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# RECENT TRENDS/DEVELOPMENTS IN SOLAR ENERGY SECTOR IN INDIA

# EMERGING PHOTOVOLTAIC TECHNOLOGY

By

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A DISSERTATION REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR

**MBA in Power Management**

OF

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CENTRE FOR CONTINUING EDUCATION

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# EN TERPRISES

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Subject: -Willingness for Guiding Dissertation of Abhishek kumar verma (Registration No.500066176).

Dear Sir,

Abhishek kumar verma is registered for Power Management, with the University of Petroleum & Energy Studies, Dehradun in 2018-20 batch.

I hereby give my acceptance to guide the above student through the Dissertation work '**Recent Trends/Developments In Solar Energy Sector IN INDIA'**, which is a mandatory requirement for the award of EMBA degree.

Thanking You
Yours Sincerely
Sunil Kumar
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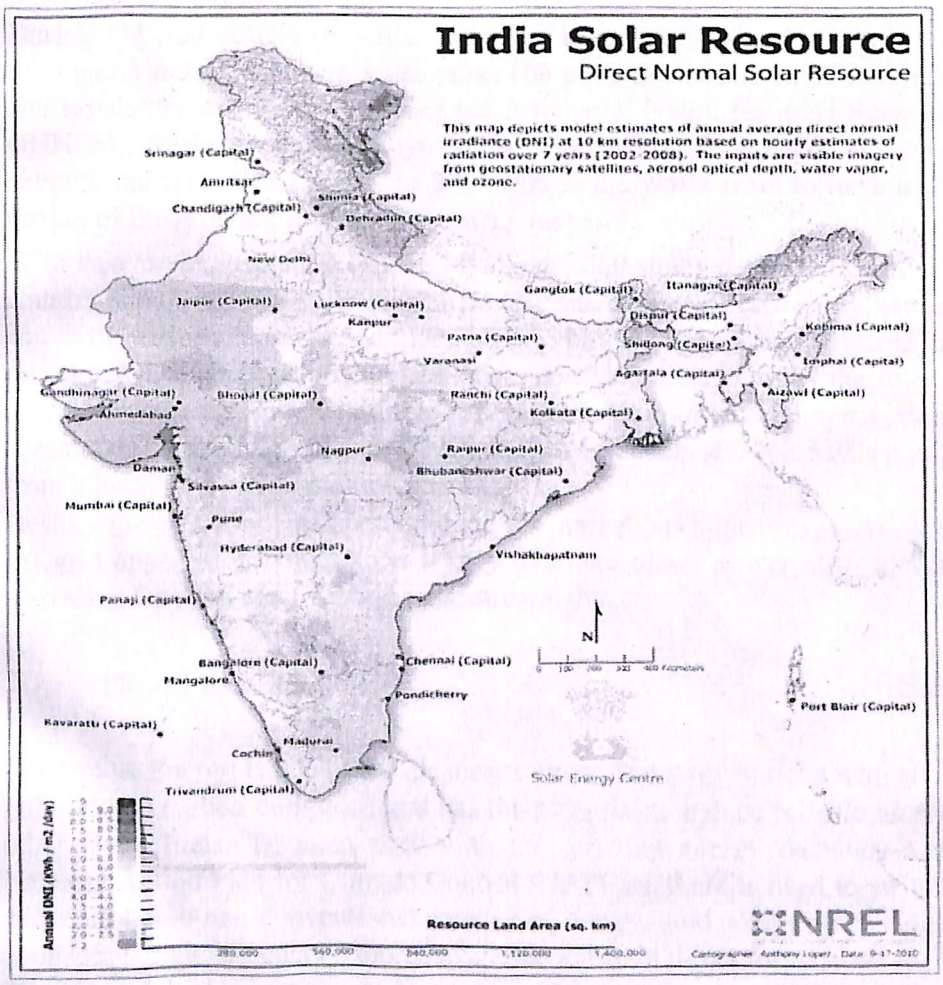
## ABSTRACT

Renewable energy is one of the cleanest sources of energy options with almost no pollution or carbon emissions and has the potential to significantly reduce reliance on coal and Other fossil fuels. By expanding renewable energy, world can improve air quality, reduce global warming emissions, create new industries and jobs, and move world towards a cleaner, safer, and affordable energy future.

India meets close to 65% of its electricity needs from fossil fuels and is expected to continue doing so in the foreseeable future. At this juncture, Renewable Energy (RE) is being seen as one of the important means to meet the growing power needs of the economy while enhancing energy security through diversification of fuel sources and providing opportunities for mitigating greenhouse gas emissions.

After persistent efforts, the share of renewable energy which stood at a meager 2% of installed capacity in 2003 stands at nearly 12.95% with a total installed capacity of solar energy 33791.74 IVIWs as of Dec 2014.




The solar power sector offers tremendous opportunities for investing companies due to the huge size of the market, growth untapped potential and returns available on capital.

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Industrialization, urbanization, population growth, economic growth, improvement in per capita consumption of electricity, depletion of coal reserve, increasing import of coal, crude Oil and other energy sources and the rising concern over climate change have put India in a critical position

The key drivers for solar renewable energy the following:

1. The demand-supply gap, especially as population increases
2. A large untapped potential
3. Concern for the environment
4. The need to strengthen India's energy security
5. Pressure on high-emission industry sectors from their shareholders
6. A viable solution for rural electrification

## 1. INRODUCTION:-

During the past couple of years, India has emerged as an attractive investment destination for solar power developers. The government has taken several policy and regulatory initiatives including the Jawaharlal Nehru National Solar Mission (JNNSM), for large scale deployment of solar energy. As a result of such policy support and incentives, investors from around the world want to have a share of the pie of the growing Indian solar energy industry.

With an average insolation of 4-7kwh/m2 and 300 sunny days the potential of our country stands at 5000 trillion kilowatt of clean energy, if efficiently harnessed it can easily reduce our energy deficit scenario but had been long neglected in wake of huge investment needed and lack of supportive policies, finally the solar power is coming of the age with help of various technological improvement and prevalence of abetting policies. The solar power stands at 3063 MWs moving up from a mere 35 MWs just a few years ago.

Besides the grid connected potential the PV market has huge untapped potential in off grid application where soon it may overtake diesel power, also it would be providing for rural electrification and street lights.

## 2. PROBLEM DOMAIN:-

Renewable Energy is one of the cleanest sources of energy options with almost no pollution no carbon emissions and has the potential to reduce reliable on coal and other fossil fuels. To keep pace with the growing energy demands and as a National Action Plan for Climate Control (NAPCC), there is need to switch from conventional to non-conventional sources of energy. And solar energy is the most abundant permanent energy source available to use in direct form.

But as the initial costs of setting up solar PV project is very high and state-wise policies are still not formulated, investors are not willing to set up plants. In order to achieve grid parity there is a need of grid connectivity of solar PV projects but there are technical and financial barriers faced by developers in this regards. Some problems faced by Solar PV plants developers as:• Land Scarcity

- Payment Security Mechanism

- Regulatory Frameworks
- Lack of Technology
- Slow Progress Production
- Solar Latent Potential

3. SOLUTION DOMAIN: -

India has a great potential to generate electricity from solar energy and the country is on course to emerge as solar energy hub. The techno-commercial potential of photovoltaic in India is enormous. With GDP growing, the energy 'gap' between supply and demand will only widen. Solar PV is a renewable energy resource capable of bridging this 'gap'.

Most parts of India have 250-300 sunny days in a year, which is equivalent to over 5000 trillion kWh per year more than India's total energy consumption per year. Average solar incidence stands at a robust 4-7kWh/sq. meter/day.

