39.40 lakhs
2	Solar photovoltaic program Solar street lighting system Home lighting system Solar lantern Solar power plants	50 MW/sq. Km - - - -	110 MWp (p-peak) 69,849 nos. 363399 nos. 585001 nos. 2.28 MWp
3	Solar thermal program Solar water heating system Solar cooker	140 million sq.m collector area	2.15 million sq.m collector area 6.17 lakhs
4	Wind pumps	-	1284 nos.
5	Aero generator/hybrid system		675.27 KW
6	Solar photovoltaic pump	-	7068 nos
7	Remote village electrification	-	3368/830 villages/hamlets

Table 1.4: Renewable energy-estimated potential and cumulative achievements (Dec, 2007 data)

CHAPTER – 2

2.1 Solar- The centre stage of renewable energy

The radiant heat and light energy from the Sun is called as solar energy. This is the most readily and abundantly available source of energy. Since ancient times this energy has been harnessed by humans using a range of innovations and ever-evolving technologies.

The earth receives more energy in just one hour from the sun than what is consumed in the whole world for one year. This energy comes from within the sun itself through process called nuclear fusion reaction. In this reaction four atoms of hydrogen combine to form one helium atom with loss of matter. This matter is emitted as radiant energy.

India is a tropical country with sunshine in plenty and long days. About 301 clear sunny days are available in a year. Theoretically, India receives solar power of about 5000 trillion kWh/ yr (600TW approx.) on its land area. On an average, daily solar energy incident over India ranges from 4 to 7 kWh/m^2. Depending on the location sunshine hours varies from 2,300 – 3,200hours in a year. This is far more than current total energy consumption. For instance, assuming conversion efficiency of 10% for PV modules, it will still be thousand times greater than the likely electricity demand in India by the year 2015.

This energy from the sun is used as solar thermal and solar power applications. Solar thermal energy, through various technologies, is utilised for various purposes which includes Heating, Drying, Cooking, seasoning of timber, water treatment (Distillation and disinfection), Cooling (Refrigeration and Cold storage), High temperature process heat or industrial purposes

Solar power is the conversion of sunlight into electricity. Photovoltaic or PV is used to convert Sunlight directly into electricity, or uses concentrating solar power or CSP to indirectly generate electricity. Solar Photovoltaic or SPV cells convert solar radiation into DC electricity directly. SPV finds a number of applications in areas such as Domestic or household lighting, Street lighting, electrification in rural or village areas, water pumping, desalination of salty water, powering of remote telecommunication repeater stations and railway signals.

2.2 Advantages of Solar Energy

A. Environmental friendly

- Solar Energy is renewable, clean, and sustainable form of energy which helps in protecting our environment.
- It does not create pollution by releasing gases like nitrogen oxide, carbon dioxide, mercury and sulphur dioxide into the atmosphere as many conventional forms of energy do.
- Solar Energy, therefore, does not contribute to global warming, acid rain or smog.
- It actively contributes to the decrease of harmful greenhouse gas emissions.
- Since solar energy does not use any fuel, it neither increases the cost nor does it add to the problems of the transportation and recovery of fuel or the storage and disposal of radioactive waste.

B. Saves money

- After the recovery of initial investment, the Sun's energy is practically FREE.
- The payback period for the investment can be short depending on electricity usages of household.
- The government provides financial incentives so as to reduce the cost incurred.
- Your utility company can buy the additional energy that your system produces, building up a credit on your account. This is called net metering.
- It's not affected by the supply and demand of fuel and is therefore not subjected to the ever-increasing price of gasoline.

C. Independent/ semi-independent

Solar Energy can be utilized to balance out consumption of energy supplied by utility. It does not only reduce the electricity bill, but will also supply our business/home with electricity whenever there is a power outage.

These systems can operate completely independent, without a connection to a gas or power grid at all. Therefore they can be installed in remote locations, like holiday log cabins thus these are more practical as well as cost effective as compared to the supply of utility electricity to a remote and new site. Solar Energy enhances local job opportunities and wealth creation, thus contributing to local economies.

D. Low/ no maintenance

- Solar Energy systems once installed will last for decades and are almost maintenance free.
- Once installed, there are no recurring costs.
- They do not consist of moving parts, creates no noise, do not release any offensive smells and do not require addition of any fuel.
- Addition of solar panels is easy in case your family's needs grow in future.
- The dependence on non-renewable sources of energy could be reduced and lesser threat on environment will be posed if we find channels of efficient utilisation of solar energy.

2.3 Solar Photovoltaic

Solar photovoltaic (SPV) is the process of converting solar radiation (sunlight) into electricity using a device called solar cell. A solar cell is a semi-conducting device made of silicon or other materials, which, when exposed to sunlight, generates electricity. The magnitude of the electric current generated depends on the intensity of the solar radiation, exposed area of the solar cell, the type of material used in fabricating the solar cell, and ambient temperature. Solar cells are connected in series and parallel combinations to form modules that provide the required power.

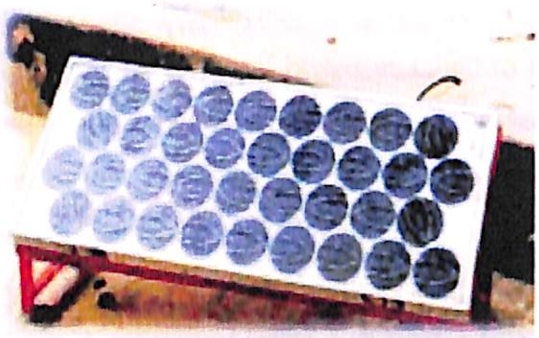


Figure 2.1: SPV Technology

A. Crystalline solar cells

Most solar cells are made of a single crystal or multi-crystalline silicon material. Silicon ingots are made by the process of crystal growth, or by casting in specially designed furnaces. The ingots are then sliced into thin wafers. Single crystal wafers are usually of 125 × 125 mm or larger sizes with 'pseudo-square' shape; multi-crystalline wafers are typically square shaped with a dimension of 100 × 100 mm or larger. Using high temperature diffusion furnaces, impurities like boron or phosphorous are introduced into the silicon wafers to form a p-n junction. The silicon wafers are thus converted into solar cells. When exposed to sunlight, a current is generated in each cell. Contacts are attached to the top and bottom of each solar cell to enable inter-connections and drawing of the current.

B. Thin-film solar cells

Thin-film solar cells are made from amorphous silicon (a-Si), copper indium selenide/cadmium sulphide (CuInSe2/CdS) or cadmium telluride/cadmium sulphide (CdTe/CdS), by using thin-film deposition techniques. These technologies are at various stages of development and have not yet reached the maturity of crystalline silicon. Production of thin-film Photovoltaic (PV) modules is also limited.

C. Photovoltaic (PV) module

Photovoltaic (PV) modules are usually made from strings of crystalline silicon solar cells. These cells are made of extremely thin silicon wafers (about 300 um) and hence are extremely fragile. To protect the cells from damage, a string of cells is hermetically sealed between a layer of toughened glass and layers of ethyl vinyl acetate (EVA). An insulating tedlar sheet is placed beneath the EVA layers to give further protection to the cell string. An outer frame is attached to give strength to the module and to enable easy mounting on structures. A terminal box is attached to the back of a module; here, the two ends (positive and negative) of the solar string are welded or soldered to the terminals. This entire assembly constitutes a Photovoltaic (PV) module. When the Photovoltaic (PV) module is in use, the terminals are connected either directly to a load, or to another module to form an array. Single Photovoltaic (PV) modules of capacities ranging from 10 Wp to 120 Wp can provide power for different loads. For large power applications, a Photovoltaic (PV) array consisting of a number of modules connected in parallel and/or series is used.

D. Standard Capacity/Ratings and Specifications:

The wattage output of a PV module is rated in terms of peak watt (Wp) units. The peak watt output power from a module is defined as the maximum power output that the module could deliver under standard test conditions (STC). The STC conditions used in a laboratory are

- 1000 watts per square metre solar radiation intensity
- Air-mass 1.5 reference spectral distribution
- 25 °C ambient temperature.

Figure 2.2: SPV modules

SPV modules of various capacities are available, and are being used for a variety of applications. Theoretically, a PV module of any capacity (voltage and current) rating can be fabricated. However, the standard capacities available in the country range from 5 Wp to 120 Wp. The voltage output of a PV module depends on the number of solar cells connected in series inside the module. In India, a crystalline silicon module generally contains 36 solar cells connected in series. The module provides a usable direct current (DC) voltage of about 16.5 V, which is normally used to charge a 12-V battery.

In an SPV system, the components other than the PV module are collectively known as "balance of system" (BoS), which includes batteries for storage of electricity, electronic charge controller, inverter, etc. These batteries are charged during the daytime using the DC power generated by the SPV module. The battery/battery bank supplies power to loads during the night or non-sunny hours. An inverter is required to convert the DC power from the PV module or battery to AC power for operating the load. Some loads such as DC pumps do not require an inverter or even a battery bank.

2.4 Standards for SPV

Photovoltaic standards in India have been established by the Bureau of Indian Standards (BIS). So far, there are eight standards prescribed by the BIS for SPV. These standards mainly relate to the areas listed below.

- SPV terminology
- Measurements of cells and modules
- Methods of correcting the measurements
- Qualification test procedure for crystalline silicon modules
- General description of SPV power generating systems
- Parameters of stand-alone SPV systems

Standards are under preparation for "balance of system" BoS components such as batteries, inverters, and charge controllers. These standards are based mainly on the corresponding International Electro technical Commission (IEC) or European standards.

2.5 Advantages of Solar Photovoltaic (SPV) Systems

The major advantages of using Solar Photovoltaic (SPV) systems are as follows.

- Abundant solar radiation is available in most parts of India. Hence, SPV systems can be used anywhere in the country.
- Solar Photovoltaic (SPV) systems are modular in nature. Hence, they can be expanded as desired and used for small and large applications.
- There are no running costs associated with Solar Photovoltaic (SPV) systems, as solar radiation is free.
- Electricity is generated by solar cells without noise.
- PV systems have no moving parts. Hence, they suffer no wear and tear.
- As most of the components of Solar Photovoltaic (SPV) systems are pre-fabricated, these systems can be installed quickly. Hence, PV projects have short gestation periods.

- Solar Photovoltaic (SPV) modules have long-life, and require no maintenance. Only "balance of system" BoS components such as batteries and inverters require minor maintenance.

2.6 Solar Photovoltaic (SPV) Lighting Systems:

Solar Photovoltaic (SPV) lighting systems are becoming popular in both the rural and urban areas of the country. In rural areas, Solar Photovoltaic (SPV) lighting systems are being used in the form of portable lanterns, home-lighting systems with one or more fixed lamps, and street-lighting systems. Applications in urban areas include glow-sign display systems on the streets, traffic signalling, message display systems based on light-emitting diodes (LEDs), and systems to illuminate advertisement hoardings.

A. Solar street lighting system:

A solar street-lighting system (SLS) is an outdoor lighting unit used to illuminate a street or an open area usually in villages. A CFL is fixed inside a luminary, which is mounted on a pole. The PV module is placed at the top of the pole, and a battery is placed in a box at the base of the pole. The module is mounted facing south, so that it receives solar radiation throughout the day, without any shadow falling on it.

Figure 2.3: Solar Street Light

A typical street-lighting system consists of a PV module of 74 Wp capacity, a flooded lead – acid battery of 12 V, 75 AH capacity, and a CFL of 11 W rating. This system is designed to operate from dusk to dawn (that is, throughout the night). The CFL automatically lights up when the surroundings become dark and switches off around sunrise time. The cost of an SLS is about Rs 19 000. Variations in the cost are possible on account of local taxes, additional transportation costs, etc. The Ministry provides financial assistance for the promotion of some of the above solar lighting systems among eligible categories of users.

2.7 Solar Photovoltaic (SPV) power plants:

In an Solar Photovoltaic (SPV) power plant, electricity is centrally generated. This electricity is either made available to users through a local grid in a 'stand – alone' mode, or connected to the conventional power grid in a 'grid-interactive' mode. Stand - alone power plants provide grid-quality power locally to people to meet their requirements for lighting and other needs. Power plants are preferred over individual SPV systems if a number of users are in close proximity. The cost of power may be of the order of Rs 15 per kWh for a grid-interactive power plant and higher for stand-alone power plant.

Figure 2.4: SPV Power Plant

A. Stand-alone Solar Photovoltaic (SPV) power plant:

A stand-alone SPV power plant is typically designed for specific requirements. The capacity of a stand-alone power plant varies from 1 kWp to 25 kWp, and in some cases even higher. These systems are used where conventional grid supply is not available, or is erratic or irregular. A stand-alone power plant functions like an uninterrupted power supply system (UPS) and provides a constant, stable, and reliable supply to the loads. These power plants can also be used in areas where grid supply is available; in such places the power plants operate like a hybrid power plant, working with grid, as well as with SPV. The capacity of its battery bank depends on user requirements. The most common use for such plants is the electrification of remote villages. Other uses include power for hospitals, hotels, communications equipment, railway stations, border outposts, etc., Stand-alone SPV power plants comprise PV array, battery bank, inverter, and charge controller. Depending on the system voltage, SPV modules are arranged in series and parallel combinations. The standard combinations are 2, 4, 6, 10, 20 or more modules. The corresponding system voltages are in the range of 24 to 240 V. The size of the battery bank is determined by the system voltage and ampere-hour requirements of the load. The inverter is selected based on the system voltage and peak-load capacities. Other components such as junction boxes, distribution boxes, and cables are selected according to the maximum amount of current to be handled by them. The cost of a stand-alone power plant depends on the PV array size, battery bank capacity, inverter, etc. The approximate cost of a standalone power plant is between Rs 3.00 lakhs and Rs 3.50 lakhs per kW of PV capacity. Distribution costs (such as in a village) may be extra.

2.8 Solar Generators

A solar generator is a small capacity, stand-alone Solar Photovoltaic (SPV) power system based on a Photovoltaic (PV) array, connected to a battery bank and an inverter of appropriate size. This system is designed to supply power to limited loads (such as lights and fans) for a period of two to three hours daily in situations such as conventional power failure or load-shedding. The MNES currently promotes four models of solar generators, with capacities of 150, 350, 450, and 600 Wp. These solar generators are mainly meant to replace the conventional small-capacity petrol-based generators that are used during routine load-shedding periods in urban areas by shops, clinics, and other small establishments. The components of a typical solar generator are a small SPV array connected to a battery bank of appropriate size and an inverter based on 12, 24, or 48 V. The system is designed to supply power to loads such as lights, fans, credit-card operating machines, and personal computers for a period of two to three hours. The cost of the four solar generator models promoted by the MNES varies from Rs 35 000 to Rs 145 000.

2.9 Building-integrated PV Systems

In a building-integrated photovoltaic (BIPV) system, photovoltaic (PV) panels are integrated into the roof or façade of a building. Building- integrated photovoltaic (BIPV) systems are becoming common in Europe, the USA, and Japan. The Solar Photovoltaic (SPV) panels generate electricity during the daytime, which is used to meet a part of the electrical energy needs of the building. Building-integrated photovoltaic (BIPV) systems have significant potential in India, where a large number of buildings are constructed every year for different purposes, and where energy consumption in buildings is growing at a rapid rate. Although the initial costs of a building-integrated photovoltaic (BIPV) system are high, long-term savings result from a reduction in electricity consumption. India needs more experience in the field of building-integrated photovoltaic (BIPV) technology. In order to encourage this application and to prepare manufacturers and users, the Ministry supports BIPV projects by meeting 80% of the cost of photovoltaic (PV) modules installed in the systems on government and semi government buildings.

2.10 SPV Pumping System

Water pumping is one of the most important applications of PV in India. An SPV water pump is a DC or AC, surface-mounted or submersible or floating pump that runs on power from an SPV array. The array is mounted on a suitable structure and placed in a shadow free open space with its modules facing south and inclined at local latitude. A typical SPV water-pumping system consists of an SPV array of 200 – 3000 Wp capacity, mounted on a tracking/non-tracking type of structure. The array is connected to a DC or AC pump of matching capacity that can be of s u r f a c e - m o u n t e d, submersible, or floating type. Interconnecting cables and electronics make up the rest of the system. SPV water pumps are used to draw water for irrigation as well as for drinking.

The normal pumping heads are in the range of 10 metres (m) for irrigation, and 30 m for drinking water. It is possible to use pumps with even greater head, especially for drinking water supply. The SPV array converts sunlight into electricity and delivers it to run the motor and pump up water. The water can be stored in tanks for use during non-sunny hours, if necessary. For maximum power output from the SPV array, the structure on which it is mounted should track the sun. Electronic devices are used to do this in some models, thereby enabling the systems to operate at maximum power output. The power from the SPV array is directly delivered to the pump in the case of DC pumps.

