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Solar Energy Fundamentals and Challenges in Indian restructured power sector

Ashok Upadhyay [*], **Arnab Chowdhury** [**]

[*] Deputy Director (Generation), M.P. Electricity Regulatory Commission, Bhopal, Madhya Pradesh
[**] Pursuing MBA (Power Mgmt.), University of Petroleum and Energy Studies., Dehradun, Uttarkhand

Abstract- In recent years the solar energy technologies has experienced phenomenal growth. The realization of technological improvements, growing public awareness of environmental issues, the economic climate and number of policy instruments have facilitated and sustained this strong interest in these technologies. Since the cost of electricity generated from solar is still expensive and also the power from renewable resources including solar is infirm power, large scale development of renewable resources did not take place and distribution utilities are also least interested to purchase power from renewable sources. This paper provides an overview of technical, economic and policy aspects of solar energy development. It reviews the status of solar energy in terms of resource potential, existing capacity, along with historical trends and future growth prospects of solar energy. The paper also focuses on the technical, economical, and institutional barriers to the development and utilization of solar energy technologies. The paper reviews existing fiscal and regulatory policy instruments to support solar energy development, indicating how successful these policy apparatus are in achieving their goals. And finally a review based on existing studies of the future prospects of solar energy supply under various scenarios in Indian restructured power sector is provided.

Index Terms- Environmental issues, economic climate, policy instruments

I. Introduction

The Indian power sector is predominantly based on fossil fuels, with about three-fifths of the country's power generation capacity being dependent on vast indigenous reserves of coal. But in few last decades Indian government has taken several steps to reduce the use of fossil fuels-based energy while promoting renewable generation. Solar energy constitutes the most abundant renewable energy resource available and in most regions of the world even its technically available potential is far in excess of the current total primary energy supply. As such solar energy technologies are a key tool to lower worldwide carbon emissions. The wide range of technologies available today, to harness the sun‘s energy, is classified into passive and active technologies. The active technologies, which formed the content of this paper, are broadly divided into photovoltaic and solar thermal, where solar thermal can be further classified into solar-thermal electric and non-electric applications. The market for many of the solar energy technologies has seen dramatic expansion over the past decade in particular the expansion of the market for grid-connected PV systems and solar hot water systems have been remarkable. At present India is fifth largest country in the world of electricity generation, having presently installed capacity of 243 GWs out of which 69.5 % is from thermal, 16.5 % from hydro, 2% from nuclear and rest about 12% from renewable energy sources. Although Indian power sector has experienced a seven times increased in its installed capacity a jump from 30,000 MW in 1981 to over 243028 MW by March, 2014 but still there is a huge gap in generation and demand in India hence need to be established more generation plants preferable to be come from renewable sources by governmental as well as various private participation. As per the load generation balance report for FY2013-14 issued by CEA, the anticipated peak shortage in the country during FY2013-14 works out to 6.2% based on the anticipated demand and availability of power. Solar energy has emerged as a viable, cost-effective and commercial option for grid connected power generation. During the past few years, a significant trust has been given to the development and induction of solar energy technology for use in different sectors. India is the only country in the world with an exclusive Ministry to promote the renewable energy sources. Presently the installed capacity of solar energy projects in India is approximately 3000 MW. India plan to produce 20 GW of solar power by 2020. While the cost of energy from many solar energy technologies remains high compared to conventional energy technologies, the cost trend of solar energy technologies demonstrates rapid declines in the recent past and the potential for significant declines in the near future. In addition to cost, it is found that a number of barriers that appear to limit the rapid growth of such technologies. These include technical barriers such as low-efficiencies, challenges with energy storage, reliability of balance of system components; and institutional barriers such as lack of information, outreach and regulatory structure. In response, a number of highly effective policy instruments have come together in some of the most successful markets for solar energy. These include fiscal and market based financial incentives (e.g. feed-in-tariff, rebates, tax credits), regulations (e.g. renewable portfolio standards, solar energy mandates) as well as a number of pilot demonstration projects. While the continued operation of such initiatives is imperative for the future growth of these markets it is also becoming apparent that innovative ways to reduce the fiscal burden of policy incentives are needed. As such, there is presently growing interest in market-based mechanisms to complement existing fiscal policy incentives.

Solar energy has experienced phenomenal growth in recent years due to both technological Improvements resulting in cost reductions and government policies supportive of renewable energy development and utilization. This paper analyzes the technical, economic and policy aspects of solar energy development and deployment. While the cost of solar energy has declined rapidly in the recent past, it still remains much higher than the cost of conventional energy technologies. Like other renewable energy technologies, solar energy benefits from fiscal and regulatory incentives and mandates, including tax credits and exemptions, feed-in-tariff, preferential interest rates, renewable portfolio standards and voluntary green power programs in many countries. Potential expansion of carbon credit markets also would provide additional incentives to solar energy deployment; however, the scale of incentives provided by the existing carbon market instruments, such as the Clean Development Mechanism of the Kyoto Protocol, is limited. Despite the huge technical potential, development and large-scale, market-driven deployment of solar energy technologies world-wide still has to overcome a number of technical and financial barriers. Unless these barriers are overcome, maintaining and increasing electricity supplies from solar energy will require continuation of potentially costly policy supports. Drives moving in the direction of reduction of capital cost of solar energy through technological development and increase in Plant Utilization Factor with overall improvement in efficiency. Drives are also moving in the direction of developing storage facilities for energy from solar to make them firm and useful form of energy.