India already has the world's best solar resources and can position itself to be global leader in Solar PV. To meet energy demands, the government has approved the Jawaharlal Nehru National Solar Mission (JNNSM), aimed at generating 20GW by 2022. But now it is revised to IOOGW by 2022. JNNSM, a major initiative of Govt of India, has set itself a goal of creating an enabling policy framework.

- National Solar Mission by Govt of India; IOOGW power by 2022
- Solar PV and Thermal Technology
- Solar Park Development by States
- Incentives for Promoting Solar Projects for Developers • State Transmission Grid Connectivity
- Enabling Frameworks for growth of Solar Energy Sector

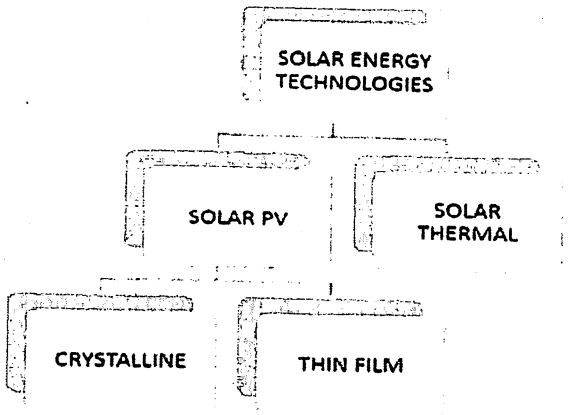
4. SYSTEM DOMAIN:-

India is located in the equatorial sun belt of the Earth, thereby receiving abundant radiant energy from the Sun. In most parts of India, clear sunny weather is experienced 250-300 days a year. The average global radiation varies from 1600 - 2200 kWh/m , which is comparable with radiation received in the tropical and subtropical regions. The equivalent energy potential is about 6,000 million GWh of energy per year.

Solar Energy Technologies:

Mainly solar energy technology used is two types:

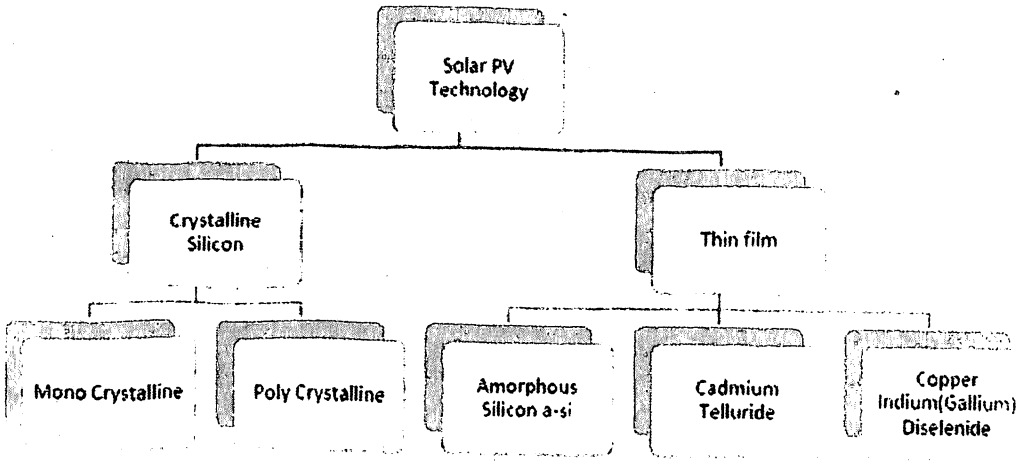
I. Solar PV Energy Technology
2. Solar Thermal Energy Technology




The solar PV is the direct conservation of Sun's radiation into Direct Current (DC). Solar PV systems shall be designed with either mono/poly crystalline silicon modules or using thin film photovoltaic cells or any other superior technology having higher efficiency.

Three key elements in a solar cell form the basis of their manufacturing technology:

- First is the semiconductor, which absorbs light and converts it into electronhole pairs.
- Second is the semiconductor junction, which separates the photo-generated carriers ( electrons and holes), and
- Third are the contacts on the front and back of the cell that allow current to flow to the external circuit.




**Crystalline Technology:**

Crystalline silicon (c-Si) has been used as the light-absorbing semiconductor in most solar cells, even though it is a relatively poor absorber of light and requires a considerable thickness (several hundred microns) of material.

**Mono crystalline**: produced by slicing wafers (up to 150mm diameter and 350 microns thick) from a high-purity single crystal

Poly crystalline silicon is made by sawing a cast block of silicon first into bars and then wafers. The main trend in crystalline silicon cell manufacture is toward multi crystalline technology. Thin Film Technology:

The materials costs are significantly reduced. The thin film semiconductor layers are deposited on to either coated glass or stainless steel sheet.

Amorphous silicon is the well-developed of thin film technologies. Disadvantage of such cells is suffered from significant degradation in their power output (in the range of 15-35%) when exposed to sun.

5. APPLICATION DOMAIN:-

Harnessing of non polluting renewable energy resources to control green house gases (GHG) is receiving impetus from the Government of India. The solar mission, which is part of the NAPCC has been set up to promote the development and use of solar energy for power generation and other uses. The solar photovoltaic device systems for power generation had been deployed in the various parts in the country for electrification where grid connectivity is either not feasible or not cost effective. With the downward trend in the cost of solar energy and appreciation for the need for development of solar power, solar power projects have recently been implemented. A significant part of the large potential of solar energy photovoltaic power systems of varying sizes and affordability coupled with ensuring adequate return on investment.

There are various applications where solar energy has significant role:

- Solar Rooftop system
- Solar Agriculture water pumping
- Solar water Heater
- Solar street lights
- Solar cooker
- Un-electrified off grid village connectivity
- Climate Control project

6. FEASIBIALITY STUDY:-

6.1 Introduction to feasibility study

Solar Photovoltaic technology in one of the first among several renewable energy technologies that have been adopted worldwide for meeting the basic needs of electricity particularly in remote areas. The PV system electric power is of particular value when it coincides with the peak demand. Solar Photovoltaic systems can increases the reliability of the system to which they are connected, can reduce transmission and distribution losses as they generates the electricity close to the consumption point.

6.2 Purpose

A large untapped potential of solar energy is available in India. Most parts of India receive solar energy around 5k Wh/m per day over around 300 clear sunny days per annum. Even if 1% of this land is used to harness solar energy at an overall efficiency of 10%, as much as 46700 kWh/year of electricity can be generated. The main objective of design of the system is to improve the quality of power for a given load factor and to achieve this in an optimal way. This depends on population, demand and proximity to grid.

6.3 Economic Feasibility

The project economic are based on the initial investment, which is partially offset by a rebate. Solar energy is clean energy, no pollution. The Government of India is also very keen to provide subsidies and other incentives and tax rebate to solar project developers. The initial cost Of photovoltaic is based on, at a minimum, following components:

- Solar Array/panels
- Mounting Hardware
- Inverters
- Conduit & Wiring
- Panel installation
- Metering

6.4 Technical Feasibility

To generate solar power, photovoltaic cells or solar cell, need to be exposed to sunlight. Photons contain various amount of energy corresponding to the different wavelengths of solar spectrum. When photons strike a photovoltaic cell, they may be reflected, pass right through or to be absorbed. When enough sunlight is absorbed by the semiconductor material, an electric current is flow in the circuit. Major components of Solar Projects are:

- Solar PV Modules
- Solar Cells
- Solar Tracking System
- Inverters
- Grid Connection Interface

6.5 Behavioral Feasibility

Optimal performance of a particular Solar Photovoltaic systems depends upon the fact that how reliable are the different components that are used in that system. If the components used in the system are easily replaceable than this could have positive impact on the system performance. For improving the behaviouralperformance of SPV system selected components should be reliable

and easily replaceable with the availability of cheap local technicians for maintenance and repair.