In the case of AC pumps, however, an inverter is used to convert the DC output of the array into AC. No storage batteries are used in an SPV pump. An SPV pump based on a one-horsepower motor can irrigate about 1 – 1.5 hectares of land under a variety of crops except paddy and sugar cane (assuming a 10-m water table). Using the same pump along with drip irrigation, it is possible to irrigate up to 6 hectares of land for certain crops. A two-horsepower SPV pump could irrigate about 2– 3 hectares of land under many crops except paddy and sugar cane (again assuming a 10-m water table).

Figure 2.5: SPV pumping systems

The cost of an SPV pump depends on the capacity and type of pump. For example, a DC surface pump with a 900 W array may cost about Rs 150 000; a similar pump of 1800 W may cost about Rs 300 000; and an 1800 W AC submersible pump may cost about Rs 422 000.

2.11 Solar Energy in India

India lies in the sunny regions of the world. Most parts of India receive 4–7 kWh (kilowatt-hour) of solar radiation per square metre per day with 250 – 300 sunny days in a year. The highest annual radiation energy is received in western Rajasthan while the north-eastern region of the country receives the lowest annual radiation. Solar energy, experienced by us as heat and light, can be used through two routes: the thermal route uses the heat for water heating, cooking, drying, water purification, power generation, and other applications; the photovoltaic route converts the light in solar energy into electricity, which can then be used for a number of purposes such as lighting, pumping, communications, and power supply in un-electrified areas. Energy from the sun has many features, which make it an attractive and sustainable option: global distribution, pollution free nature, and the virtually inexhaustible supply.

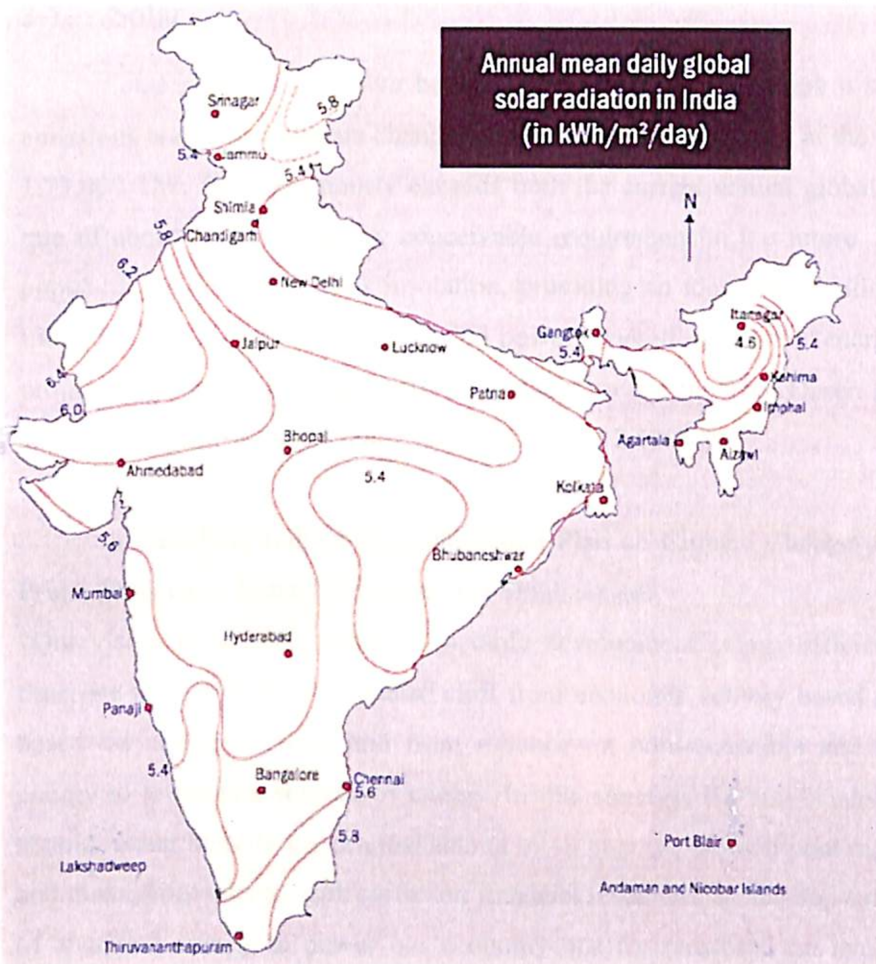


Figure 2.6: Solar Radiation in India.

CHAPTER – 3

3.1 Solar

Solar power is attractive because it is abundant and offers a solution to fossil fuel emissions and global climate change. Earth receives solar energy at the rate of approximately 1,73,000 TW. This enormously exceeds both the current annual global energy consumption rate of about 15 TW, and any conceivable requirement in the future. India is both densely populated and has high solar insolation, providing an ideal combination for solar power in India. India is already a leader in wind power generation. In solar energy sector, some large projects have been proposed, and a 35,000 km^2 area of the Thar Desert has been set aside for solar power projects, sufficient to generate 700 to 2,100 GW.

In launching India's National Action Plan on Climate Change on June 30, 2008, the Prime Minister of India, Dr. Manmohan Singh stated:
"Our vision is to make India's economic development energy-efficient. Over a period of time, we must pioneer a graduated shift from economic activity based on fossil fuels to one based on non-fossil fuels and from reliance on non-renewable and depleting sources of energy to renewable sources of energy. In this strategy, the sun occupies centre-stage, as it should, being literally the original source of all energy. We will pool our scientific, technical and managerial talents, with sufficient financial resources, to develop solar energy as a source of abundant energy to power our economy and to transform the lives of our people. Our success in this endeavour will change the face of India. It would also enable India to help change the destinies of people around the world."

The National Action Plan on Climate Change also points out: "India is a tropical country, where sunshine is available for longer hours per day and in great intensity. Solar energy, therefore, has great potential as future energy source. It also has the advantage of permitting the decentralized distribution of energy, thereby empowering people at the grassroots level".

In July 2009, India unveiled a $19 billion plan, to produce 20 GW of solar power by 2020. On November 23, 2009, Dr. Farooq Abdullah, Union Minister for New and Renewable Energy in a statement in the Parliament said that "the Government has approved a new policy on development of solar energy in the country by launching of the Jawaharlal Nehru National Solar Mission". The mission aims at development and deployment of solar energy technologies in the country to achieve parity with grid power tariff by 2022.

A. INDIA – POTENTIAL

In terms of all renewable energy, currently India is ranked fifth in the world with 15,691.4 MW grid-connected and 367.9 MW off-grid renewable energy based power capacity. India is among top 5 destinations worldwide for solar energy development as per Ernst & Young's renewable energy attractiveness index.

B. ANNUAL INSOLATION

With about 300 clear sunny days in a year, India's theoretical solar power reception, just on its land area, is about 5 PWh/year (i.e. = 5 trillion kWh/yr ~ 600 TW). The daily average solar energy incident over India varies from 4 to 7 kWh/m^2 with about 1500–2000 sunshine hours per year, depending upon location. This is far more than current total energy consumption. The India Energy Portal estimates that if 10% of the land were used for harnessing solar energy, the installed solar capacity would be at 8,000GW, or around fifty times the current total installed power capacity in the country. For example, even assuming 10% conversion efficiency for PV modules, it will still be thousand times greater than the likely electricity demand in India by the year 2015.

Daytime production peak coincides with peak electricity demand making solar ideal supplement to grid.

The main features of the National Solar Mission are:

- Make India a global leader in solar energy and the mission envisages an installed solar generation capacity of 20,000 MW by 2022, 1,00,000 MW by 2030 and of 2,00,000 MW by 2050.
- The total expected investment required for the 30-year period will run is from Rs. 85,000 crore to Rs. 105,000 crore.
- Between 2017 and 2020, the target is to achieve tariff parity with conventional grid power and achieve an installed capacity of 20 gigawatts (Gw) by 2020.
- 4-5GW of installed solar manufacturing capacity by 2017.

The Mission will be adopted in a 3-phase approach

Phase I: Remaining period of the 11th Plan and first year of the 12th Plan (up to 2012-13)
Phase II: The remaining 4 years of the 12th Plan (2013-17)
Phase III: The 13th Plan (2017-22) as Phase 3.

The target for phase I is to ramp up grid connected solar power generation to 1000MW and an additional 3000MW by the end of phase II through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff. The mission also plans to promote programs for off-grid applications, reaching 1000 MW by 2017 and 2000 MW by 2022.

At the end of each plan, and mid-term during the 12th and 13th Plans, there will be an evaluation of progress, review of capacity and targets for subsequent phases, based on emerging cost and technology trends, both domestic and global. The aim would be to protect Government from subsidy exposure in case expected cost reduction does not materialize or is more rapid than expected.

PRESENT STATUS

INSTALLED CAPACITY

Solar power has so far played an almost non-existent role in the Indian energy mix. The grid-connected capacity (all PV) in India now stands at 2631.93 MW as of 31st January 2015.However, the market is set to grow significantly in the next ten years, driven mainly by rising power demand and prices for fossil fuels, the ambitious National Solar Mission (NSM), various state level initiatives, renewable energy quotas including solar energy quotas for utilities as well as by falling international technology costs. Encouraging the spread of solar power generation (both CSP and PV) and aiming for grid-parity (currently at around RS.5/kWh) by 2022 and parity with coal power generation (currently at around RS.4/kWh) by 2030, is a key element in India's comprehensive, long term energy supply strategy. Keeping in view the solar annual insolation, solar power could therefore easily address India's long-term power requirements. However, it has to be cost-competitive. As of December 2011, solar power generation in India costs around RS.10/kWh, or over 2.5 times as much as power from coal. Importantly, it is crucial that the industry receives the right policy support to ensure that projects are executed and performed up to the mark.

NATIONAL SOLAR MISSION

NTPC Vidyut Vyapar Nigam(NVVN) ,the nodal agency for implementing the first phase of JNNSM , received 418 applications against a requirement of 650 MW(500 MW Solar Thermal and 150 MW Solar PV) for Batch I. Out of this 343 applications were for solar PV and 55 for Solar Thermal. The interest was high in the investor community for solar PV as applications worth 1715 MW (343*5 MW) were received as against a total of 150 MW. 30 bidders were selected through reverse bidding and projects were allocated to companies that offered highest discount to base tariff rate of Rs. 17.91/kWh. Projects totalling 610 MW were awarded with 145 MW under solar PV and 470 MW under Solar Thermal. The winning bids for solar PV varied from Rs. 10.95/kWh to Rs. 12.76/kWh and for Solar Thermal it was Rs. 11.14/kWh in Phase I Batch I. Camelot Enterprises Private Ltd was the lowest bidder and other successful bidders included Mahindra Solar One, Azure Power, Sun Edison Energy, Lanco Infratech. The project capacity under Batch I is 5 MW for solar PV and minimum 5 MW and maximum 100MW for Solar Thermal. By July 2011, negotiations were concluded, PPAs awarded and financial closure achieved for 34 projects.

Under batch II, the project size has been increased up to 20 MW and the base price for solar PV projects is Rs. 15.39/kWh. NTPC Vidyut Vyapar Nigam (NVVN) received 154 applications for 1915 MW of solar PV projects against a requirement of 350 MW. The results of the bidding for solar PV projects indicate that the grid parity for solar power may not be too far off. The winning bids varied from Rs. 7.49/kWh to Rs. 9.41/kWh. The average bid price for both batch I and II was Rs. 12.15/kWh. French project developer Solairedirect emerged as the lowest bidder and Green Infra Solar the highest bidder. The other successful bidders included companies like Welspun Solar, Azure Power, Sun Borne Energy and Mahindra Solar One. Around 70% and 85% of the allocated capacity under Phase I Batch I and Phase I Batch II respectively is to be implemented in Rajasthan.

GUJARAT: Most Progressive state in Solar Installation

Gujarat is witnessing a large market for the resale of PPAs by developers who often took up projects with the intent to sell them at a higher price to international developers. This has increased the project development costs and is threatening to make many projects unviable. As a result, only a limited number of projects under the Gujarat solar policy are currently moving forward successfully. As of 31st December, 175 MW of the 968.5 MW worth of projects with signed PPAs have been commissioned. Many projects are finding it difficult to attain financial closure and are facing significant delays.

Land acquisition is proving to be a challenge for projects in Gujarat. There are a limited number of land-banks (large areas of land acquired and consolidated by the government for the use of developers), thereby pushing developers to purchase private land, which is usually a burdensome and slow process. Developers have to engage directly with multiple land owners, facing issues with prices, location, land transfer procedures and right-of-way, amongst others. With the increasing interest from developers, there is a nexus developing between brokers and land owners impacting the price of land in Gujarat. The limited availability is leading to multiple brokers offering the same pieces of land to different developers. Realizing this, the owners have started quoting higher prices for the land. The brokers in turn have begun promising them a higher price in order to secure their clientele. This is significantly escalating land prices for potential sites in the state.

The solar park at Charanka is meant to solve many of these problems. So far, however, land has only been demarcated. The majority of the area remains undeveloped. The solar park policy by the Gujarat Power Corporation Limited (GPCL) provides not more than 50 acres of land for a 10MW PV plant. While this is practicable for plants working with crystalline modules, it is a limitation for thin film plants, which typically require more land for a 10MW plant. Another challenge is that the park is required to provide under-ground transmission lines but the transmission utility in Gujarat, the Gujarat Energy Transmission Corporation Limited (GETCO), does not currently have the expertise to execute this. Such issues, while they will not necessarily derail the solar park, will create further delays for developers who are already facing challenges in meeting their deadlines. For this reason, Kiran Energy, with a 20MW project in the park, has secured a guarantee by the government against possible penalties for delays in executing their project.

HISTORICAL GROWTH OF THE SOLAR MARKET IN INDIA

The Rural Electrification Program of 2006 was the first step by the Indian Government in recognizing the importance of solar power. It gave guidelines for the implementation of off-grid solar applications. However, at this early stage, only 33.8MW (as on 14-2-2012) of capacity was installed through this policy. This primarily included solar lanterns, solar pumps, home lighting systems, street lighting systems and solar home systems. In 2007, as a next step, India introduced the Semiconductor Policy to encourage the electronic and IT industries. This included the Silicon and PV manufacturing industry as well. New manufacturers like Titan Energy Systems, Indo Solar Limited and KSK Surya Photovoltaic Venture Private Limited took advantage of the Special Incentive Scheme included in this policy and constructed plants for PV modules. This move helped the manufacturing industry to grow, but a majority of the production was still being exported. There were no PV projects being developed in India at that stage. There was also a need for a policy to incorporate solar power into the grid. The Generation Based Incentive (GBI) scheme, announced in January 2008 was the first step by the government to promote grid connected solar power plants. The scheme for the first time defined a feed-in tariff (FIT) for solar power (a maximum of Rs. 15/kWh). Since the generation cost of solar power was then still around Rs. 18/kWh, the tariff offered was unviable. Also, under the GBI scheme, a developer could not install more than 5MW of solar power in India, which limited the returns from scale. One of the main drawbacks of the GBI scheme was that it failed to incorporate the state utilities and the government in the project development, leaving problems like land acquisitions and grid availability unaddressed. As a result, despite the GBI scheme, installed capacity in India grew only marginally to 6MW by 2009. In June 2008, the Indian government announced the National Action Plan for Climate Change (NAPCC). A part of that plan was the National Solar Mission (NSM).

The NSM guidelines indicated that the government had improved on the shortcomings of the GBI scheme. It aimed to develop a solar industry, which was commercially driven and based on a strong domestic industry. The extra cost of generation of solar power was being borne by the federal government under the GBI scheme. Even before the NSM, Gujarat was the first state to come up with its own solar policy in January 2009. The Gujarat solar policy initiated a process of the states formulating their own policy frameworks independent of the federal guidelines. The renewable purchase obligations for state distribution companies, a demand-driven scheme, further accelerated the formulation of solar policies at the state level. These policies exist independent of each other as well as the NSM. One of the key novelties of the Gujarat policy was that it introduced the concept of solar parks. These parks offered a comprehensive solution to concerns over land acquisition, grid connectivity, and water availability, hence offering developers a project allocation packaged with the necessary infrastructure. Other states like Karnataka, Andhra Pradesh and Rajasthan have followed suit in developing solar power development programs. Rajasthan has implemented land banks as well to make land acquisition easier. As more states plan to meet their solar power obligations, new policies are expected to be offered, creating as very vibrant set of markets across the subcontinent.

3.2 Development of Solar Electricity System under Different Policy Measures in India

Government of India has recognized the importance of solar energy as one of the sustainable sources of energy under National Action Plan for Climate Change (NAPCC). NAPCC aims to derive 15% of its energy requirements from RE sources by the year 2020 [10]. Various policy measures, such as preferential tariff or fixed tariff or feed-in tariff (FiT), RPO, excise duty exemption, and soft loan, have been implemented to achieve the above-mentioned target.

RPO is one of the tools which have been implemented by many countries to achieve their ambitious RE goals. In India, state electricity regulatory commissions (SERCs) determine the obligated entities, which generally include distribution companies, captive consumers, and any open-access users. Then these SERCs fix a certain proportion of electricity consumption as RPO targets for the above-mentioned obligated entities. Due to significant cost difference in solar and non-solar RE technologies, most of the states have come up with their separate targets for solar electricity, as shown in Table 3.1. As per the National Tariff Policy, it is envisaged that the targets for solar RPO shall be 0.25% by 2012-2013 extending to 3% by 2022, but only the state of Bihar has followed it in its solar policy the way it is expected.

Table 3.1: State-wise solar RPO.

State	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Andhra Pradesh	0.25	0.25	0.25	0.25	0.25	0.25					
Arunachal Pradesh											

Assam	0.10	0.15	0.20	0.25							
Bihar	0.25	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.50	3.00
Chhattisgarh	0.25	0.50									
Delhi	0.10	0.15	0.20	0.25	0.30	0.35					
JERC (Goa and UT)	0.30	0.40									
Gujarat	0.50	1.00									
Haryana	0.00	0.05	0.75								
Himachal Pradesh	0.01	0.25	0.25	0.25	0.25	0.25	0.50	0.75	1.00	2.00	3.00
Jammu and Kashmir	0.10	0.25									
Jharkhand	0.50	1.00									
Karnataka	0.25										
Kerala	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Madhya Pradesh	0.40	0.60	0.80	1.00							
Maharashtra	0.25	0.25	0.50	0.50	0.50						
Manipur	0.25	0.25									
Mizoram	0.25	0.25									
Meghalaya	0.30	0.40									
Nagaland	0.25	0.25									
Orissa	0.10	0.15	0.20	0.25	0.30						
Punjab	0.03	0.07	0.13	0.19							
Rajasthan	0.50	0.75	1.00								
Sikkim											
Tamil Nadu	0.05										
Tripura	0.10	0.10									
Uttar Pradesh	0.03	0.05									
West Bengal	0.50	1.00									
			0.25	0.30	0.40	0.50					

A study conducted by MNRE shows that most of the states could not install capacity of solar system as per their RPO compliance requirement for the year 2012-2013 as on 12th of November 2012 (Table 3.2). The states like Uttar Pradesh (422.7 MW), Haryana (172.2 MW), Maharashtra (151.3 MW), and so forth, are far away from their RPO target. However, states of Gujarat (488.3 MW), Rajasthan (82.3 MW), and Karnataka (61.1 MW) have already surpassed their RPO requirement. Other states like Madhya Pradesh, Orissa, Punjab, and Uttarakhand may soon exceed their targets.

Table 3.2: Expected solar RPO requirement and compliance for 2012-2013

State	Projected demand* (MU) 2012-2013	Solar RPO target (2012-2013) %	Solar RPO target (2012-2013) MU	Capacity required for meeting solar RPO MW	Total capacity tied up as on 31.11.2012* MW	Installed capacity as on 31.11.2012 MW	Gap to be fulfilled in 2012-2013 MW
Andhra Pradesh	98,956	0.25	247.39	148.6	75.5	23.75	73.1
Assam	6,810	0.15	10.21	6.1	5	—	1.14
Bihar	15,272	0.75	114.54	68.8	0	—	68.82
Chhattisgarh	21,174	0.50	105.87	63.6	29	4.00	34.61
Delhi	28,598	0.15	42.90	25.8	2.525	2.53	23.25
JERC (Goa and UT)	12,860	0.40	51.44	30.9	1.7	1.69	29.21
Gujarat	79,919	1.00	799.19	480.2	968.5	689.81	(488.3)
Haryana	40,167	0.75	301.25	181.0	8.8	7.80	172.2
Himachal Pradesh	8,647	0.25	21.62	13.0	0	—	13.0
Jammu and Kashmir	14,573	0.25	36.43	21.9	0	—	21.8
Jharkhand	6,696	1.00	66.96	40.2	36	16.00	4.2
Karnataka	65,152	0.25	162.88	97.9	159	14.00	(61.1)
Kerala	21,060	0.25	52.65	31.6	0.025	0.03	31.6
Madhya Pradesh	53,358	0.60	320.15	192.3	213.21	7.25	(20.9)

Maharashtra	150,987	0.25	377.47	226.8	75.5	21.00	151.3
Manipur	608	0.25	1.52	0.9	0	—	0.9
Mizoram	418	0.25	1.04	0.6	0	—	0.6
Meghalaya	2,154	0.40	8.62	5.2	0	—	5.2
Nagaland	596	0.25	1.49	0.9	0	—	0.9
Orissa	24,284	0.15	36.43	21.9	54	13.00	(32.1)
Punjab	48,089	0.07	33.66	20.2	51.825	9.33	(31.6)
Rajasthan	55,057	0.75	412.93	248.1	330.4	201.15	(82.3)
Tamil Nadu	91,441	0.05	45.72	27.5	18.105	17.05	9.4
Tripura	1,010	0.10	1.01	0.6	0	—	0.6
Uttarakhand	11,541	0.05	5.77	3.5	5.05	5.05	(1.6)
Uttar Pradesh	85,902	1.00	859.02	516.1	93.375	12.38	422.7
West Bengal	41,896	0.25	104.74	62.9	52.05	2.05	10.9
			Total	2537.2	2179.59	1047.84	

However, when annual solar capacity requirement for RPO compliance is analyzed (Table 3.3), it is found that India would need ~34,000 MW of solar capacity to achieve the target of 3% contribution from solar electricity till 2022. It means that set RPO targets are not sufficient to have a solar energy dominant RE development scenario. The policy makers expect to fill this gap with states' solar energy promotion policies and programmes. Most of the states have come up with their solar energy specific policies which are discussed in detail in subsequent sections.

Table 3.3: Solar power capacity requirement by 2022

Year	Energy demand (MU)* (A)	Solar RPO (%) (B)	Solar energy requirement (MU) for RPO compliance (AxB)	Solar capacity requirement for RPO compliance (MW)	Solar capacity requirement for solar dominant scenario (MW)

2011-2012	953,919	0.25	2,385	1,433	514
2012-2013	1,022,287	0.25	2,556	1,536	2414
2013-2014	1,095,555	0.50	5,478	3,291	5414
2014-2015	1,174,074	0.75	8,806	5,291	8414
2015-2016	1,258,221	1.00	12,582	7,560	12414
2016-2017	1,348,399	1.25	16,855	10,127	17490
2017-2018	1,443,326	1.75	25,258	15,176	22490
2018-2019	1,544,936	2.25	34,761	20,885	28490
2019-2020	1,653,700	2.50	41,343	24,839	35490
2020-2021	1,770,120	2.75	48,678	29,247	—
2021-2022	1,894,736	3.00	56,842	34,152	—

As far as state-wise installation is concerned, Table 3.4 clearly demonstrates that states of Gujarat (65.83%) and Rajasthan (19.20%) have major share in total installed capacity (1047.87 MW). Other states like Andhra Pradesh (23.75 MW) and Maharashtra (21.00 MW) also have significant contribution. However, it is quite remarkable that out of 26 states 19 have shown their presence in the class of solar India in spite of relatively high generation cost (Table 3.4). It is expected that when cost will reduce with increasing capacity, states which have low or no capacity may contribute significantly.

Moreover, Table 6 shows that the installed capacity (1047.87 MW) under various policy measures is dominated by state policies (65.83%) which is in particular the success mantra of state of Gujarat (689.81 MW). The peculiarity of theses installation scenarios should be taken into account while devising the policy for future.

Table 3.4: State-wise distribution of installed solar capacity as on 31st of November, 2012

Sr. no.	States	JNNSM	State policy	RPSSGP/GBI scheme	REC	Other	Total	% of total
1	Andhra	12.00	—	9.75	—	2.00	23.75	2.27
2	Pradesh							
3	Arunachal	—	—	—	—	0.03	0.03	0.00
4	Pradesh							
5	Chhattisgarh	—	—	4.00	—	—	4.00	0.38

6	Delhi	—	—	—	—	2.53	2.53	0.24
7	Goa and UT	—	—	—	—	1.69	1.69	0.16
8	Gujarat	—	689.81	—	—	—	689.81	65.83
9	Haryana	—	—	7.80	—	—	7.80	0.74
10	Jharkhand	—	—	16.00	—	—	16.00	1.53
11	Karnataka	5.00	—	—	—	9.00	14.00	1.34
12	Kerala	—	—	—	—	0.03	0.03	0.00
13	Madhya	—	—	5.25	2.00	—	7.25	0.69
14	Pradesh							
15	Maharashtra	11.00	—	5.00	—	5.00	21.00	2.00
16	Orissa	5.00	—	7.00	—	1.00	13.00	1.24
17	Punjab	2.00	—	6.00	—	1.33	9.33	0.89
18	Rajasthan	137.50	—	10.00	2.75	50.90	201.15	19.20
19	Tamil Nadu	5.00	—	5.00	—	7.05	17.05	1.63
	Uttarakhand	—	—	5.00	—	0.05	5.05	0.48
	Uttar							
	Pradesh	5.00	—	7.00	—	0.38	12.38	1.18
	West	—	—	—	—	2.05	2.05	0.20
	Bengal							
	Total	182.50	689.81	87.80	4.75	83.01	1047.87	

Table 3.5: Policy-wise distribution of installed solar capacity as on 31st of November, 2012

Projects	Capacity (MW)	% of total
Projects under JNNSM	182.5	17.42
Projects under the state policy	689.81	65.83
Projects under RPSSGP/GBI	87.8	8.38
scheme	4.75	0.45
Projects under REC scheme	83.01	7.92
Other projects		
Total	1047.87	

Development under JNNSM

To achieve the long-term goal of NAPCC, Jawaharlal Nehru National Solar Mission (JNNSM) was launched on 11th January, 2010, with an objective to maximize generation of power from solar energy. Thus, it also constitutes a major contribution by India to the global effort to meet the challenges of climate change. The immediate aim of the mission is to focus on setting up an enabling environment for solar technology penetration in the country both at a centralized and decentralized level.

Table 3.6 shows JNNSM's targets with time line. The first phase (up to March 2013) focuses on promoting off-grid systems including hybrid systems to serve the population which is located in remote areas. For the first phase modest targets were set under the expectation that this development would bring down costs under enabling framework and support for entrepreneurs to develop markets. This cost reduction would help in creating conducive environment to achieve the ambitious targets of the second phase (2013–17) and third phase (2017–2022).

Table 3.6: JNNSM targets with timeline

	2010–2013	2013–2017	2017–2022
Utility grid power including roof top (MW)	1000–2000	4000–10000	20000
Off-grid solar applications (MW)	200	1000	2000
Solar collectors (sq. m)	7 million	15 million	20 million

To attract the investors, JNNSM devises various incentive instruments such as RE Voucher/Stamp, Capital Subsidy, Interest Subsidy, Viability Gap Funding (VGF), and Green Energy Bonds. However, the capacity built is only 182.5 MW which is concentrated around few states like Rajasthan (137.5 MW), Andhra Pradesh (12 MW), Maharashtra (11 MW), and so forth (refer: Table 5) under first phase (as on 31st of November, 2012). This seeks immediate attention of policy makers for reviewing their implementation strategy.

Recently announced JNNSM second phase policy mandate includes the learning from the initial setback. It gives more weightage to state scheme (5400 MW) than central scheme

(3600 MW) for target capacity installation (Table 3.7). It also focuses more on VGF for incentivizing the projects.

Table 3.7: Technology-wise capacity targets under JNNSM Phase II (MW)

Segment	Share (%)	Capacity	Central scheme	State scheme
Solar PV	70	6300	2520	3780
Solar thermal	30	2700	1080	1620
Total		10000	3600	5400

To make the efforts more concentrated and specific, in a recent initiative, MNRE has given approval to the development of 54 solar cities. As of now (January 21, 2013), 8 master plans have been approved for eight cities—Agra and Moradabad from Uttar Pradesh; Thane and Kalyan-Dombivli from Maharashtra; Indore from Madhya Pradesh; Kohima from Nagaland; and Aizawl from Mizoram and Chandigarh. Thus by reducing scale, MNRE expects better solar capacity development in the near future.

Development under REC

The REC mechanism is a market-based instrument to promote renewable sources of energy and development of market in electricity, leading to the sustainable development of the country. REC mechanism has been designed to address the mismatch between availability of renewable electricity and the requirement of the obligated entities to meet their RPO by purchasing green attributes of RE remotely located in the form of REC. The implementation issues as well as institutional framework for India have been discussed in detail by Singh and MNRE. Goyal and Jha discussed in detail the framework to promote RE through a framework which puts into place Renewable Purchase Obligation (RPO) mechanism.

In India, RECs trading began in March 2011, on the platform of Indian Energy Exchange (IEX) and Power Exchange of India (PXI). Though during initial period it could not perform as per expectation, but the performance has been improving during the last few months, as shown in Table 10. But still due to large unmet demand, solar REC price has been hovering around the forbearance price (Table 3.8) of Rs. 13400/REC. However, a recent notification by MNRE which clarified state agencies for allowing use of solar REC to nonsolar RPO if it is above its minimum prescribed limit may increase the liquidity of solar REC market which is expected to decrease the price of it.

Table 3.8: Floor and forbearance prices for RECs (Rs.2/REC)*.

	REC prices till 2011	REC prices for 2012–2015
Forbearance price	17000	13400
Floor price	12000	9300

1 REC = 1 MWh.

21 USD = INR 54.5 as of September 20, 2012.

Table 3.9: Solar REC trading details from IEX

Year	Month	Buy bids (REC)	Sell bids (REC)	Cleared volume (REC)	Cleared price (Rs/REC)	No. of participants
2011	February	11	—	—	—	1
	March	30,001	—	—	—	3
	April	—	—	—	—	—
	May	—	—	—	—	—
	June	—	—	—	—	—
	July	—	—	—	—	—
	August	1	—	—	—	1
	September	7	—	—	—	4
	October	1	—	—	—	1
	November	43	—	—	—	2
	December	495	—	—	—	—
2012	January	2,635	2,635	—	—	10
	February	582	582	—	—	9
	March	5,782	5,782	—	—	26
	April	289	289	—	—	9
	May	1,637	1,637	5	13,000	16
	June	9,489	9,489	336	12,750	17

	July	8,554	8,554	93	12,800	11
	August	1,728	1,728	129	12,850	13
	September	1,317	1,317	735	12,500	23
	October	1,263	1,263	820	12,680	19
	November	1,458	1,458	733	12,720	21
	December	1,608	1,608	931	12,620	36

Though the capacity installed under this mechanism is only 4.75 MW (Table 6), but capacity registered under this mechanism has reached close to 20 MW. And the present high price of REC holds bright prospects for this newly launched incentive scheme.

Development under RPSSGP/GBI Scheme

Rooftop Photovoltaic (PV) and Small Solar Power Generation Programme (RPSSGP) is a Generation-Based Incentives (GBIs) programme of the Ministry of New and Renewable Energy (MNRE) under the JNNSM for rooftop and other small solar plants. As of now, the installed capacity of 87.8 MW, which is well distributed across many states (Table 5), has been developed under this scheme. Due to limited access to smart grid/net metering connectivity, this incentive has not yet been harnessed to its fullest by the developers.

Development under the State Policy

Most of the states have been using preferential tariffs as a tool to promote solar energy in their states (Table 3.10). But, due to huge financial burden, states of Gujarat and Andhra Pradesh have switched their focus from preferential tariff to REC market in their recently announced solar policies [25, 26]. Moreover, state of Gujarat has also made provision for sharing Clean Development Mechanism (CDM) benefits to developers, starting from 100% in first year after commissioning, and thereafter reducing it by 10% every year till the sharing becomes equal (50 : 50) between the developers and the consumers.

Likewise several states have also come up with many other encouraging policies like Accelerated Depreciation (AD) on capital investment, soft loan for financing, reduced or no transmission and wheeling charges, no cross subsidy surcharge for open-access transactions, reduced or no intra-state Availability-Based Tariff (ABT), non-applicability of merit order dispatch principles, exemption from electricity tax, tax concessions, refund of stamp duty and registration charges paid for land purchase, single window clearance, faster power evacuation approval, and so forth.