6.6 Time Feasibility

The project developer shall report tie up of financing arrangements for the projects within a given time slot after signing the PPA. At this stage, project developer would furnish within the aforesaid period the necessary documents to establish that the required criteria have been fulfilled. Penalty schedule is also introduced in case of failure to achieve the milestone.

6.7 Resource Feasibility

The daily average solar energy incident varies in the range of 4-7 kWh per square meter of surface area depending on the location and time of the year. The solar radiation data assumes critical importance as it impacts the viability of solar power projects, which are quite capital intensive.

MNRE has taken the cognizance of the requirement and has started the augmentation of the network of solar radiation resource assessment (SRRA) stations, to begin with, by setting up such stations at site with high potential for solar power generation in the country.

With launch of JNNSM, the requirement for solar radiation data gains utmost importance as it is required by

- Solar project developers to design their project optimally to achieve competitive costs of energy generation.
- Financial institutions to be convinced about the viability of the solar power projects.
- The government to formulate policies backed by scientific rationale. • Regulators to determine levelised tariff.

## 7. EXPECTED OUTCOMES:-

Solar energy is our future. Fossil fuels damage our environment and we have developed an unhealthy addiction to them. Solar energy is clean, cost-efficient, environmentally and economically friendly. The surface of our plant absorbs the energy equivalent of a barrel of oil for every square meter from sun.

- To meet demand and supply energy gap
- Viable solution for Rural Electrification
- Reduction in Green House Gases (GHG)
- Positive contribution to Indian Economy
- Sustainable Energy Growth
- Domestic Content Manufacturing
- Creation of Job, control unemployment

# DISSERTATION FOR THE DEGREE OF MBA

# RECENT TRENDS/DEVELOPMENTS IN SOLAR ENERGY SECTOR IN INDIA – EMERGING PHOTOVOLTAIC TECHNOLOGY

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# CONTENTS



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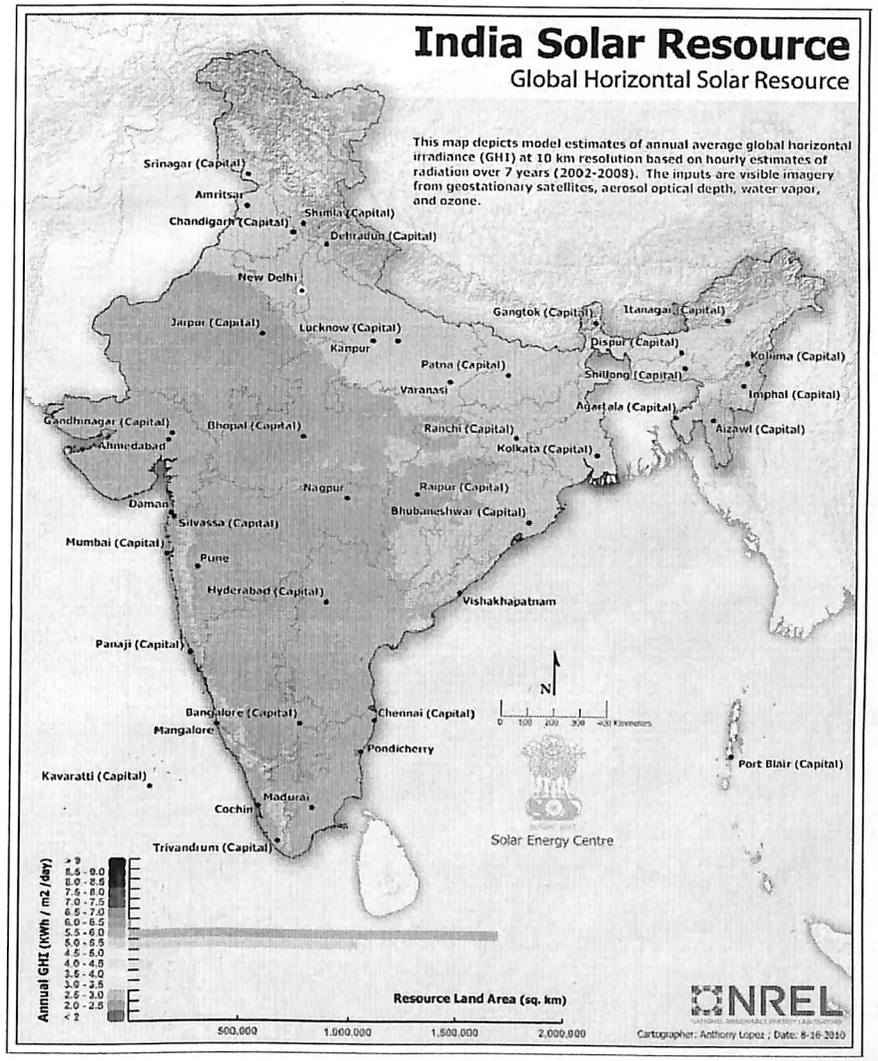
# EXECUTIVE SUMMARY:

- Renewable energy is one of the cleanest sources of energy.
- By using renewable energy, world can improve air quality, reduce global warming emissions, create new industries and jobs, and move world towards a cleaner, safer, and affordable energy future.
- Currently India stood on 12.95% with a total installed capacity of solar energy 36951.46 MWs as of Feb 2019.
- National Solar Mission has set a target of **175 GW by 2022 out of which 100 GW solar energy** generated.
- **National Action Plan on Climate Change (NAPCC)** has recommended increasing the share of renewable energy to 10% by 2019 and 15% by 2022
- 23 SERCs have specified the renewable purchase obligations (RPO) for their licensee distribution companies.

# Dissertation by: Abhishek Kumar verma
# Recent Trends/Developments in Solar Energy Sector In India – Emerging Photovoltaic Technology



- NAPCC, envisaged the National Solar Mission (NSM) as one of the 8 mission which form the integrated strategies on context of climate change.
- India is endowed with abundant solar energy with around 300 sunny days.
- This report will give insight into the recent developments/trends in Solar Energy sector in India
- **Solar PV** has some key advantages. Its modular design and ability to fit on existing real estate makes it attractive for both the residential and commercial segments



# Chapter 1: Introduction

- **India Power Scenario**

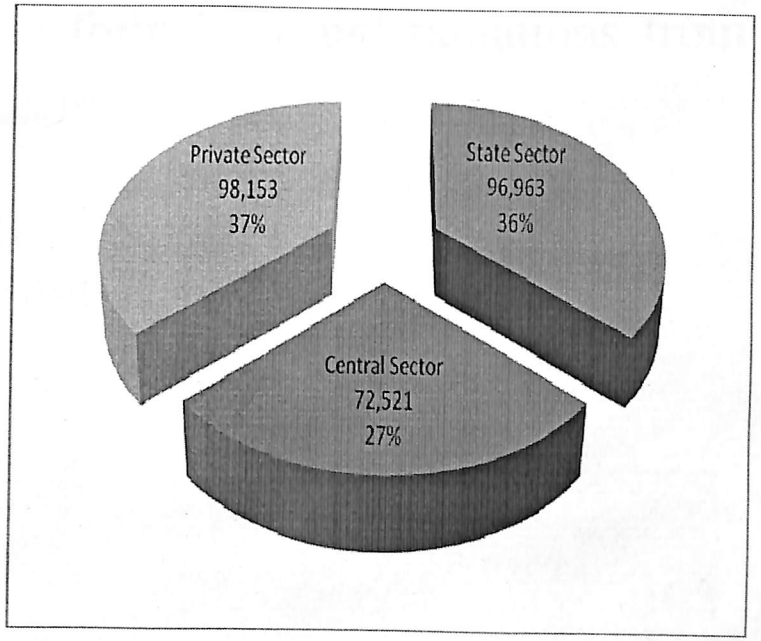
Thermal Energy – 188,898 MW

Hydro Energy – 41,267 MW

Nuclear Energy - 5,780 MW

Renewable - 31,692 MW

Total - 2,67,637 MW




As on 31.03.2019

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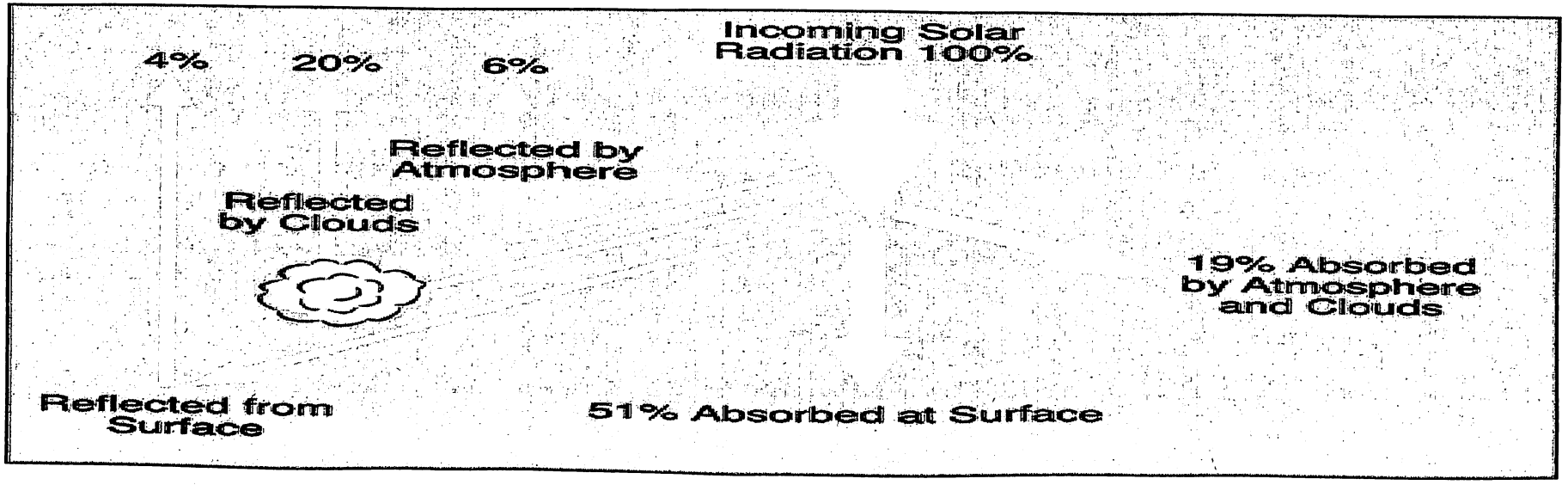
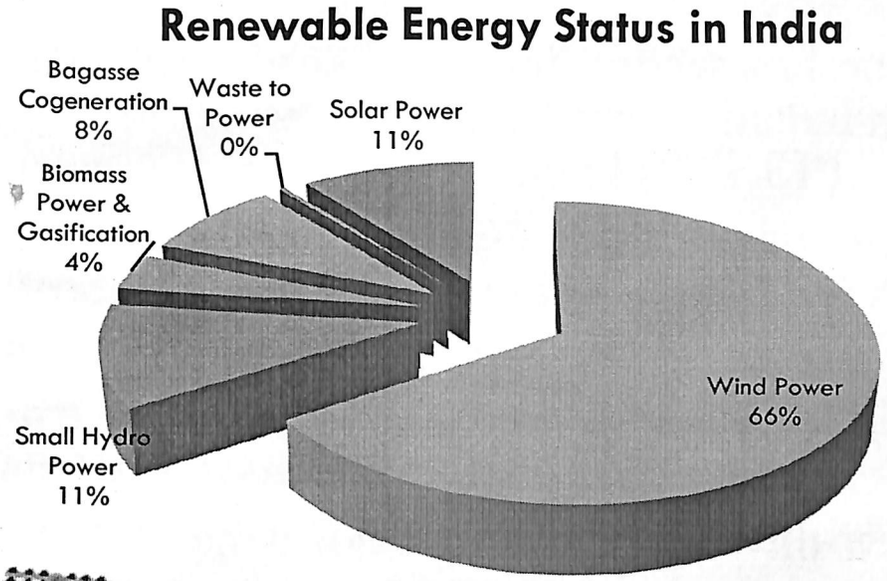
## Solar Energy

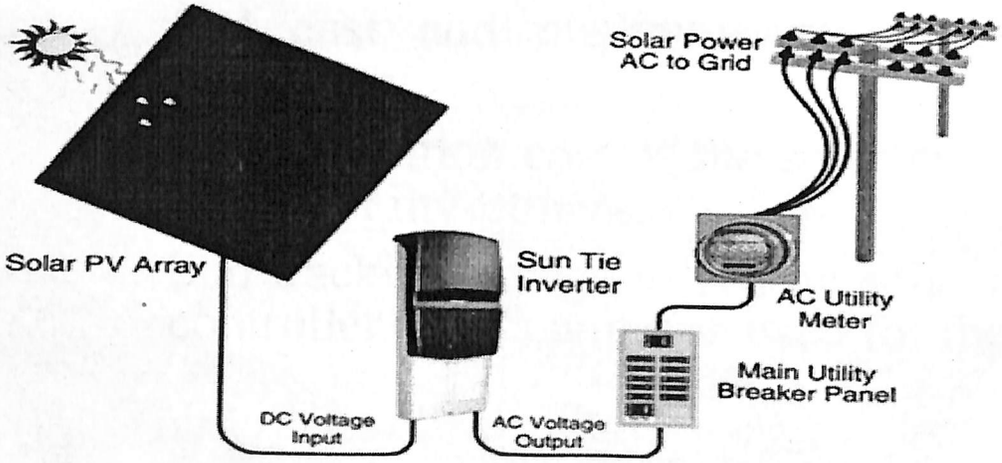
- Solar Energy is the energy received in the form heat and radiations from Sun
- Extraterrestrial Solar Radiation is 1367 watts per square
- Albedo Effect : 30% is reflected back to space
- 5th rank in world in renewable energy generation.