Table 3.10: Compilation of recently declared preferential tariffs for solar PV and solar thermal technologies

	Solar PV		Solar thermal	
State/centre	Tariff (Rs/kWh)	Control period	Tariff (Rs/kWh)	Control period
CERC	Lev-10.39 AD-1.04 After AD-9.35	FY 2012-2013	Lev-12.46 AD-1.24 After AD-11.22	FY 2012-2013
Andhra Pradesh	17.91 (without AD) 14.95 (with AD)	2010-2011 and 2011-2012	15.31 (without AD) 12.85 (with AD)	2010-2011 and 2012-2013
Bihar	10.9 (without AD) 09.85 (with AD)	Up to March 31, 2015 commissioning	13.11 (without AD) 11.87 (with AD)	Up to March 31, 2015 commissioning
Gujarat	For MW scale plants: Jan 2012–March 2013: 10.37 (without AD), 09.28 (with AD), FY 2013-2014: 9.64 (without AD), 8.63 (with AD), FY 2014-2015:	Jan 29, 2012 to March 31, 2015	12.91 (without AD) 11.55 (with AD)	Jan 29, 2012 to March 31, 2015

	8.97 (without AD), 8.03 (with AD) For kW scale plants Jan 2012–March 2013: 12.44 (without AD), 11.14 (with AD), FY 2013-2014: 11.57 (without AD), 10.36 (with AD), FY 2014-2015: 10.76 (without AD), 9.63 (with AD)			
Haryana	9.18 (SPV crystalline) 8.90 (SPV thin film)	3 years (till FY 2013–FY 2015)	12.17	3 years (till FY 2013–FY 2015)
Karnataka	14.5 (including rooftop and small solar PV plants)	Up to March 31, 2013 commissioning	11.35	Up to March 31, 2013 commissioning
Kerala	15.18 (including incentives)	For projects commissioned before Dec. 31, 2009		
Madhya Pradesh	10.44 (capacity > 2 MW),	Aug 2012 to March 2014	12.65	Aug 2012 to March 2014

	10.70 (capacity up to 2 MW)			
Maharashtra	Lev-11.16 (11.66-RT and SSPGP) AD-1.65 (1.65) After AD-9.51 (10.01)	FY 2010–2014 (5 years from the date of commencement)	Lev-13.44 AD-1.97 After AD-11.47	FY 2010–2014 (5 years from the date of commencement)
Orissa	Lev-17.80 AD-3.03 After AD-14.77	Plant commissioned in FY (2012-2013) onwards	Lev-14.73 AD-2.41 After AD-12.32	Plant commissioned in FY (2012-2013) onwards
Punjab	Lev-10.39 AD-1.04 After AD-9.35	FY 2012–2016 (5 years from the notification of order)	Lev-12.46 AD-1.24 After AD-11.22	FY 2012–2016
Rajasthan	9.63 (plant commissioned by 31st of March 2014) with AD-10.45 9.63 (roof top and SSPG commissioned by 31st March 2014)		11.95 (without AD) With AD-10.45 11.95 (small solar thermal power gen commissioned by 31st of March 2015)	FY 2012-2013
Tamil Nadu	Lev-18.45 AD-4.11 After AD-14.34	FY 2010-2011 (till 31/05/12)	Lev-15.51 AD-3.35 After AD-12.16	FY 2010-2011 (till 31/05/12)
Uttarakhand	Lev-17.70 AD-1.65 After AD-16.05	FY 2009–2012 (3 years from the	Lev-12.95 AD-1.15 After AD-11.80	FY 2009–2012 (3 years from the

		commencement of these regulations)		commencement of these regulations)
Uttar Pradesh	15 (commissioned by Dec 2011, not covered under GOI incentive scheme)	FY 2010–2014 (5 years)	13 (commissioned by Dec 2011, not covered under GOI incentive scheme)	FY 2010–2014 (5 years)
West Bengal	10 (capacity ranging 100 KW to 2 MW availing GBI) 10 (grid connected plant not eligible for any incentive and commissioned up to 2012-2013) 10 (projects commissioned after FY 2012 till FY 2015)	FY 2013–2017 (5 years)	NA	NA

3.3 STATE SOLAR POLICIES

GUJARAT SOLAR POLICY (Solar Power Policy – 2009)

Gujarat is the first state to launch its own solar policy in 2009. The Gujarat solar policy was in place a year before the NSM was announced.

Operative Period: From the date of issuance to March 31, 2014

The initial target is to achieve 500 MW of installed capacity by the end of this period.Gujarat Energy Development Agency (GEDA) and Gujarat Power Corporation Limited (GPCL) have been appointed as nodal agencies for the facilitation and implementation of the policy. Gujarat Solar Power Policy is the only policy, which has awarded projects with a fixed FiT, on a first-come-first serve basis. This has resulted in the allocation of a number of projects to in-experienced or unknown developers.

TARIFF

Solar PV	**Rs. 15/kWh for the first 12 years from the date of commissioning**	**Rs. 5/kWh for the remaining 13 years**
Solar Thermal	Rs. 12/kWh for the first 12 years	**From the date of commissioning Rs. 3/kWh for the remaining 13 year**

This gives a levelized tariff of Rs. 13.30/kWh for PV and Rs.10.54/kWh for Solar Thermal over 25 years. There were no timelines or guarantees required from the developers by the government to sign PPAs after the allotment of projects. Although, some companies like Moser Baer signed PPAs as early as January 12th 2009, many awaited the formalization of the NSM as its draft policy indicated a more attractive tariff of Rs. 17.91/kWh for PV and Rs. 15.40/kWh for Solar Thermal. Until late 2009, many developers had not signed PPAs in Gujarat. After the NSM policy was formalized in December 2009, developers moved away from Gujarat towards the NSM. In the first phase of the Gujarat policy, only 396.5 MW worth of PPAs were signed out of 716 MW allotments, leading to a conversion rate of 55% (PPAs signed as a percentage of projects allotted).

The tremendous interest from developers for NSM led to the competitive bidding for projects and a subsequent fall in tariffs. The fall in the NSM tariff below the levelized tariff in Gujarat suddenly made the Gujarat policy very attractive again to developers. Further, a significantly higher feed-in-tariff in the first 12 years in Gujarat matches investor's timelines, as they would look to cover the cost of debt during this period. To ensure developer commitment, Gujarat's solar policy for the second phase has been amended to include a deposit that would be encashed, if the developers fail to sign the PPAs. Larger available project sizes and the relative ease of land acquisition has led to larger developers getting serious about the Gujarat policy and signing PPAs and starting the implementation of projects. This has led to an increase in the conversion rate from 55% to 95%, with 537 MW worth of PPAs signed for 565 MW of the projects allotted for solar PV projects. With an increase of over 44% in the number of PPAs signed, Gujarat has significantly improved the credibility of its solar program from the first to the second phase. As compared to the NSM, the Gujarat policy has longer timelines for the execution of the projects. At the same time, it has a stringent penalty mechanism for delays and intends to levy penalties on redundant projects. Delays in commissioning the projects can incur penalties of Rs. 10,000 a day per MW for the first 60 days and Rs. 15,000 thereafter. The enforcement of these penalties is yet to be decided on. An initial 48.5 MW of the first phase were required to be commissioned by December 31, 2010. However, a 5MW project by Lanco Infratech and a 1MW project by SunEdison were the only ones that have met their deadlines. Six projects, including a 10MW solar PV project by Zebasolar and projects by Azure Power and Dreisatz GmbH were delayed despite their initial commitment to start operations.

On December 29th 2010, India's first solar park was inaugurated at Charanaka in Patan district of northern Gujarat. So far, land has been allotted in the solar park for projects worth 176MW to 16 companies from the first and second phases. The total capacity of the solar park is 500MW with 30,000 sq. m per MW land allotted to Solar Thermal and 20,000 sq. m per MW of land allotted to PV projects. The solar park has been financed with over Rs. 12 billion by financial institutions like the International Finance Corporation (IFC), the Asian Development Bank (ADB) and the Infrastructure Development Finance Corporation (IDFC). The park tackles land procurement, water availability and grid connectivity issues and offers a "single-window" clearance process. Sixteen companies, including SunEdison Energy India (25MW), Alex Astral Power (25MW), Roha Energy (25MW), GMR Gujarat Solar (25MW), Kiran Energy (20MW), Emami Cement (10MW) and Azure Power (5MW) have been allotted projects worth a total of 176MW in the park. They have all signed PPAs with the state government.

KARNATAKA SOLAR POLICY (Solar Policy 2011 – 16)

Karnataka, a south-western state of India, announced its solar policy on July 1, 2011. Under the solar policy 2011-16, the Karnataka Government proposes to promote solar power as part of renewable energy generation policy in the state.

Operative Period: July 1, 2011 to March 31, 2016.

It targets 350 MW worth of projects till 2016.

- 200 MW is to be developed for direct sale to the distribution companies in the state (40 MW to be added each year)
- 100 MW under REC Mechanism
- 50 MW for bundling of power with thermal power from outside the state at rates to be determined by the State Government subject to approval of KERC.

The minimum capacity of solar PV projects is 3 MW and maximum capacity of 10 MW, while for Solar Thermal the minimum is 5MW with no cap on maximum. The quantum of power to be procured by ESCOMs from solar resources under purchase obligation is 0.25% of the total consumption and the shortfall in procurement of solar energy by the ESCOMs can be made good by purchase of solar specific RECs. Though the state has come up with its own policy, it will continue to support programs like the NSM. The state has set a combined target of 126 MW of solar power to be developed by 2013-14 through NSM and its own solar policy.

The Karnataka Renewable Energy Development Limited (KREDL) is the nodal agency for the policy. As part of its solar policy, KREDL has called for bids for 80 MW worth of project and received 22 bids from potential developers. The winners are to be selected through reverse bidding process. Under the REC Scheme of MNRE, KREDL has received proposals to set up 350 MW worth of solar projects.

The policy also allows developers to inject power at 11KV and above, while under NSM, the requirement is 33KV and above. Developing 11KV substation at power plant is cheaper than a 33KV substation which requires high cost components, so this will bring down the project development cost for the developers.

RAJASTHAN SOLAR POLICY (Rajasthan Solar Energy Policy, 2011)

On April 19th 2011, Government of Rajasthan issued Rajasthan Solar Energy Policy, 2011 to promote solar energy in the state.The policy aims to help Rajasthan, develop as a global hub of solar power for 10000-12000 MW capacity over the next 10 to 12 years to meet energy requirements of Rajasthan and other states of India.

It targets a minimum of 550MW of grid connected solar power in Phase 1 (up to 2013).

- Projects will be awarded through a process of competitive bidding.
- PV projects will be worth 300MW, out of which 100MW are reserved for project developers and 200MW for panel manufacturers.
- The minimum and maximum sizes for PV projects are 5MW and 10MW.
- Module manufacturers that set up their manufacturing plant in Rajasthan can bid for either 10MW or 20MW worth of PV projects based on their manufacturing capacity.
- A further 50MW will be allocated for rooftop PV (1MW each) and other small solar power plants.
- The DISCOMS in Rajasthan will provide PPAs for the projects. In addition, projects worth 100MW (50MW PV and 50MW CSP) are targeted for bundled solar power. In such projects, the developer can sell conventional power and solar power in a ratio of 4:1 at the weighted average tariff to the distribution utilities in Rajasthan. Varied project sizes will attract small as well as large developers looking to invest in projects of different scale.

Rajasthan Renewable Energy Corporation Limited (RRECL) has been appointed as the nodal agency for single window clearance of projects. The benchmark tariffs offered according to the new tariff revision are Rs.10.12/kWh for PV and Rs. 12.08/kWh for Solar Thermal projects for 25 years.

Unlike the National Solar Mission, there is no domestic content requirement in the Rajasthan solar policy. The developer can choose any established and operational technology from India or abroad. The draft also gives clear parameters for setting up evacuation infrastructure from the plant to the nearest substation. This has been an issue between the distribution utility and developers in other solar policies. For solar PV and Solar Thermal projects, if the power plant lies within 15km of the nearest substation, the cost will be borne by the distribution company (DISCOM). For any length above 15km, the cost will be borne by the developer. For rooftop projects, the cost will be borne by the DISCOM but the developer will need to take permission from the DISCOM before finalizing the location of the project. The policy has taken up lessons from forerunners like the NSM and the Gujarat solar policy – it declined to have the 5MW limit on individual projects that made the NSM less attractive to large players but, unlike the Gujarat policy, it has placed fixed limits on overall capacity allocation. The policy also addresses the concerns of the developers, with regards to the allocation of land and water, availability of an evacuation network and the localized supply chain. Finding the right location and acquiring land is one of the major bottlenecks so far for projects in India. To solve this problem, the policy looks to create land banks from government land. Some of these land banks are situated near cities like Bikaner and Barmer. Under the policy, after the 25 years of the PPA, the developer can use the land for commercial purpose.

APPLICATIONS

SOLAR THERMAL

Solar Energy ——>>> **Heated Water** ——>>> **Electricity**

Solar thermal electricity technologies produce electric power by converting the sun's energy into high-temperature heat using various mirror configurations, which is then channelled to an on-site power plant and used to make electricity through traditional heat-conversion technologies. The plant essentially consists of two parts; one that collects solar energy and converts it to heat, and another that converts the heat energy to electricity.

TYPES OF HEAT COLLECTORS:

Evacuated Glass Collector - Evacuated-tube collector consists of parallel rows of glass tubes connected to a header pipe. Each tube has the air removed from it to eliminate heat loss through convection and radiation. Evacuated-tube collectors fall into two main groups.

Direct-flow evacuated-tube collectors - These consist of a group of glass tubes inside each of which is a flat or curved aluminium fin attached to a metal (usually copper) or glass absorber pipe. The fin is covered with a selective coating that absorbs solar radiation well but inhibits radiative heat loss. The heat transfer fluid is water and circulates through the pipes, one for inlet fluid and the other for outlet fluid.

Heat pipe evacuated-tube collectors - These consist of a metal (copper) heat pipe, to which is attached a black copper absorber plate, inside a vacuum-sealed solar tube. The heat pipe is hollow and the space inside, like that of the solar tube, is evacuated. The reason for evacuating the heat pipe, however, is not insulation but to promote a change of state of the liquid it contains. Inside the heat pipe is a small quantity of liquid, such as alcohol or purified water plus special additives. The vacuum enables the liquid to boil (i.e. turn from liquid to vapor) at a much lower temperature than it would at normal atmospheric pressure. When solar radiation falls on the surface of the absorber, the liquid within the heat tube quickly turns to hot vapor rises to the top of the pipe. Water, or glycol, flows through a manifold and picks up the heat, while the fluid in the heat pipe condenses and flows back down the tube for the process to be repeated.

Flat Plate Collector - Flat-plate collectors are the most common solar collectors for use in solar water-heating systems in homes and in solar space heating. A flat-plate collector basically consists of an insulated metal box with a glass or plastic cover (the glazing) and a dark-colored absorber plate. Solar radiation is absorbed by the absorber plate and transferred to a fluid that circulates through the collector in tubes. In an air-based collector the circulating fluid is air, whereas in a liquid-based collector it is usually water.

Flat-plate collectors heat the circulating fluid to a temperature considerably less than that of the boiling point of water and are best suited to applications where the demand temperature is 30-70°C (86-158°F) and/or for applications that require heat during the winter months.

Air-based collectors are typically used for heating buildings and drying crops. Liquid-based may be glazed or unglazed. Glazed liquid collectors are the commonest type of solar collector for providing domestic and commercial water and for heating indoor swimming pools. Unglazed collectors are often used for heating outdoor pools. A special type of unglazed collector called a perforated plate collector is used to preheat ventilation air for commercial buildings or, in some cases, for drying crops.

Flat collectors can be mounted in a variety of ways, depending on the type of building, application, and size of collector. Options include mounting on a roof, in the roof itself, or free-standing.

RURAL ELECTRIFICATION

Lack of electricity infrastructure is one of the main hurdles in the development of rural India. India's grid system is considerably under-developed, with major sections of its populace still surviving off-grid. As of 2004 there are about 80,000 un-electrified villages in the country. Of these villages, 18,000 could not be electrified through extension of the conventional grid. A target for electrifying 5,000 such villages was fixed for the Tenth National Five Year Plan (2002–2007). As on 2004, more than 2,700 villages and hamlets had been electrified mainly using SPV systems. Developments on cheap solar technology are considered as a potential alternative that allows an electricity infrastructure comprising of a network of local-grid clusters with distributed electricity generation. That could allow bypassing, or at least relieving the need of installing expensive, and lossy, long-distance centralised power delivery systems and yet bring cheap electricity to the masses.3000 villages of Odissa will be lighted with Solar power by 2014.

3.4 CHALLENGES AND CONSTRAINTS

LAND SCARCITY

Per capita land availability is a scarce resource in India. Dedication of land area for exclusive installation of solar cells might have to compete with other necessities that require land. The amount of land required for utility-scale solar power plants — currently approximately 1 km^2 for every 20–60 megawatts (MW) generated could pose a strain on India's available land resource. The architecture more suitable for most of India would be a highly distributed, individual rooftop power generation systems, all connected via a local grid. However, erecting such an infrastructure which doesn't enjoy the economies of scale possible in mass utility-scale solar panel deployment — needs the market price of solar technology deployment to substantially decline so that it attracts the individual and average family size household consumer. That might be possible in the future, since PV is projected to continue its current cost reductions for the next decades and be able to compete with fossil fuel.

SLOW PROGRESS

While the world has progressed substantially in production of basic silicon mono-crystalline photovoltaic cells, India has fallen short to achieve the worldwide momentum. India is now in 7th place worldwide in Solar Photovoltaic (PV) Cell production and 9th place in Solar Thermal Systems with nations like Japan, China, and the US currently ranked far ahead. Globally, solar is the fastest growing source of energy (though from a very small base) with an annual average growth of 35%, as seen during the past few years.

LATENT POTENTIAL

Some noted think-tanks recommend that India should adopt a policy of developing solar power as a dominant component of the renewable energy mix, since being a densely populated region in the sunny tropical belt, the subcontinent has the ideal combination of both high solar insolation and a big potential consumer base density. In one of the analyzed scenarios , while reining on its long-term carbon emissions without compromising its economic growth potential, India can make renewable resources like solar the backbone of its economy by 2050.

GOVERNMENT SUPPORT

The government of India is promoting the use of solar energy through various strategies. In the latest budget for 2010-11, the government has announced an allocation of Rs.10 billion towards the Jawaharlal Nehru National Solar Mission and the establishment of a Clean Energy Fund. It's an increase of Rs. 3.8 billion from the previous budget. Also budget has also encouraged private solar companies by reducing customs duty on solar panels by 5 percent and exempting excise duty on solar photovoltaic panels. This is expected to reduce the roof-top solar panel installation by 15- 20 percent. The budget also proposed a coal tax of USD 1 per metric ton on domestic and imported coal used for power generation

PROBLEMS AND SUGGESTIONS

PROBLEMS

Standalone EPC players will cater to ISPPs and corporations

The above scenario will increase demand for engineering, procurement, and construction (EPC) players, as developers opt to outsource turnkey projects due to a lack of internal expertise. EPC players can look forward to $3 billion in annual sector revenues by 2017, thanks to a wide client base of utilities, small independents, and niche players.

The EPC market will remain fragmented

With project sizes typically ranging from 10 to 25 MW, small and medium-sized players will have few constraints competing against larger national and international ones. Scale-driven procurement efficiencies will diminish as rapidly declining costs and improving technology options inhibit the long-term framework agreements that characterize conventional-energy procurement structures.

Manufacturing space will still be dominated by imports

One area of the solar market won't be dominated by small local companies: manufacturing of modules. Given global overcapacity in this segment, module-manufacturing facilities likely will not be built in India unless mandated by local regulations. If that happens, the lower-cost economics of Indian manufacturers could delay grid parity by two to three years. Nonetheless, global players have already started setting up bases for balance of systems (BoS) in India, a trend that is likely to continue.

CHAPTER – 4

Challenges in Solar Power Development in India

4.1 Introduction

Background

The grid-connected capacity (all photovoltaic) in India stood at 37MW in July 2011, which is only 13MW more than the installed capacity at the beginning of the year. Though small, this is progress and the pace of progress is likely to increase in the next few years. The solar industry is set to grow significantly in the next ten years, driven mainly by the ambitious NSM, various state level initiatives, Renewable Purchase Obligations (RPOs) as well as by falling technology costs.

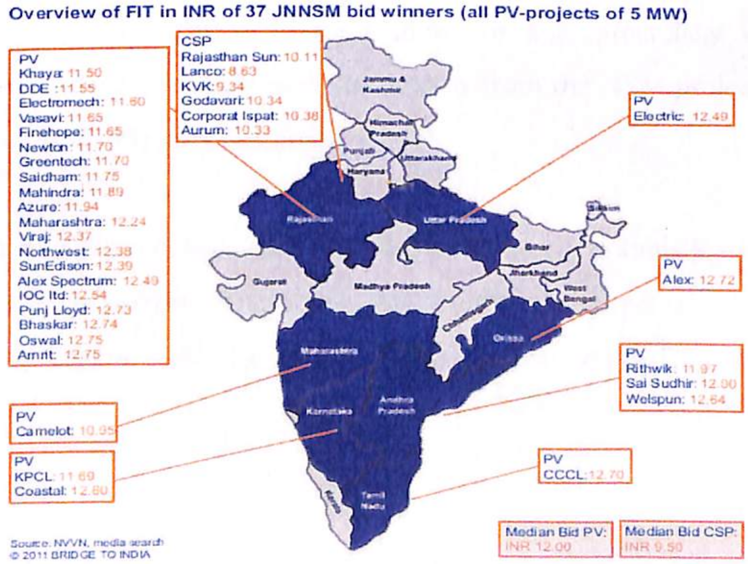
The NSM targets an installation of 20GW of grid-connected and 2GW of off grid solar power by 2022. In the first of a total of three phases, from 2010 to 2013, the government aims to set up 1,000MW of grid-connected power plants, encouraging the more developed Photovoltaic (PV) technology as well as Concentrated Solar Power (CSP) equally with 500MW each. In addition, 200MW of off-grid and 100MW of tail end and other small-grid solar power are to be installed.

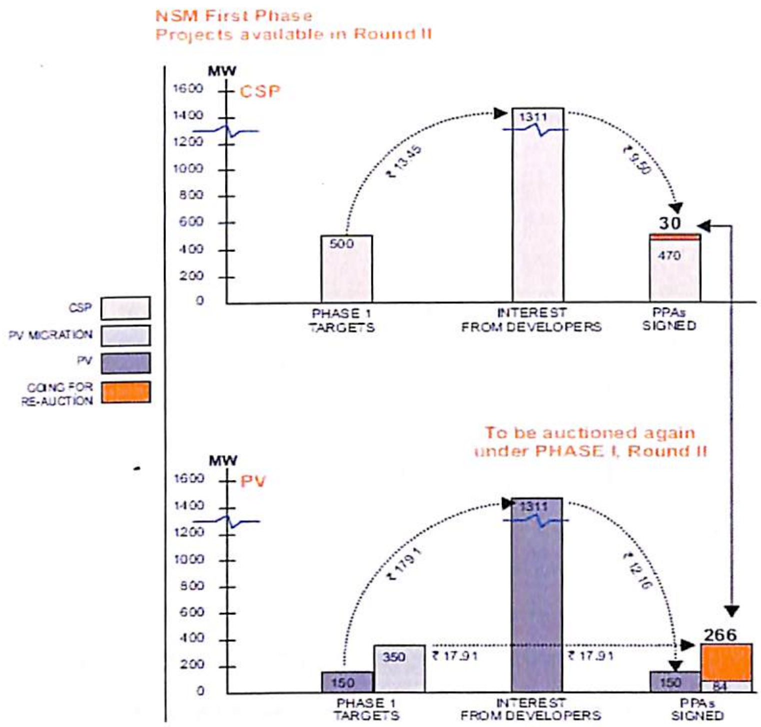
Encouraging the spread of solar power generation (both CSP and PV) and aiming for grid-parity (currently at around INR 5 or $0.12 per kWh) by 2022 and parity with coal power generation (currently at around INR 4 or $0.10 per kWh) by 2030, is a key element in India's comprehensive, long term energy supply strategy. As of December 2010, solar power generation in India costs around INR12 ($0.30) per kWh, or over three times as much as power from coal. At the moment, bankability remains a key challenge for projects as they try and obtain non-recourse project finance. Indian banks are still on a learning curve as they are yet to fully understand solar technology in India. They are unconvinced about the reliability of the technology and are sceptical about performance and profitability. International banks are wary of the significant market risks and have adopted a 'wait and watch' policy leaving most of the early risks to the Indian banks.

For the financial year 2010-2011, the government originally offered a feed-in tariff of INR17.91 ($0.44) per kWh for PV projects, rooftop projects as well as projects migrated from previous incentive programs to the NSM, and INR15.40 ($0.38) for CSP. Power Purchase Agreements (PPAs) would have a validity of 25 years. In June 2010, the Central Electricity Regulatory Commission (CERC) estimated that the tariff would allow investors an internal rate of return (IRR) on equity of about 16-21% after taxes3. On September 18th 2010, the application deadline for projects under the first phase of the NSM, more than 400 project developers put forward bids for the 650MW on offer. Of this, 150MW was for PV generation and 500MW was for CSP. The maximum size for a CSP bid was 100MW and for a PV bid 5MW. Given the oversubscription of the first round for projects, the government decided to award contracts based on competitive bidding to those project developers that offered the highest discount on the initial tariff of INR 17.91 ($0.44) for PV and INR 15.40 ($0.38) for CSP. Companies offering the highest discount to the tariff rate prescribed by the Central Electricity Regulatory Commission (CERC) were selected to produce 620MW under the first phase. Thirty projects worth 150MW for PV and seven projects worth 470MW for CSP were selected.

The first phase of the NSM has a target of 1,000MW of installed capacity by 2013. PPAs worth 234MW for PV (including migration projects worth 84MW) and 470MW for CSP have been signed so far. The NTPC Vidyut Vyapar Nigam Limited (NVVN), the government agency implementing the Mission, is set to allot the remaining capacity of 296MW in the next months, though the exact date is unknown.

Overview of FIT in INR of 37 JNNSM bid winners (all PV-projects of 5 MW)





According to the MNRE, competitive bidding in Round 1 allowed them to achieve a 30% reduction in costs from lower tariffs. As a result, this round too will likely be allotted through an inverse bidding auction. This is despite criticism from the industry that bidding leads to a competitive environment that favors players with a short-term, capex-focus over more serious, long-term, generation-focused players. For this second batch of Phase 1 of the NSM, the governmentis considering allotting PV projects of up to 25MW per project with the minimum capacity remaining at 5MW[4]. If finalized, competitive bidding could see greater participation by larger companies which can execute and finance larger projects and reduce costs through scale effects (especially in project development and financing). Also, for banks and export credit agencies such as KfW-IPEX, larger projects are easier to finance as higher investment volumes allow for a commercially viable, thorough due-diligence process. Previously, they have stayed away from the NSM projects as the 5MW project size did not justify their transaction costs.

There is a risk that the bidding process has led to an overly optimistic assessment of the many imponderables in the market. These are, for example, the actual on-site irradiation or the performance of plants under Indian conditions. A fear echoed by some leading industry experts is that developers have underestimated costs, risks and the complexity of setting-up solar power plants. There is also a danger that as a result of the highly competitive auctioning process, project quality will suffer and plants will not generate the estimated amount of power.

The Photovoltaic Segment

For PV, the highest discount offered on the CERC tariff in the auction of the first batch of the first phase of the NSM was INR 6.96 ($0.17) per unit and the lowest successful discount was INR 5.15 ($0.12) per unit. The tariff range is INR10.95 to INR12.76 ($0.27 to $0.31) per unit with an average tariff of INR12.16 ($0.30) per kWh. With a 32.1% fall, the new tariff is significantly lower than the feed-in-tariff announced by CERC earlier in the year. Some of the successful bidders include well known players such as SunEdison, Azure Power Rajasthan, Mahindra Solar One and IOC Ltd. However, most of the successful bidders are less well-known companies. The promoters behind these companies are unknown. Some of the larger industrial houses were not awarded projects as they did not bid aggressively. A possible reason is that the 5MW cap on projects made them too small to be of any interest. Such companies are instead looking at 10-15MW size projects available under state programs. A total of 21 successful NSM bids are for projects in Rajasthan. Eight of these are for a single district, Nagaur, followed by five in Jodhpur and four in Jaisalmer. Other projects are located in the states of Tamil Nadu, Andhra Pradesh, Karnataka and Maharashtra.

Selection of PV projects under the first phase of the NSM does not require any technical experience of the project developers, as companies are not assessed on the basis of their expertise in solar project development. Instead, the policy requires a bank guarantee of INR3m ($75,000) per MW as well as unconsolidated, audited annual accounts for the last four years as evidence of the net financial worth of the companies. As a result, a number of unknown players have been allotted projects.

Concentrated Solar Power Segment

The challenges to CSP projects are more severe than for PV. There is no domestic manufacturing base for CSP equipment in India and there are only a handful of experienced technology providers abroad. As such, developers are finding it difficult to find reliable, low-cost options, a necessity to make their projects viable at the low tariffs following the NSM auction. With an absence of CSP technology in India and a lack of projects for reference, banks are exceptionally wary of funding CSP projects.

For CSP projects, the highest discount offered was INR 4.82 ($0.12) per unit and the lowest successful discount was INR 3.07 ($0.07) per unit[7]. All CSP projects have made use of accelerated depreciation of 80% in the first year. The base feed-in-tariff before the discount was INR 13.45 or $0.33 (without accelerated depreciation the feed-in-tariff was INR 15.40 or $0.38). The new tariff range taking into account accelerated depreciation is therefore INR 8.63 to 10.38 ($0.21 to 0.25) per unit. With an average tariff of INR 9.50 ($0.23) per unit, the new tariff is 29.3% lower than the original base feed-in-tariff.

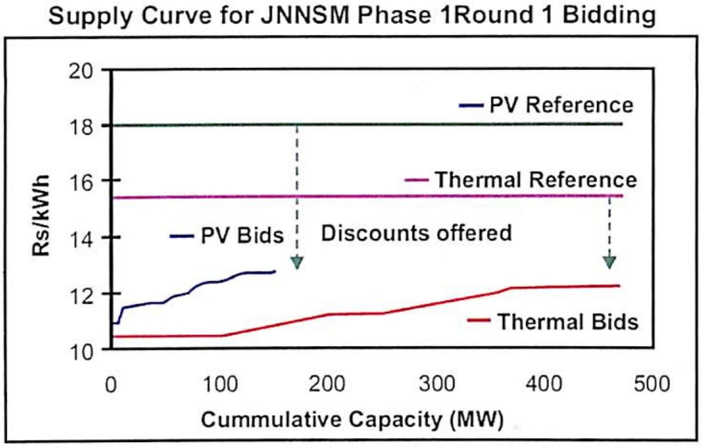
In spite of the recent rise of the CSP industry, both globally and in India, the technology still remains in the hands of a select few, thereby keeping costs high. The components used in CSP projects have not reached economies of scale and lack competitive pressures. There are not more than four to five manufacturers worldwide for most components. There needs to be a continuous deployment of the technology to support indigenization and bring down costs.

CSP power plants have a need for auxiliary power which is often unavailable or unreliable in remote areas. This power is needed to stop the heat-exchange fluids from freezing at night. In order to meet this requirement, projects have to provide for an alternative power supply which increases project costs. The government would do well to address this problem either by providing monetary support or by ensuring access to reliable auxiliary power.

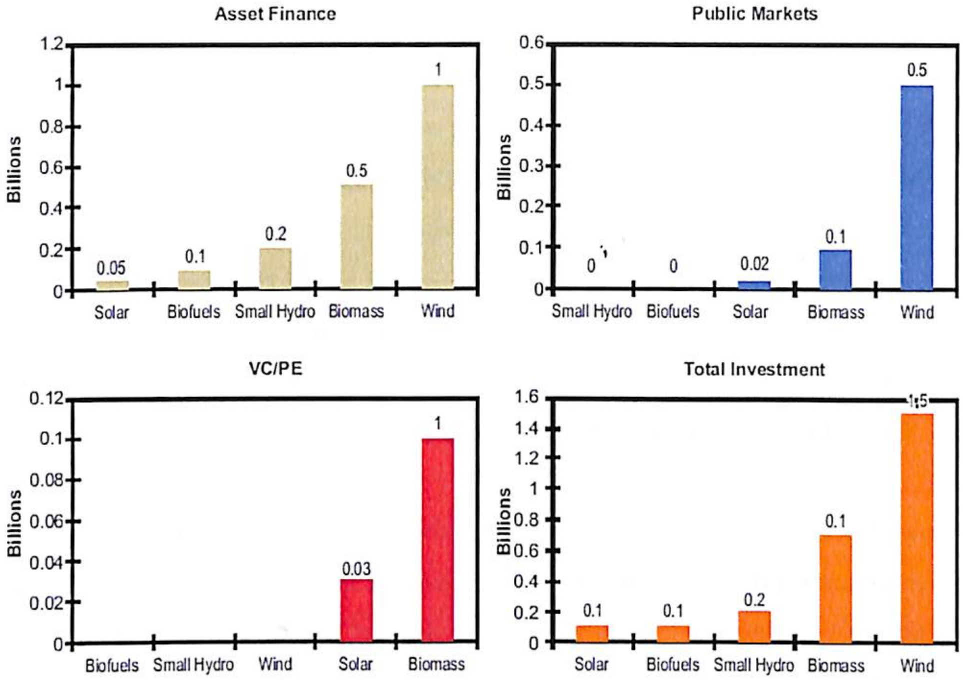
4.2 Key Industry Risks & Suggested Policy Interventions

The first and most important risk is the lack of reliable irradiation data, without which it is difficult to calculate the generated output and therefore, the return on investment. There are so far only a few projects in the country that provide actual generation data as a reference. Currently, there is an up to 30% variation between the satellite data provided for example by the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy and the MNRE on the one side, and on the ground measurements on the other. At the moment, the Indian Meteorological Department manages a network of 45 radiation monitoring stations across India, of which New Delhi, Patna, Jaipur and Thiruvananthapuram have data loggers installed. In addition to these stations, the MNRE is currently in the process of establishing 50 new stations across the country through the Centre for Wind Energy Technologies (CWET) in Chennai. CWET is an autonomous body under the MNRE and has pioneered wind data measurement, monitoring and modelling. It is expected to take over a similar role for Indian solar radiation monitoring as well. Reliable data over a sustained period of time from different monitoring stations across the country would enable players to mitigate the risks.