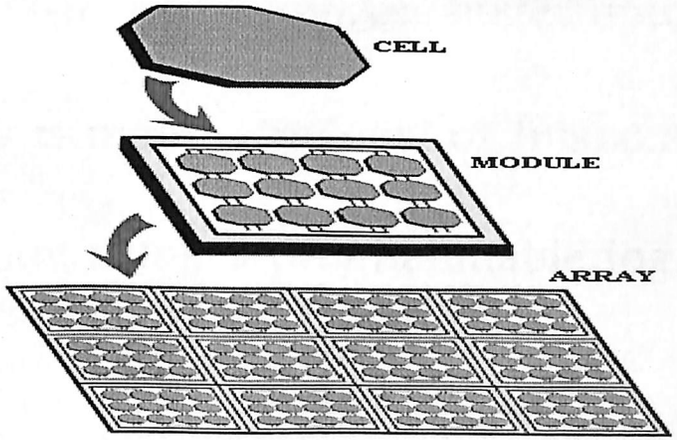


# Solar Photovoltaic Plant

- Directly converts sun light into electric current.
- PV plants are based on two technologies
  - Grid connected
  - OFF Grid



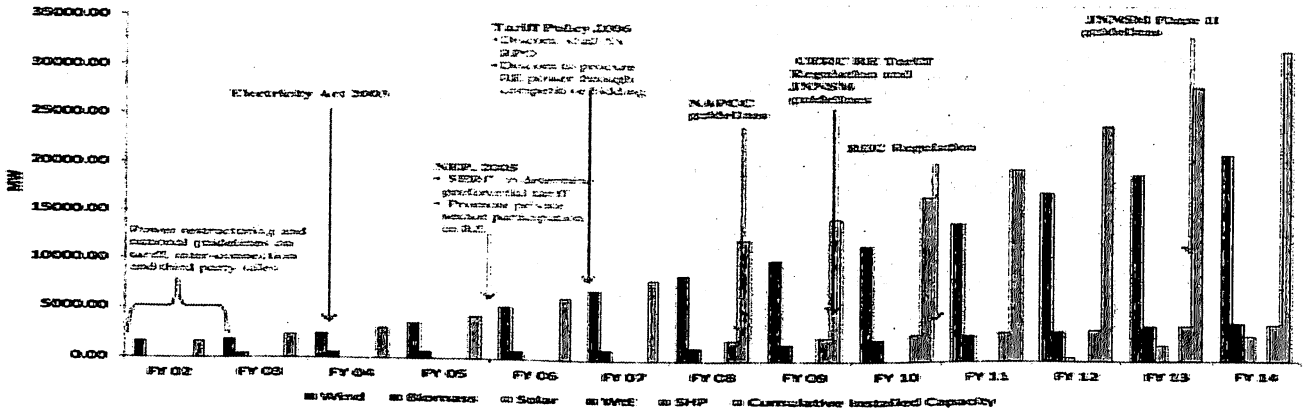
# Chapter 2: Literature Review

- Solar energy generation technologies have broad societal impact and need to be assessed considering multiple perspectives including: social, technological, economic, environmental, and political **(STEEP).**
- Solar energy is utilized in various ways, such as industrial & domestic water heating, drying of products, space heating, cooling & refrigeration, power production etc
- A photovoltaic (PV) cell, is known as Solar Cell, which is made up of a semiconductor device that generates electricity when light falls on it.
- Solar Photovoltaic (SPV) power plants have long working life with zero fuel cost and negligible maintenance cost but requires huge initial Investment.
- The generation cost of the solar electricity is mainly the cost of financing the initial investment.
- Sun tracking design to follow solar radiation using a programmable logic controller (PLC) unit was used for the movement of a PV module

# Historical Development

- **Commission for Additional Sources of Energy (CASE)** in the Department of Science & Technology in March 1981
- **In 1982 Department of Non-conventional Energy Sources (DNES)**
- In 1992, DNES became the **Ministry of Non-conventional Energy Sources**
- In October 2006, the Ministry was re-christened as the **Ministry of New and Renewable Energy (MNRE).**

## Renewable Energy: Historic Trends and Growth Enablers



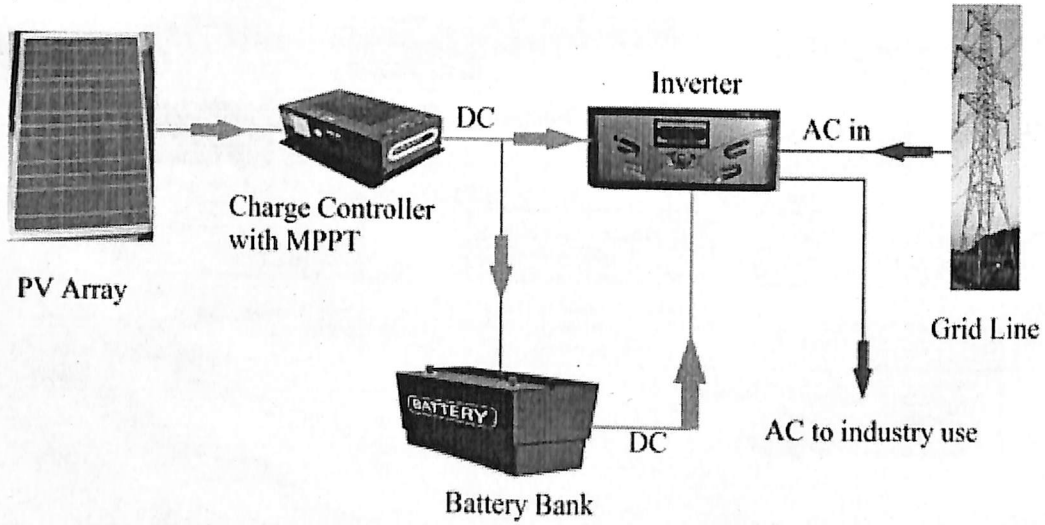
# LEGISLATION AND REGULATORY FRAMEWORK

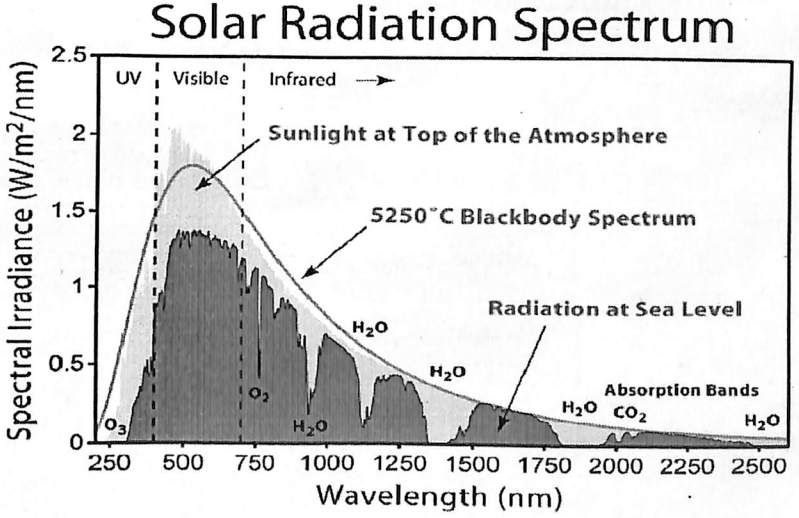
- Electricity Act 1910
- Electricity Supply Act 1948
- Electricity Regulatory Commission Act 1998
- Electricity Act 2003
- National Electricity Policy 2005
- National Tariff Policy 2005
- Indian Electricity Grid Code
- Tariff Regulations for Renewable Energy 2009
- Tariff Regulations for Renewable Energy 2012
- Tariff Regulations for Renewable Energy 2013-14