Bankability remains an issue for the vast majority of projects with signed PPAs at the moment in India. Project developers are finding it challenging to attain financial closure. Especially difficult is obtaining non-recourse debt financing. The need to keep capital costs low in order to make projects viable continues to create challenges for players in the Indian market. The low feed-in tariffs that result from competitive bidding will create questions around project viability in the eyes of the banks. In addition, Indian developers continue to struggle to obtain financing for projects due to their lack of a track-record in solar.



For projects under the NSM, banks are especially wary of the heavily discounted tariffs that have arisen from the bidding process. The present tariffs are among the lowest in the world for solar, and banks are concerned that the project risks have been underestimated in order to win bids. Banks are also wary of the small margins that projects are looking to operate on in order to be viable at such low tariffs. Pre-selection of the developers based on technical criteria, and not just on financial criteria, could help avoid unrealistic bidding by developers.



Source: REN21, 2010

Another issue with regard to financing is that Indian banks are structurally geared only for working capital loans that are typically short-term (6-8 years). This does not work for solar projects that typically require longer-term loans of up to 15 years. In addition, the cost of financing in India is very high with interest rates going up to 12%. High interest rates reduce project viability. The banking industry will likely develop financial products or financing terms that address these challenges. In the meantime, financial assistance from the government in the form of long-term loans and lower interest rates could help the industry.

In order to successfully raise debt from banks, project developers are required to provide comprehensive and accurate Detailed Project Reports (DPRs) that form the basis for a strong business case for their projects. Many developers do not have prior experience in the solar sector and are unable to produce such reports at the standard and detail required by banks. Further, there is a reluctance on the part of the developers to invest in good feasibility studies of sites prior to bidding for the PPAs. A consolidated government body providing standards for project feasibility studies and DPRs would go a long way in allowing developers to be better prepared for executing their projects after obtaining their PPAs.

The pricing of Renewable Energy Certificates (RECs) is posing a challenge for the mechanism to be viable. The Central Electricity Regulatory Commission (CERC) has announced a fall in the prices of RECs from the year 2012. They will earn a forbearance price of INR13.69 per kWh and a floor price of INR9.88 per kWh as opposed to a forbearance price of INR17 per kWh and a floor price of INR12 per kWh available at present. The industry sees such a move as a signal that prices of RECs will consistently be reduced in the future, creating uncertainty on their price over time. This could see developers staying away from developing projects through the REC route. There is a need to introduce a policy change that would guarantee a long-term REC price-band, in order to make developers comfortable about this mechanism.

With limited projects under the NSM, there may be a lack of accurate information on the project parameters for benchmarking the success of the technology in India and deriving learnings for the future. There is a need to diligently benchmark projects during construction and post the date of completion, without any deviations. The government should set up a focused program to ensure this, in the same manner as projects are required to setup monitoring stations on-sight.

Reliable transmission infrastructure remains a significant problem for the industry as a whole. In large parts of the country, the necessary transmission network is not in place. In areas where the grid exists, efficiency is often poor and there can be high transmission losses. Significant policy corrections are needed if the industry is to tide over such bottlenecks. The lack of evacuation infrastructure is currently posing a significant challenge for projects nearing completion. In Gujarat, for example, the Gujarat Energy Transmission Corporation (GETCO) is creating delays in providing the right infrastructure. Their expertise and technology is not yet adequate to integrate solar into the grid. There needs to be a focused effort by the government to speed up the provisioning of the required grid infrastructure in order to ensure that projects are executed on time.

Competitive bidding of projects under the NSM has led to aggressive bidding by developers. Close to 50MW of PV projects have not been able to attain financial closure due to doubts over their viability. Many of the players are new and unknown and there is a danger that they have underestimated the risks in order to provide high discounts. Clearly, bank guarantees are not enough to discourage developers from being aggressive with their discounts. The MNRE should also include technical requirements into the pre-selection of developers to avoid this issue.

Solar projects require long term loans as the life span of the power plant runs over 25 years. Further, given the highly competitive tariffs arising out of the bidding process under the NSM, developers cannot afford to take on debt at the high interest rates prevalent in the economy. The government should provide financial assistance in the form of long-term loans at favourable interest rates for the industry to take off successfully.

Since large-scale solar project development is still new in India, government agencies are yet to get familiar with the technology. Often, relevant government departments are unsure about the permits and clearances that need to be provided for solar power plants. The issue is aggravated in the case of projects under the NSM as these are centrally funded projects that need to be implemented at the state level. A consolidated government body providing information on the permits and streamlining the allotment of clearances will allow developers to execute projects on time and avoid penalties.

For CSP projects in particular, there are only a few projects under the NSM and no history of any CSP deployment in the country. This leaves limited room for assessing the performance of the technology in Indian conditions. The government needs to support the development of demonstration and research projects in order to be able benchmark project performance.

There is very limited indigenous production of CSP technology. Even internationally, the technology remains in the hands of a select few, keeping the costs of the technology high. Special focus needs to be paid to this industry in order to ensure its balanced development along with PV. The government should consider absorbing "one-time technology costs" in projects to support large scale deployment of the technology. This will support indigenization of the technology and bring down costs.

The continuity and clarity on the future of the NSM policy is missing, particularly beyond the year 2013. The industry could benefit from a road map with the time lines for bidding. The allocation of projects for different phases, as well as different batches, should be announced in advance with clear timelines.

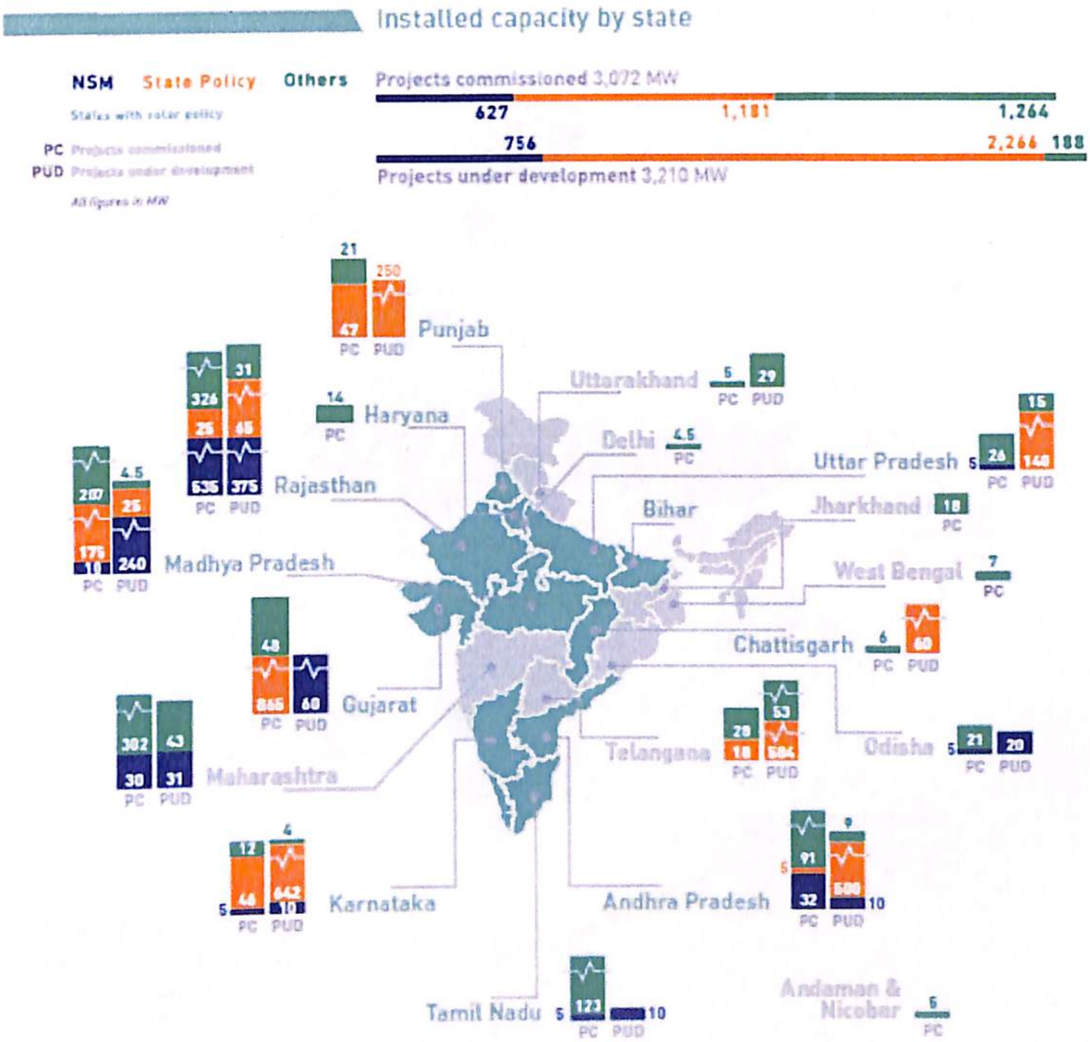
4.3 Conclusion

The fact that the euphoria over the NSM among the policy makers and the environmentalists is not echoed by prospective lenders clearly indicates that the mission carries significant risks. At the industry level, prospective NSM players face risks concerning data availability and data accuracy, bankability, inadequate support and transmission infrastructure, lack of policy clarity and continuity. The sobering fact here is that apart from the question of bankability which may be unique to the solar industry, other risks are common to all energy and infrastructure projects in India and one can hope that these issues will be addressed as the Indian industry matures. However, the pace of these improvements may not be in line with the needs of the industry, which is detrimental to attracting private investment.

At the national level, the strategic policy objectives of the NSM remain unclear. Is one of the strategic objectives to develop a globally competitive PV manufacturing industry in India? If that is the case, it is not necessary that a huge domestic demand for PV is created through the Renewable Purchase Obligations (RPOs), especially in the light of the fact that an artificially created PV market will not only come at the expense of subsidies but also displace alternative renewable energy sources such as biomass and small hydro power which are far cheaper. China, which currently accounts for about 60 percent of the world's PV manufacturing capacity, dependsalmost entirely on the export market to develop its domestic PV industry. Unless domestic content is mandated in the early phase of the NSM, Indian subsidies could go to imported components. On the other hand, domestic content requirements will make solar power more expensive than it already is.

The disproportionate focus on MW scale projects at a huge cost is unlikely to provide electricity to the rural poor. While MW scale plants are justified for CSP projects due to technological limitations, MW scale projects for PV excludes the deployment of small scale PV can be the key to rural electrification. In fact the largest advantage of PV systems is that they are small, portable and decentralized, attributes that can be a key to rural lighting solutions. The same holds true for commercial captive power solutions with, for example, businesses currently relying entirely on expensive power from diesel gen-sets or for telecommunication towers. On the other hand, installing grid-connected larger plants may be a necessary intermediate step to accelerate the implementation of the technology by reducing costs through a more rapid scalability.

When over INR 2,400 billion ($60 billion) is to be invested in creating and sustaining a solar industry, it is very important that India is clear about its industrial and strategic objectives. Large scale solar development is at its initial stages in the country. It is understood that the appropriate policy support from the government is crucial for the industry to successfully take off. Through the NSM, the government has exhibited a clear intention to do what it takes to ensure that solar power develops in a viable and sustainable manner. In order to successfully achieve this objective, it is crucial that the government goes the extra mile in ensuring that the aforesaid policy shortcomings are addressed in a constructive manner.



Project types

NSM

Target of 15 GW by 2022

Offtake by central government entities on reverse bidding basis

Financial support in the form of feed in tariffs or Viability Gap Funding or interest rate subvention

State policies

3.2 GW projects currently under development

Offtake by state government entities on reverse bidding basis

Bankability of state distribution companies major concern

Public sector

1 GW projects by public sector with offtake by central or state government entities

Viability gap funding of $167k per MW

Module/cell sourcing from within India

Private sale of power

Bilaterally negotiated projects with offtake by private consumers

Driven by commercial parity of solar power

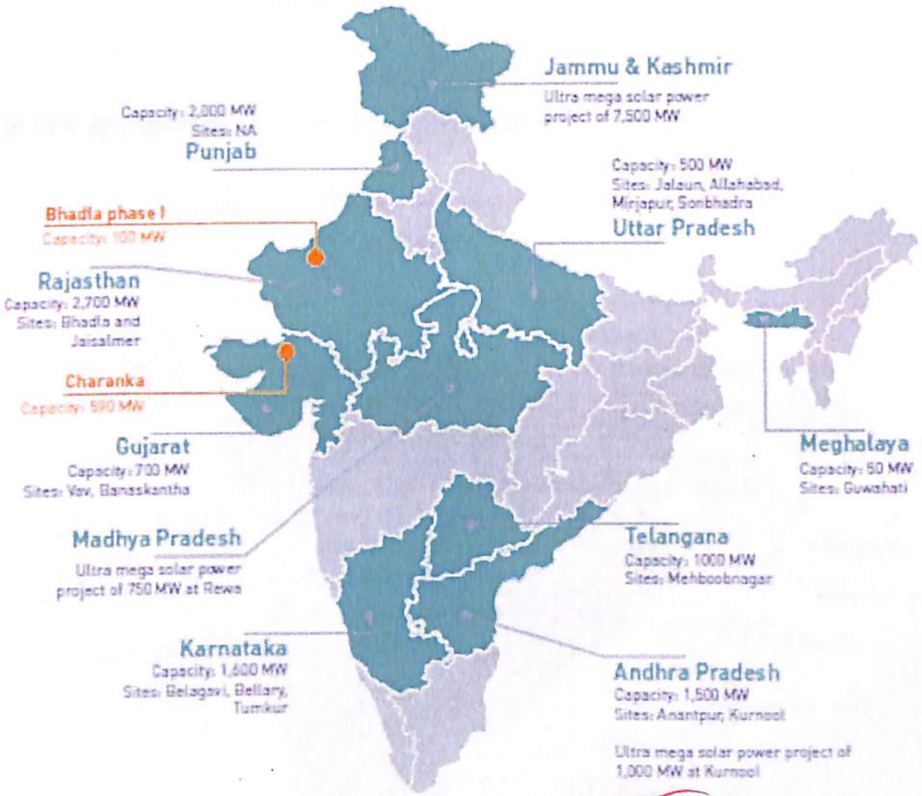
Unpredictable open access policies

Payment risk of private consumers

Positives **Negatives**

Solar parks

Government of India plans to set up 20 solar parks, each with a capacity of over 500 MW