# Chapter 3: Research Design, Methodology & Plan

## Solar PV Plant major Component

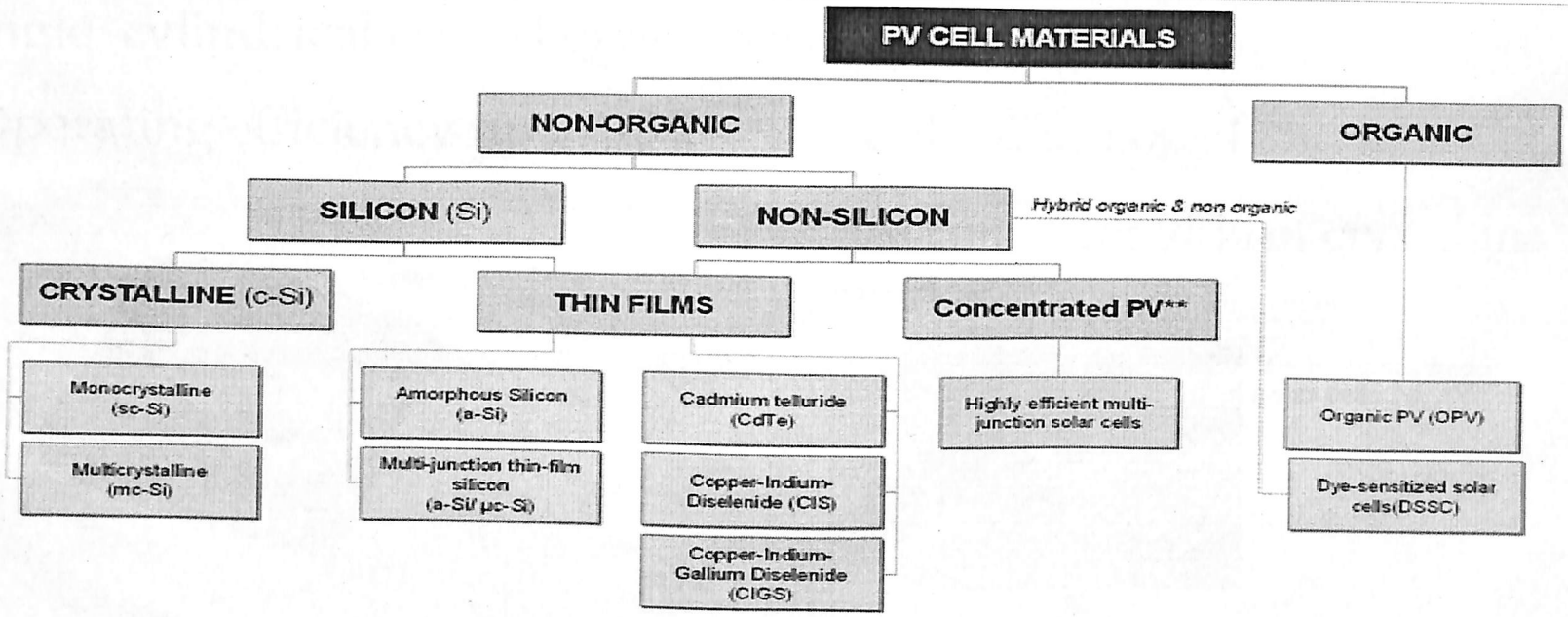
- Solar PV Modules
- Solar Cells
- Solar PV Tracking System
- Inverters
- Step-up Transformers
- The Grid Connection Interface



# SOLAR TECHNOLOGIES

- Wafer based crystalline silicon solar cells
- Thin-film solar cells, which includes, Copper Indium Gallium Diselenide (CIGS), Cadmium Telluride, Amorphous silicon (a-Si) etc.
- Concentrating Photovoltaic (CPV)



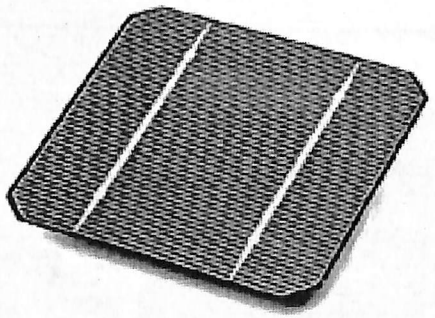
## Silicon Crystalline Technology

- Currently makes up 86% of PV market
- Very stable with module efficiencies 10-16%

### Mono crystalline PV Cells

•Made using saw-cut from single cylindrical crystal of Si

•Operating efficiency up to 15%

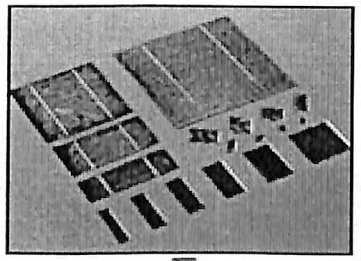


### Multi Crystalline PV Cells

•Caste from ingot of melted and re-crystallised silicon

•Cell efficiency ~12%

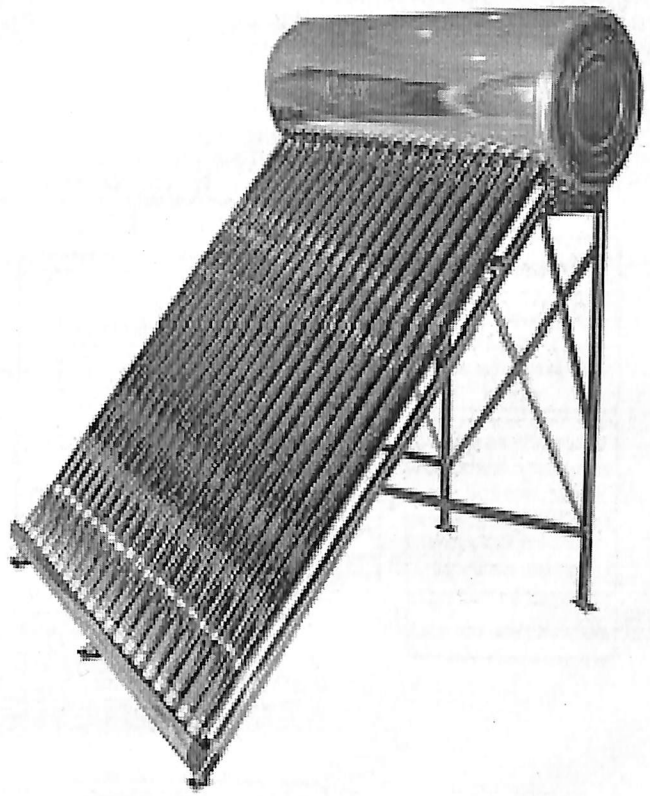
•Accounts for 90% of crystalline Si market

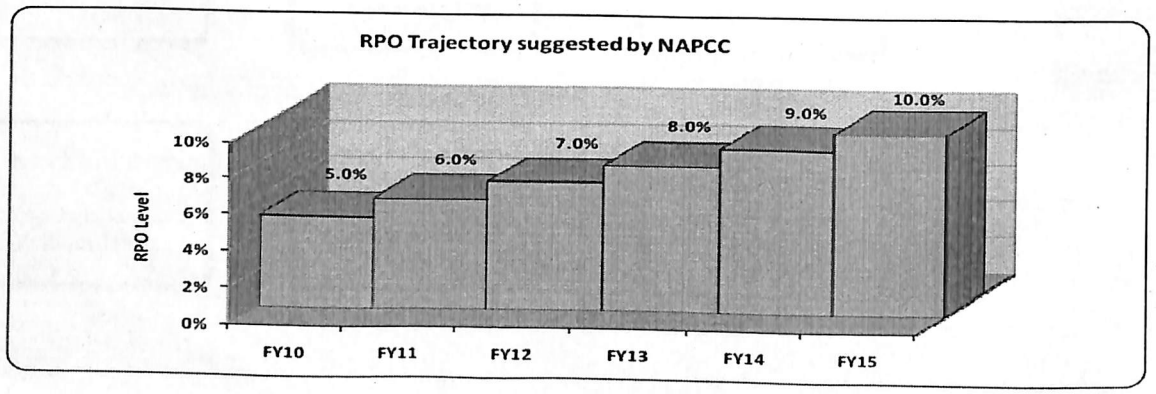


Multicrystal silicon solar cells

# Solar Energy Scheme/Plan

- National Action Plan on climate Change
- National Solar Mission
- RPSSGP Scheme
- Solar Water Heater
- Solar Lanten/Lights
- Solar Cooker