Rooftop solar

Government target by 2022 **40 GW**

285 MW current installed capacity

$47bn estimated investment required

Customer types

Commercial & Industrial Customers

Driven by commercial parity of solar power

High upfront cost of ownership; long pay back period

Poor bankability of private consumers

Residential Customers

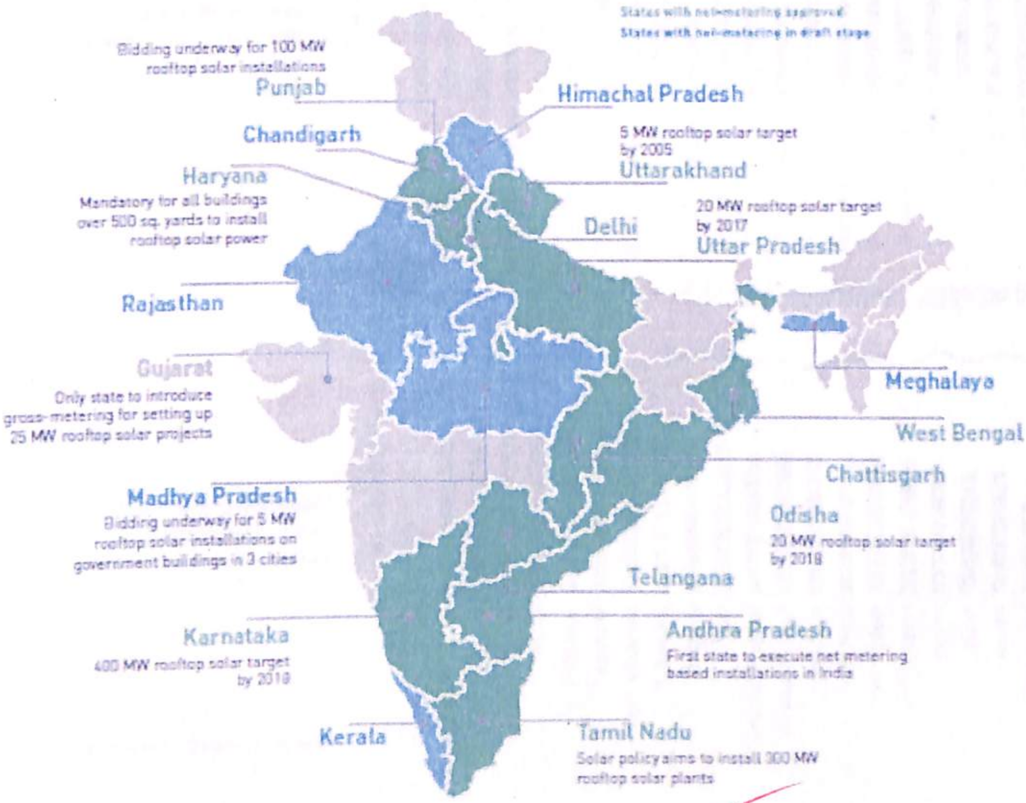
High cost of solar power vs residential grid tariffs

Poor customer affordability

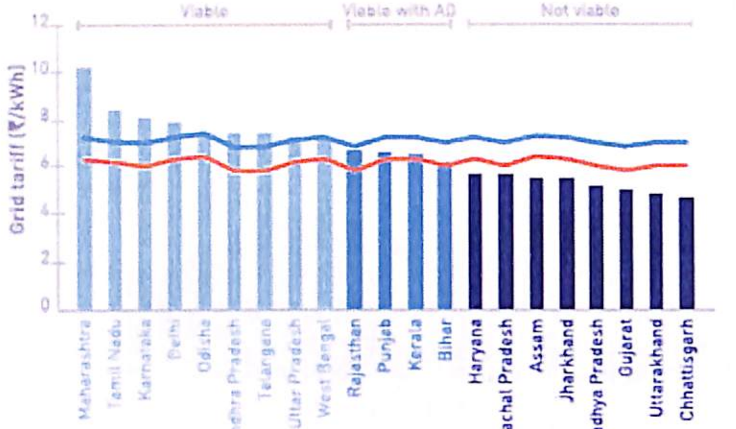
Poor supply of grid power in many areas

Positives **Negatives**

Rooftop policy by state

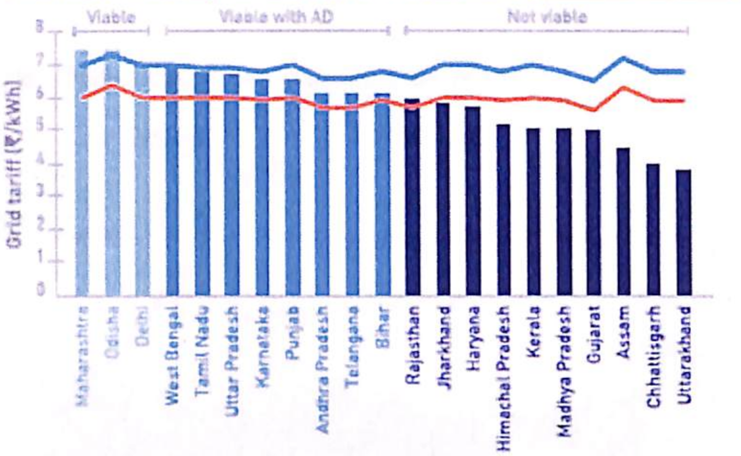


Financial viability for commercial customers



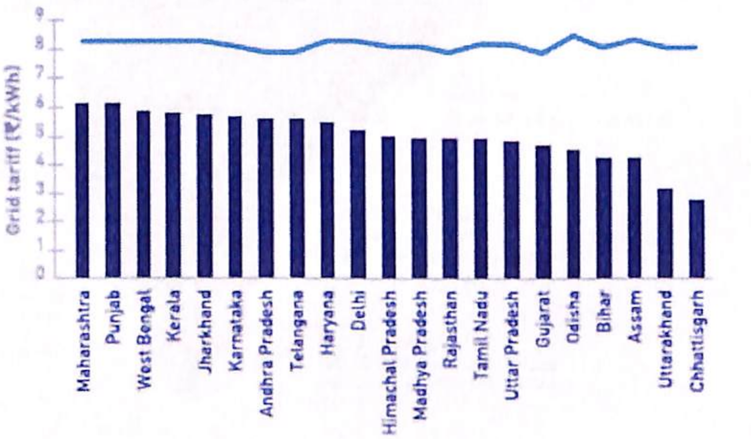
Solar power has achieved grid parity with commercial tariffs in nine states and in another four states with accelerated depreciation (AD) benefit

Financial viability for industrial customers



Solar power has achieved grid parity with industrial tariffs in three states and in another eight states with AD benefit

Financial viability for residential customers



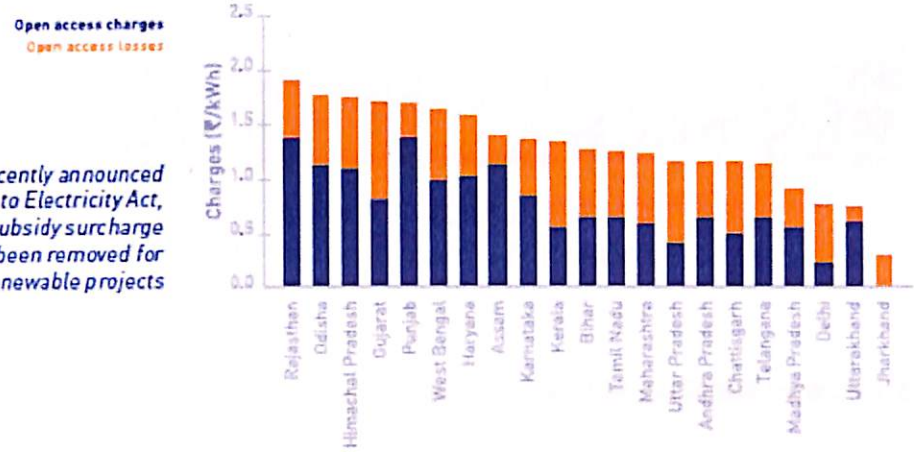
Residential tariffs in India are highly subsidized and below the cost of rooftop solar power

Source: BRIDGE TO INDIA research

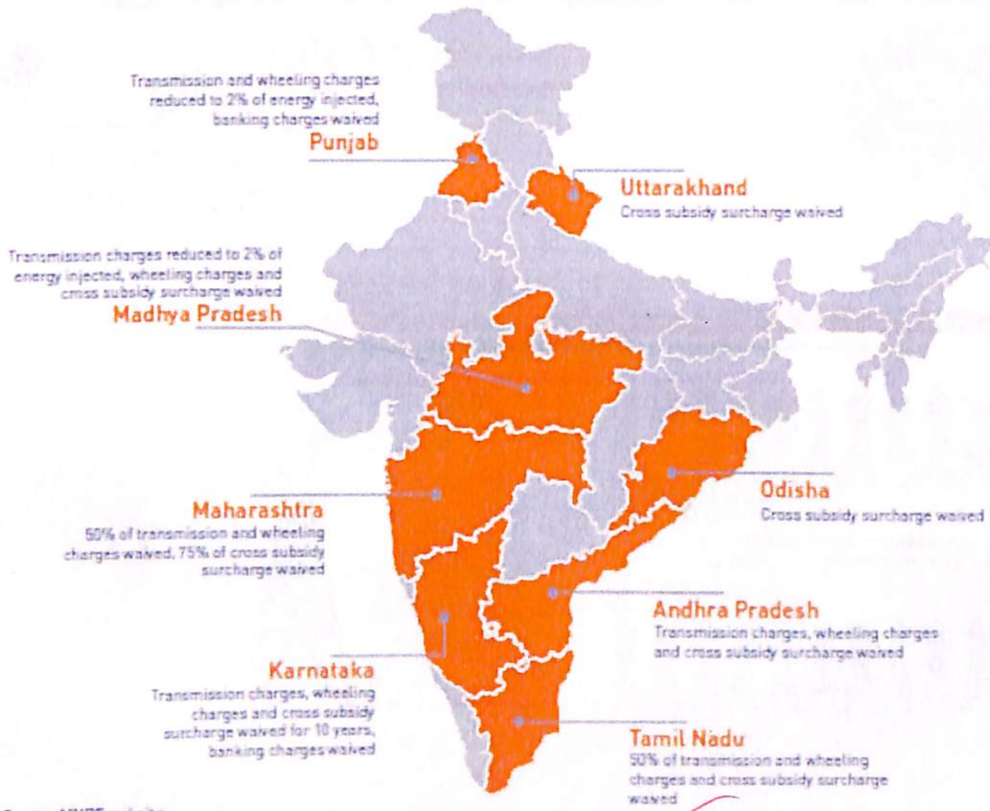
Open access regulations

Open access charges and losses

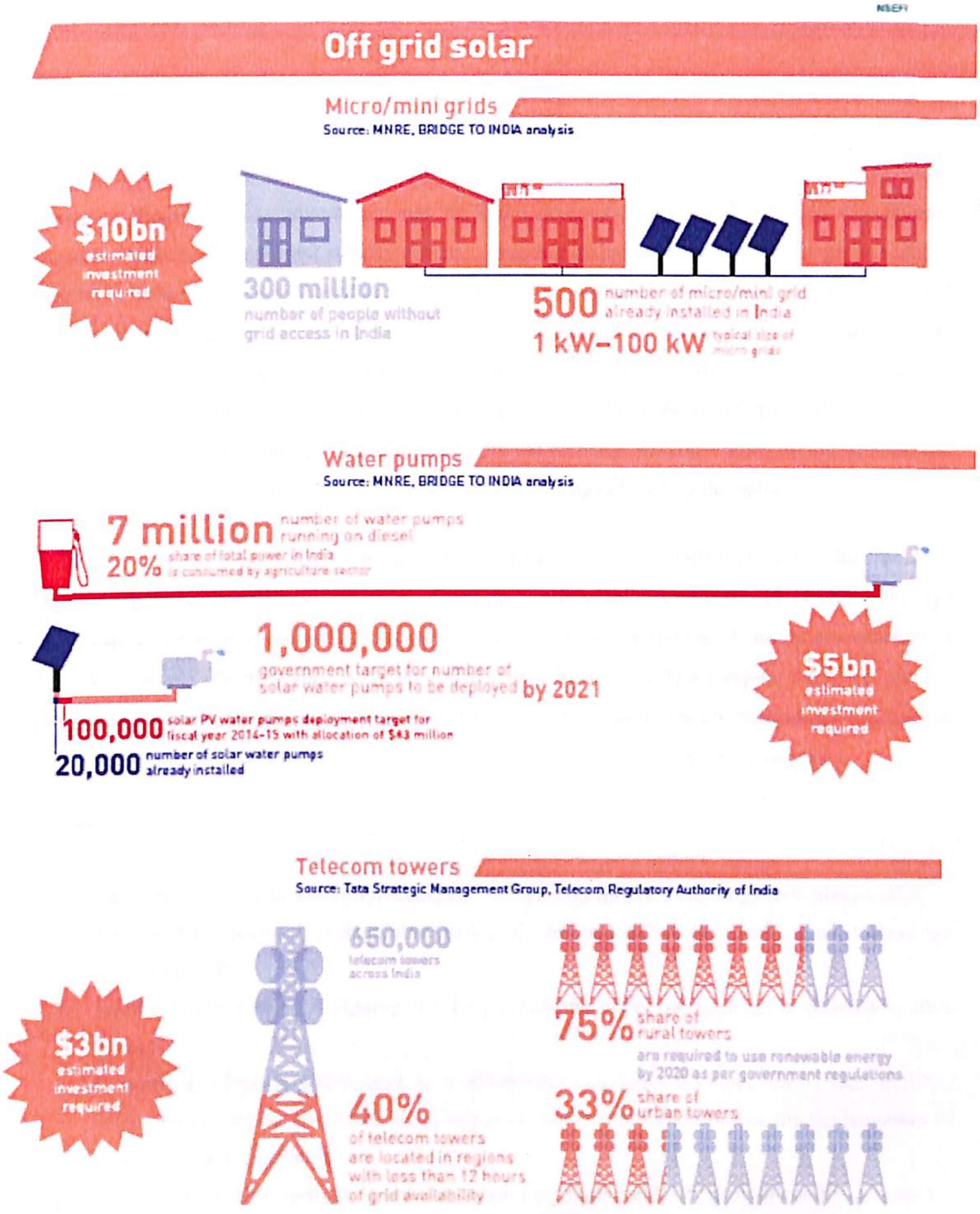
In the recently announced amendments to Electricity Act, cross subsidy surcharge has been removed for renewable projects



Open access incentives for solar projects



Source: MNRE website, BRIDGE TO INDIA research



Captive power generation is plagued with some issues. The main idea behind setting up solar based captive power plants was to get uninterrupted power supply and reduce the diesel cost. Industrial users who have the required resources to set up their own power plants for internal consumption can put up SPV captive power plant. But, there are certain issues in setting up solar based captive power plants.

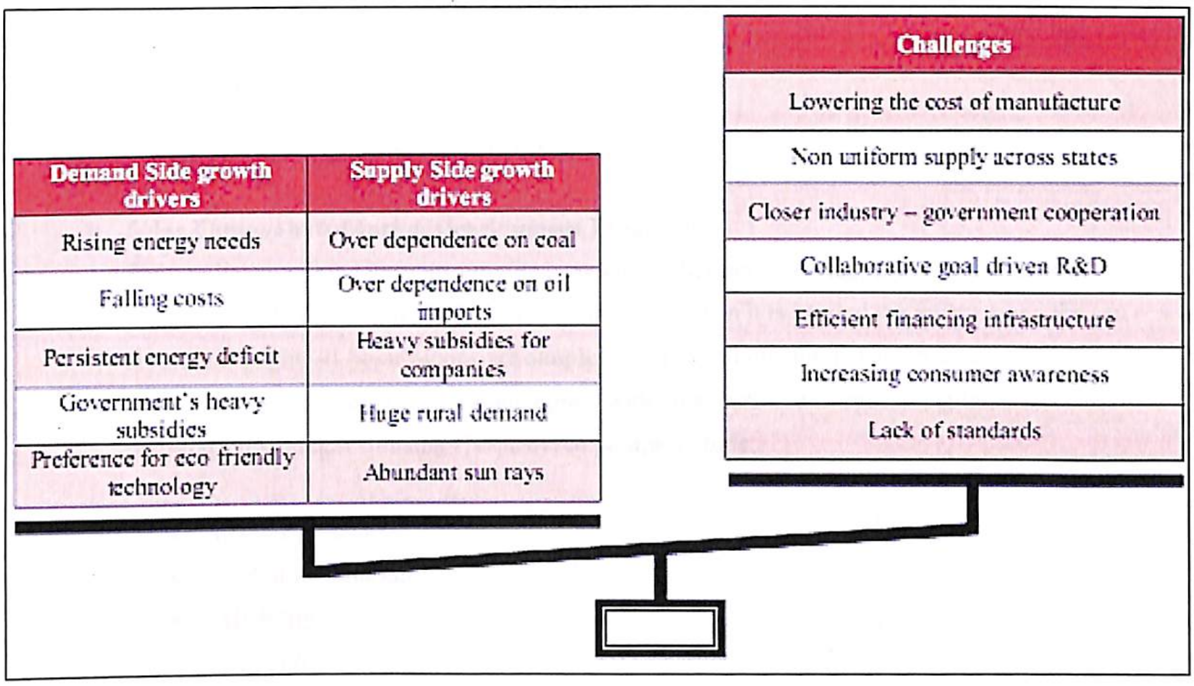
Currently Research and Development (R&D) in this sector is on a slow track due to lack of collaborative and goal driven efforts on this front. Technological innovations that improve the efficiency of current solar energy systems are necessary to exploit the solar energy potential in India. In order to facilitate this, government has to frame comprehensive R&D schemes and provide incentives along with the current subsidy schemes. Another major factor restricting the growth of this sector is the lack of standards, resulting in the fragmentation of the market among manufacturers and suppliers. Standardization of systems will lead to rationalization of cost as companies can invest in R&D and newer technologies to meet common specifications. Facilitating closer industry – government cooperation and increasing consumer awareness about the benefits of solar energy are some of the other main challenges currently faced by the industry. Exhibit 4 sums up the demand and supply drivers for the solar industry, in addition to the challenges faced by the industry.