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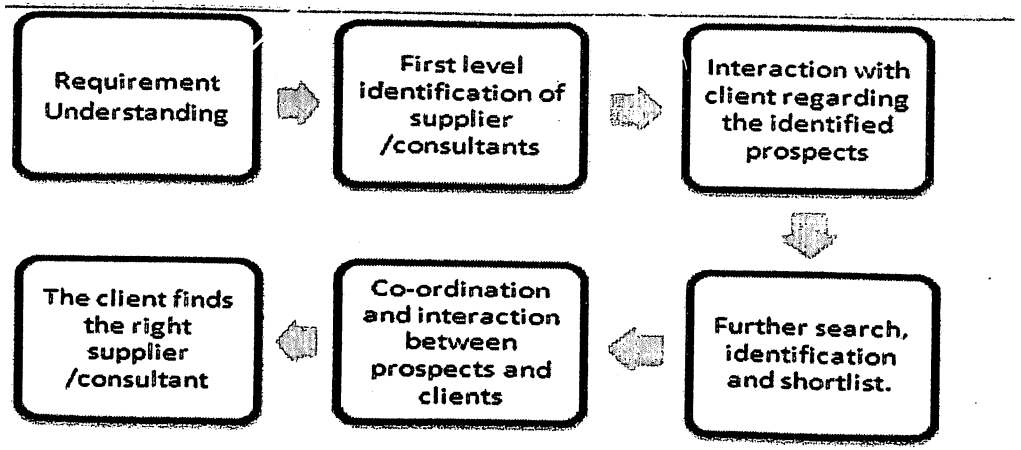
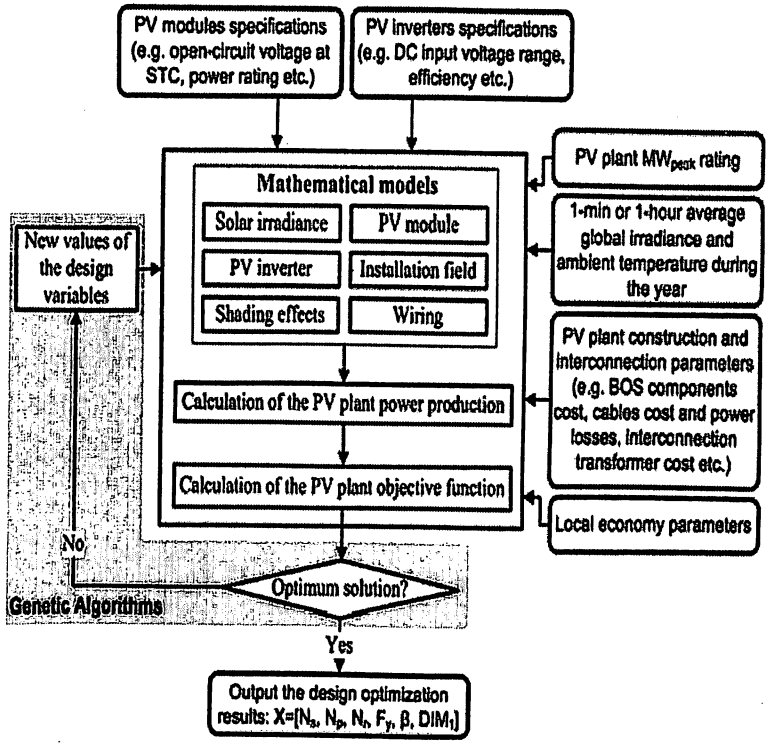
## Methodology

- This facilitates easy comparison of irradiation levels from different sources, and power output from solar plants, with variation in type and make of panel used the angle of tilt of the panel, the use of tracking mechanism, local weather conditions such as temperature, and losses such as panel degradation, inverter losses and so on.
- Data from the above mentioned sources is analyzed using software such as PV System and RET Screen.




KEREKES *et al.*: OPTIMIZATION METHOD FOR DESIGNING LARGE PV PLANTS



# Chapter 4 : Finding & Analysis

## SOLAR UMPP

The scheme aims to provide a huge impetus to solar energy generation by acting as a flagship demonstration facility to encourage project developers and investors, prompting additional projects of similar nature, triggering economies of scale for cost-reductions, technical improvements and achieving large scale reductions in GHG emissions.

- **Solar Renewable Purchase Obligation (RPO) mandate**
- **Implementation arrangements**
- **Power Purchase Agreement**
- **Fund for Power Evacuation**
- **Central Financial Assistance (CFA)**

## Solar Parks

Ministry of New and renewable Energy **(MNRE)** has drawn a scheme to set up number of solar parks across various states in the country, each with a capacity of Solar Projects generally above 500 MW. The Scheme proposes to provide financial support by Government of India

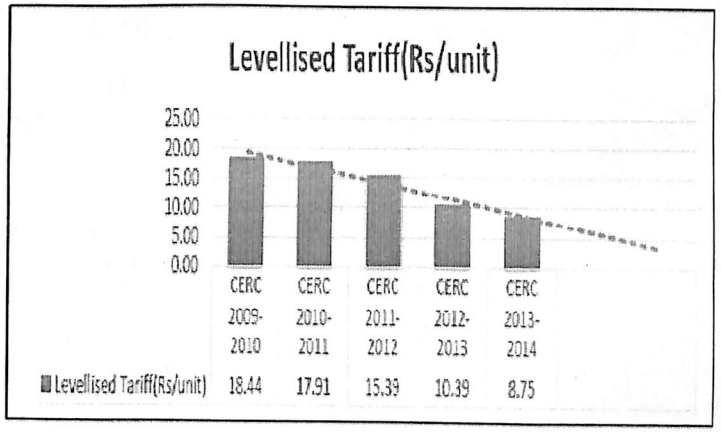
### State having Solar Parks purposed:

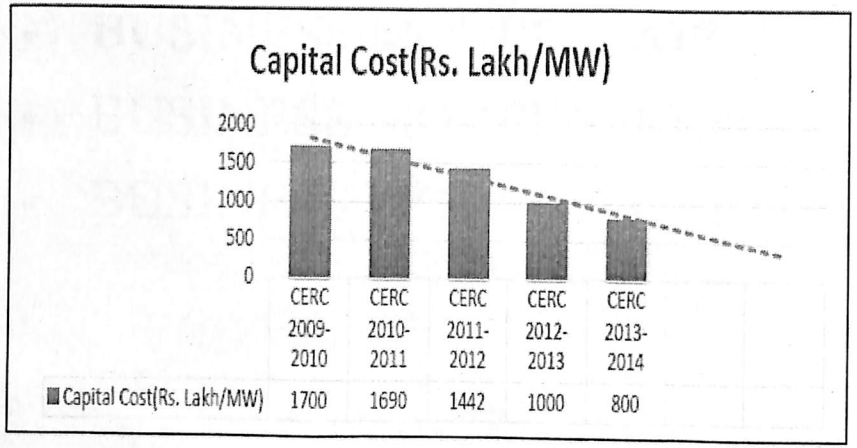
- Madhya Pradesh
- Andhra Pradesh
- Rajasthan
- Uttar Pradesh
- Gujarat
- Telangana
- Karnataka
- Punjab
- Jammu & Kashmir
- Maghalaya