The solar industry in India is still in its nascent stage and faces many challenges such as high costs of solar power generation. In India, cost of solar electricity produced on-grid is Rs. 18.44/unit. This high cost is mainly due to dependence on imports for silicon and solar wafers used for the manufacture of solar cells – about 80% of which comes through imports. Solar projects are capital intensive, and the lack of an effective financing infrastructure for these projects is another major factor impeding growth in this sector. Another challenge faced today is the disparity in solar potential across states.

Regulatory

- **The lack of closer industry-government** cooperation for the technology to achieve scale.
- **The need for focused**, collaborative and goals driven R&D to help India attain technology leadership in PV.
- **Land allotment & PPA signing** is a long procedure under the Generation Based Incentive scheme.
- **Complexity of subsidy structure & involvement** of too many agencies like MNRE, IREDA, SNA, and electricity board and electricity regulatory commission makes the development of solar PV projects difficult.
- **Training and development of human resources** to drive industry growth and PV adoption
- **The need for intra-industry cooperation** in expanding the PV supply chain, in technical information sharing through conferences and workshops, in collaborating with BOS (balance of systems) manufacturers and in gathering and publishing accurate market data, trends and projections.
- **The need to build consumer awareness** about the technology, its economics and right usage.

➤ **Funding of initiatives** like National Solar Mission is a constraint given India's inadequate financing capabilities. The finance ministry has explicitly raised concerns about funding an ambitious scheme like NSM.



CHAPTER -5

Conclusion Observation

5.1 Solution

Indian Renewable Development Agency (IREDA) initiatives:

- **Solar Photovoltaic Market Development Programme:**

  Photovoltaic pumping systems provide a welcome alternative to fuel burning generators or hand pumps. They provide the most water precisely when it is needed the most - when the sun shines the brightest! Solar pumps are simple to install and maintain. The smallest systems can be installed by one person in a couple hours, with no experience or special equipment required. Advantages of using PV-powered pumps include:

  - low maintenance
  - ease of installation
  - reliability
  - scalability

  A SPV Water Pumping System consist of a DC / AC surface mounted / submersible / floating motor pump set, electronics if any, interconnect cables, an On-Off switch and a PV array mounted on a suitable structure with a provision of tracking.

  The programme is open to all categories of users including individuals, farmers, Non-Governmental Organisations, Cooperative Societies, Corporate Bodies, Autonomous Institutions, Research Organisations, Banks, State/Central Government agencies etc. subject to condition that the beneficiaries give an undertaking to the implementing agency that they do not own a SPV water pumping system and the present system would be utilized for water lifting applications.

- **Clean Development Mechanism**

  Under the Kyoto Protocol, the CDM allows for projects in developing countries that result in a reduction of GHG emissions to earn certified emission reduction credits (CERs).8 CERs are carbon credits issued under the CDM that each represent 1 ton of carbon dioxide equivalent. CERs can be traded or sold and eventually used by industrialized countries that have ratified the Kyoto Protocol to meet parts of their emissions reduction targets. To qualify to receive CERs, the project must first be approved by the Designated National Authorities of the project host country, and then a public registration and issuance process with the UNFCCC must be completed. The additional funds generated through the sale or trade of CERs can improve the financial viability of clean energy projects.

Although there has been some criticism of the CDM process (e.g., the additional financial and technical eriteria necessary or the long and costly project certification process), India has been at the forefront of receiving CDM benefits. As of January 2010, 1,551 Indian projects have been granted host country approvals. The projects are in the fields of energy efficiency, fuel switching, industrial processes, municipal solid waste (MSW), and renewable energy. Pending registration by the CDM executive board, India will generate a total of 627 million CERs before the end of 2012. At a price of INR 500 (USD 10) per CER, they would be worth INR 313.5 billion (USD 6.27 billion). In 2009, 478 of the world total 2,011 registered projects were generated by India. Only China had registered more.9 As of September 2010, India had 532 registered CDM projects, 426 of which were in the energy sector, with the overwhelming majority comprised of renewable energy projects.

Although India's solar market appears well suited for local players, it's currently open to global players as well. Indeed, global firms that tailor their broad expertise to serve unique local needs in a frugal way could actually extract significant value. At the same time, local players can bridge capability gaps by striking appropriate alliances, or by recruiting strong teams or individuals.

- **POLICY MEASURES IN VAGUE:**

A host of fiscal incentives and facilities are available to both manufacturers and users of solar energy systems, which include:

- 100% accelerated depreciation for tax purposes in the first year of the installation of projects/systems.
- No excise duty on manufacture of most of the finished products.
- Low import tariffs for capital equipment and most of the materials and components.
- Soft loans to manufacturers and users for commercial and near commercial technologies.
- Five-year tax holiday for power generation projects.
- Remunerative price under alternate power purchase policy by State Government for the power generated through renewable energy systems, fed to the grid by private sector.

- Facility for Banking and wheeling of power.

The EPC market will consolidate, with in-house EPC arms gaining share

As in most mature sectors of the power industry, integrated utilities and larger independent developers will eventually build their own internal EPC capabilities to improve project viability and returns during the solar growth phase. For standalone EPC firms, this means a shrinking customer base. To stay viable, they will need either to embrace forward integration into developing generation capabilities or focus on the demand for captive projects, which will form a smaller part of the market. The largest independent EPC firms that specialize in project implementation will be well-positioned to enter the generation space—a low-risk option, as operational complexity and manpower requirements are relatively low for solar projects. For smaller EPC firms struggling to find low-cost financing, the development space may be less attractive, and independent captive projects set up by private industries may be the best way to maintain revenues. To generate reasonable returns, these players will have to aggregate demand from multiple projects to optimize scale economies.

Size will enable manufacturing localization

On the manufacturing side, there may be opportunities for players to establish local capacity after the industry matures in India and capacity consolidation occurs globally. Such a move could also provide a base from which to export to other locations in South Asia. This strategy is a challenge now, as inefficient infrastructure and supply chains, high energy costs, and inconsistent regulatory support make competing with imports difficult. But as local demand increases, the negative factors may be reversed, setting the stage for a resurgence of manufacturing opportunities.

Prizes at Stake

India's nascent solar-power market has the potential to grow to include a handful of billion-dollar companies across the value chain by 2020. Making an effort to understand local conditions and adapting operating models accordingly will give early adopters a major advantage. Two to three large utilities will likely dominate the developer space. In addition, a couple of independent solar players could also emerge from the competitive growth phase to build billion-dollar businesses. Standalone EPC may not be a scale opportunity by 2020, as larger players extract value through in-house EPC arms. Niche market areas could continue to enable profitable EPC businesses. A few multi-hundred-million-dollar opportunities could also be created in BoS by current global leaders and some local companies.

Three Elements to Winning in Solar

Global procurement is unlikely to remain a differentiator as more players achieve scale and become adept at it. Creating value in the Indian market, therefore, requires efficient execution, financing, and localization.

Execution

Given the substantial front-end costs of solar projects, delays can wreak havoc on profitability. Even under the most suitable conditions, managing power projects in India is tough—projects are often slowed by infrastructure issues and unreliable local vendors. In addition, stakeholder management at the national, state, and local levels often stands in the way of ensuring efficient project execution and sustained operation. Therefore, building a team of talented project managers and experienced trouble-shooters will be crucial.

Financing

Innovative means of financing will create win-win situations for all stakeholders and drive significant upfront value for project developers. Differentiated models could include teaming with technology providers from low-cost financing countries—Japan, for example—or with consumers seeking sustainability benefits or tax credits. A pool of low-cost project equity developed from retail or other cost sources can add up to a distinct advantage.

Localization

Local design and engineering will play a major role in India's solar market. Inverter and balance-of-system designs that incorporate local requirements and eliminate unnecessary elements that are geared more toward global markets can generate significant benefits. Eventually, global players will see the benefits of manufacturing locally and specifically for the Indian market. Competition from local players could further drive down systems costs.

5.2 An Open Market

Although India's solar market appears well suited for local players, it's currently open to global players as well. Indeed, global firms that tailor their broad expertise to serve unique local needs in a frugal way could actually extract significant value. At the same time, local players can bridge capability gaps by striking appropriate alliances, or by recruiting strong teams or individuals. A partnership of foreign technology and local EPC can help both parties climb up the steep learning curve fast, but mechanisms will need to be put in place to ensure that the risks and upsides are shared equally. Both parties involved will need a long-term view of the market, with lessons learned from initial projects built into subsequent ones.

Local or global, the leaders in this market will likely be those that get in the thick of things from the beginning, as the cost of entry rises significantly with grid parity nearing. A well-thought-out plan to make an immediate impact through short-term portfolio building and to build a growing advantage through planning for long-term scalability will be crucial tools for tapping into the multi-billion-dollar potential of India's solar market.
Longer-term value will come from efficiently executed projects, low-cost (and often innovative) financing, and localization. Local players will dominate the downstream solar industry.-In contrast to the global nature of the upstream industry (solar modules), we expect local, or at least well-localized players to dominate the downstream side in the initial years; this includes project development, installation, and distribution. Given sufficient time to fine-tune their business models, global players entering India for the first time will be able to prosper. Entering and learning the ropes early will be important for both local and global players.

While some players have already begun preparing, most have yet to place a bet on solar, given the uncertainties within the sector. Success in solar energy will require a long-term commitment and a sound understanding of local dynamics. The study concludes that though JNNSM first phase could not perform up to the expectations, the state level policies have been doing well to fill the gap. The recently announced JNNSM Phase II target composition of 3600 MW for central and 5400 MW for states, changes in policies and schemes in light of the experience of Phase I, and development of 54 solar cities are likely to impact the National Solar Mission performance and enhance the overall visibility of solar-based electricity generation and utilization.

The last decade has seen a sea change in India's electricity sector, from being 10th largest in the world to 5th largest now. The industry is moving away from negotiated & guaranteed arrangements of the past era, to more open market and performance based competition. The approach now is more reinvestment, although the legacy problems of cross-subsidies, losses, and rural access remain a challenge. The private sector has emerged as a key player in both conventional and renewable power, and increasingly in other parts of the business. There is still a long way to go.

The significant achievements of the power sector all sit atop a distribution business that depends on subsidies and carries growing uncovered financial losses. The losses are said to have ballooned to over Rs 1 lakhs crores and could get worse as we import higher proportion of coal and as global com - modify prices rise. The resulting uncovered losses will impact the consumers and investors unless vigorous distribution reforms are pursued. An encouraging development is the larger number of private bidders showing interest in distribution.

The recent DF (Distribution Franchisee) tenders have attracted 20 to 30 bidders, and many bring experience from other industries such as power equipment, construction, and telecoms and IT. This helps seed in new technologies and strategies, such as the use of smart meters, targeting tools and CRM (Customer Relationship Management), shared services, standardisation, multi-skilling, and other techniques that can upgrade management of distribution businesses.

The size of the distribution opportunity is very large; India could easily have over 50-60 specialist DF companies even at an enhanced size, that will attract more investment and innovation.

BIBLIOGRAPHY

BOOKS

Khan B.H, Non- Conventional Energy Resources, The McGraw Hill, 2009Prasanna Chandra, Projects Planning, Analysis, Selection, Financing, Implementation and Review, Tata McGraw-Hill, 2002

WEBSITES
www.mnes.nic.in
www.kredl.kar.nic.in
www.solar4power.com
www.solarbuzz.com
www.cercind.gov.in
www.kerc.org

DRAFTS
Jawaharlal Nehru National Solar Mission
Implementation of Solar Photovoltaic Programme – MNRE (Solar Photovoltaic group)

- IEA, World Energy Outlook, International Energy Agency, Paris, France, 2011.
- GEA, Global Energy Assessment: Toward a Sustainable Future, Cambridge University Press, Cambridge, UK, 2012.
- REN21, "Renewables 2012," Global Status Report, REN21 Secretariat, Paris, France, 2012. View at Google Scholar
- IPCC, "Special Report on Renewable Energy Sources and Climate Change Mitigation," Cambridge University Press, Cambridge, UK, 2007.
- IEA, Energy Technology Perspectives, International Energy Agency, Paris, France, 2008.
- "Solar radiant Energy over India," India Meteorological Department, Ministry of Earth Sciences, Government of India, 2009.
- M. Pipattanasomporn, A study of remote area internet access with embedded power generation [Ph.D. thesis], Virginia Polytechnic Institute and State University, Alexandria, VA, USA, 2004.
- NREL, http://www.nrel.gov/international/ra_india.html, 2010.
  http://mnre.gov.in, 2012.
- GOI, "National Action Plan on Climate Change," Prime Minister's Council on Climate Change, Government of India (GOI), New Delhi, India, 2008,

http://www.forumofregulators.gov.in/Data/study/TOR_Incentive%20structure%20for%20fulfillment%20of%20RPO.pdf.

- M. Ringel, "Fostering the use of renewable energies in the European Union: the race between feed-in tariffs and green certificates," Renewable Energy, vol. 31, no. 1, pp. 1–17, 2006. View at Publisher · View at Google Scholar · View at Scopus
- P. Menanteau, D. Finon, and M. L. Lamy, "Prices versus quantities: choosing policies for promoting the development of renewable energy," Energy Policy, vol. 31, no. 8, pp. 799–812, 2003. View at Publisher · View at Google Scholar · View at Scopus
- Global Trends in Renewable Energy Investment, Frankfurt School—UNEP Collaborating Centre for Climate & Sustainable Energy Finance, 2012.
- http://www.mnre.gov.in/information/solar-rpo/, 2013.
- WISE, "Achieving 12% green electricity by 2017," Tech. Rep., World Institute of Sustainable Energy, Pune, India, 2010. View at Google Scholar
- MNRE, Jawaharlal Nehru National Solar Mission (JNNSM), Ministry of New and Renewable Energy (MNRE), Government of India, New Delhi, India, 2010, http://www.mnre.gov.in/file-manager/UserFiles/mission_document_JNNSM.pdf.
- http://mnre.gov.in/file-manager/UserFiles/draft-jnnsmpd-2.pdf, 2013.
- http://www.pv-magazine.com/news/details/beitrag/india-identifies-54-solar-cities-releases-jnnsm-figures_100009617/#axzz2J5UVafsH, 2013.
- Singh, "Economics, regulation and implementation strategy for renewable energy certificates in India," India Infrastructure Report, Infrastructure Development in a Low Carbon Economy, Oxford University Press, New Delhi, India, 2010. View at Google Scholar
- Singh, "A market for renewable energy credits in the Indian power sector," Renewable and Sustainable Energy Reviews, vol. 13, no. 3, pp. 643–652, 2009. View at Publisher · View at Google Scholar · View at Scopus
- MNRE, "Report on development of conceptual framework for renewable energy certificate mechanism for India," Tech. Rep., Ministry of New and Renewable Energy (MNRE), New Delhi, India, 2009, Prepared by ABPS Infrastructure Advisory Private Limited. View at Google Scholar

- M. Goyal and R. Jha, "Introduction of renewable energy certificate in the Indian scenario," Renewable and Sustainable Energy Reviews, vol. 13, no. 6-7, pp. 1395–1405, 2009. View at Publisher · View at Google Scholar · View at Scopus
- MNRE, MNRE, Government of India (GoI), New Delhi, India, http://mnre.gov.in/file-manager/UserFiles/solar-rpo.pdf, 2012.
- http://mnre.gov.in/file-manager/UserFiles/september_month_2012_rerf.pdf, 2013.
- http://geda.gujarat.gov.in/policy_files/GERC%20order%20Solar%20Energy.pdf, 2012.
- http://bridgetoindia.com/archive/policy/Andhra-Pradesh-Solar-Policy-2012-Abstract.pdf, 2013.
- http://mnre.gov.in/information/renewable-energy-regulatory-framework, 2013.
- http://www.dlr.de/tt/desktopdefault.aspx/tabid-2893/httpstatus-404/, 2011.
- MNRE, MNRE, Government of India (GoI), New Delhi, India, http://mnre.gov.in/file-manager/UserFiles/Solar%20RPO/state-wise-solar-RPO-targets.pdf, 2012.
- http://www.mnre.gov.in/file-manager/UserFiles/mission_document_JNNSM.pdf, 2013.
- http://mnre.gov.in/file-manager/UserFiles/Solar%20RPO/solar-RPO-requirement-by-2022.pdf, 2013.
- http://mnre.gov.in/file-manager/UserFiles/Solar%20RPO/State%20-%20wise%20solar%20installed%20capacity%20break-up.xlsx, 2013.
- http://www.iexindia.com/Reports/RECData.aspx, 2013.