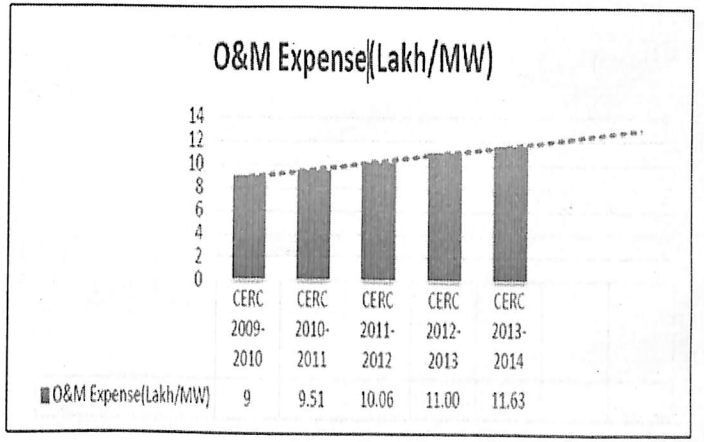
## Regulatory Tariff Structure

### CERC Tariff Structure

- Return on equity;
- Interest on loan capital;
- Depreciation;
- Interest on working capital;
- Operation and maintenance expenses;



# RENEWABLE ENERGY MARKET MODELS

- Alternate A – Preferential tariff based market model
- Alternate B – REC market model
- Alternate C – Open access and wheeling model

# BUSINESS MODELS

- BUSINESS MODEL 1: FEED IN TARIFF
- BUSINESS MODEL 2: APPC + REC
- BUSINESS MODEL 3: RESCO + REC
- BUSINESS MODEL 4: CAPTIVE + REC

# Chapter 5 : Interpretation of Data

## RPO MECHANISM

**RPO fulfilled is under two categories:**

- Non-Solar
- Solar (0.25% in most states)

These Regulations shall apply to "Obligated Entities" enumerated below:

1. Distribution companies or DISCOMs
2. Open access consumers above 1MW
3. Captive consumers above 5MW

# REC MECHANISUM

There are 2 categories of certificates:

- Solar certificates: Solar RECs include both PV and CSP technologies.
- Non-Solar certificates

There are **3 categories** of project that are eligible for REC:

- Projects for captive consumption
- Projects for third party sale (RESCO)
- Projects with a PPA with a DISCOM

## Tax & Regulatory Incentives

| Incentive | Details |
|---|---|
| Income tax Holiday | 100% for 10 consecutive years - MAT @ 20% to apply |
| Accelerated depreciation | Accelerated depreciation @ 80% on solar assets<br>Additional depreciation @ 20% on new plant/machinery in the 1st year |
| Deemed export benefits | Available to specified goods manufactured and not actually exported<br>• Advance authorization from Directorate General of Foreign Trade<br>• Deemed export drawbacks<br>• Exemption/return of Terminal Excise Duty |
| Service tax based on negative list | Certain services are exempted from service tax<br>• Services of transmission or distribution of electricity by an electricity utility |
| Customs and Excise Laws | Various duty concessions and exemptions to RE Sector |
| Reduced VAT | Certain States allow reduced VAT rates (5%) on RE projects |
| Additional one-time allowance | Available @15% in Budget 2014 on new plant and machinery |
| Tax-free Grants | Grants received from the holding company engaged in generation, distribution or transmission of power |

# Chapter 6 : Conclusion & Future Scope of Work

## Conclusion:

India's new government has been very bullish on growing solar. Plans are underway to revise the National Solar Mission (NSM) target to 100 GW by 2022.

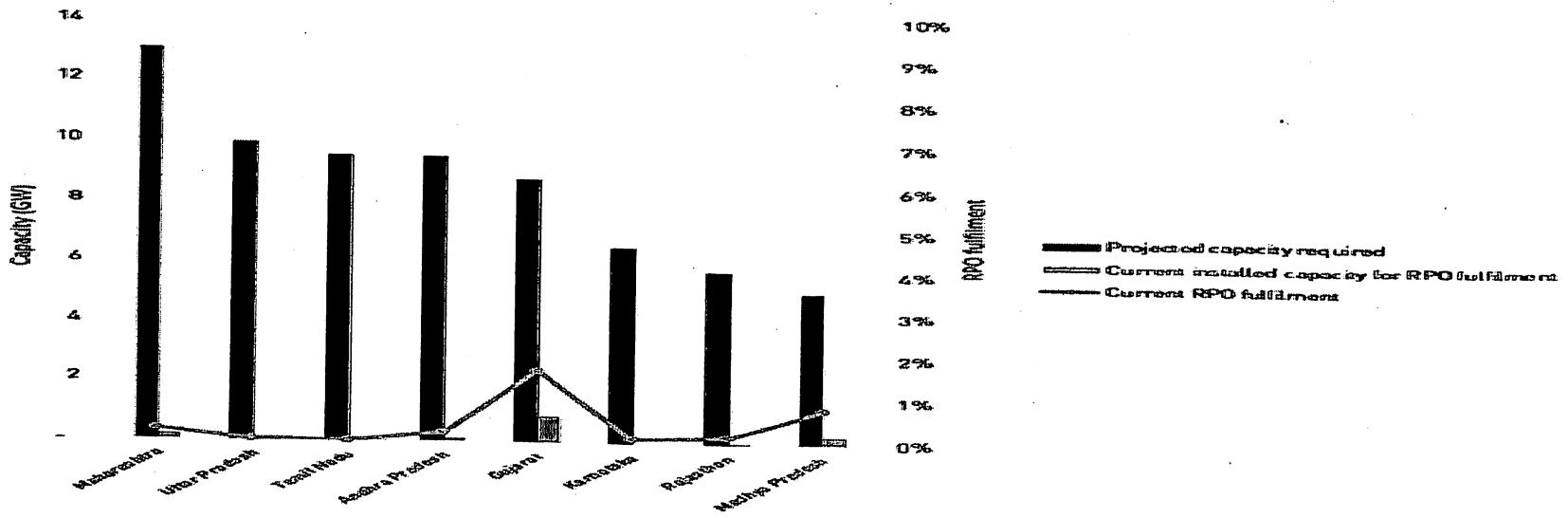
Ministry of New and Renewable Energy (MNRE) wants to increase solar Renewable Purchase Obligation (RPO) targets for obligated entities (including distribution companies) could be raised to 10.5% from the current 3%.

- An RPO target of 10.5% would be in tune with the government's goal of having 100 GW of solar by 2022.
- Cash strapped distribution companies (Discoms) might not be able to bear the burden of purchasing so much solar power
- The government is planning to reduce the cost of solar power to Discoms through a bundling mechanism and low cost financing.

# Future Scope of Work

## RE-INVEST 2019

RE-Invest 2019 is the first Renewable Energy Global Investors Meet & Expo to be organized by the Ministry of New and Renewable Energy (MNRE). Its objective is to showcase the Government of India's commitment to the development and scaling up of renewable energy in India to meet the national energy requirement in a socially, economically and ecologically sustainable .



- There will be a need to develop Off grid REC regulations & the regulations should allow off-grid RE generators to receive RECs and sell those on the Exchange.
- Steps should be taken to encourage participation of voluntary buyers. While the compliance market may remain the primary driver for the RECs in India in the initial stage, the scope for voluntary market purchases would remain promising in future.
- In states where obligated entities are buying expensive RE power over and above their RPO, they should be allowed to get RECs. Such a step will motivate RE investment in such potential state
- The overall investment climate in India has to be improved, there have to be clear and predictable policies regulating the grid and the power markets, and it would help enormously, if India's high interest rates would come down.
- The objective of providing support to various technologies can be achieved by using a multiplier for different sources. A multiplier scheme essentially allows participation in a common REC market by using a multiplier to define the equivalent number of RECs
- India should also announced the sunset date of REC mechanism while its introduction. Considering the benefits of priory declaration of target and sunset date, the tightly regulated RE sector in India will be able to attract more private investments. Thus, it will stipulate the RE development

**Think Green, Go Green, Live Green**

# THANK YOU