Restructuring of power sector has changed the traditional mission and mandates of utilities in complex way, and had large impact on environmental, social and political conditions for any particular country. At the same time, new regulatory approaches are being found for reducing environmental impacts in restructured power sector. Enactment of the Electricity Act 2003 (the Act) has provided further support to renewable energy by stipulating purchase of a percentage of the power procurement by distribution utilities from renewable energy sources. The renewable purchase obligation as well as preferential tariff for procurement of such power has been specified by various State Electricity Regulatory Commissions (SERCs). Despite all strategic policies in place, purchase of Renewable Energy Certificate (REC) has not been very encouraging and sale of now solar REC is at a very low price. SERCs must prevail upon Discoms to meet them RPO obligation. Cost of energy generated from solar can also be reduced by promoting competition within such projects. At the same time, adequate promotional measures would also have to be taken for development of technologies.

While the Electricity Act, 2003, the policies framed under the Act, and also the National Action Plan for Climate Change (NAPCC) provide for a roadmap for increasing the share of renewable in the total generation capacity in the country, there are constraints in terms of availability of RE sources evenly across different parts of the country. This inhibits the State Commissions, especially in those states where the potential of RE sources is not that significant, from specifying higher renewable purchase obligation. This paper discusses the latest technological development in the field of solar energy and its storage facilities. This would help to minimize cost of power procurement, and lead to efficient resource utilization across the country and provide incentive for investment in appropriate technologies. The paper also highlights salient features, technological development, potential and achievement, advantages and key barriers in development of solar energy projects in India. This paper also highlighted the implementation and operational or grid related issues in solar power projects.

Finally, the paper finds that the future projections for solar energy technologies are broadly optimistic. According to the projections considered here, the market for solar energy technology is expected to grow significantly in the long-term as well as short-term. Further, despite its technical and economic limitations at present, it is expected that solar energy will play an important role in the future.

II. Legal Framework

Government of India has come out with Acts, Policies and Regulations to support renewable Energy. The major contributors are as under.

1.1 Electricity Act, 2003

The Electricity Act 2003 has promotes electricity generation from co-generation and renewable energy sources. The Act accelerated the process of renewable energy development in the country (2).

- Section 3(1) of the Act provides that the National Electricity Policy (NEP) to be formulated by the central government, in consultation with the state governments for development of the power system based on optimal utilization of resources including renewable sources of energy
- Section 4 of the Act provides that the Central Government to prepare a national policy, in consultation with the state governments, permitting stand alone systems (including those based on renewable sources of energy and other non- conventional sources of energy) for rural areas.
- Section 61 (h) stipulated that the terms and conditions for the determination of tariff to be prescribed by the SERCs to promote co- generation and generation of electricity renewable sources of energy.
- Section 86(1) (e) empower the SERC's to specify, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of distribution licensee. The aforesaid section of the Act also empowers the SERCs to promote co-generation and generation of electricity through renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any persons.
- SERCs have specified a Renewable Purchase Obligation (RPO) and have specified feed-in tariff and other terms and conditions to promote co-generation and generation of electricity from renewable energy sources.

1.2 National Electricity Policy 2005

The National Electricity Policy 2005 stipulates that progressively the share of electricity from non- conventional sources would need to be increased; such purchase by distribution companies shall be through competitive bidding process; considering the fact that it will take some time before non-conventional technologies compete, in terms of cost, with conventional sources, the commission may determine an appropriate deferential in prices to promote these technologies.

1.3 Tariff Policy 2006

The Tariff Policy has stated that, in Pursuant to provisions of section 86 (1) (e) of the Act, the Appropriate Commission shall fix a minimum percentage for purchase of energy from such sources taking into account availability of such resources in the region and its impact on retail tariffs. Such percentages for purchase of energy should be made applicable for the tariffs to be determined by the SERCs latest by April, 2006.

1.4 National Action Plan of Climate Change

The National Action Plan of Climate Change has set the target of 5% renewable energy purchase for FY 2009-10 which will increase by 1% for next 10 years. The NAPCC further recommends strong regulatory measures to fulfil these targets. NAPCC have set the target to achieved 15% of total energy requirement of the country from renewable by 2020.

III. Fundamentals and Basic Concept of Solar Energy

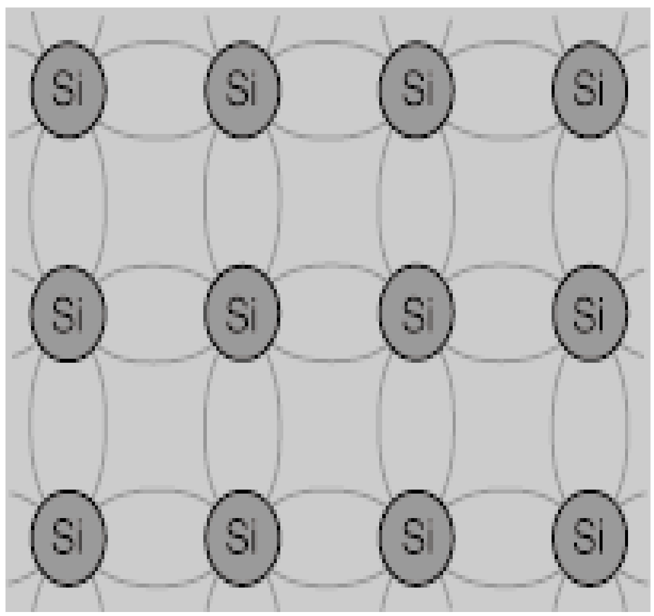
Solar energy can be produced by two methods. One is Solar PV i.e. through photovoltaic cells and other is Solar Thermal i.e. through concentrated solar power.

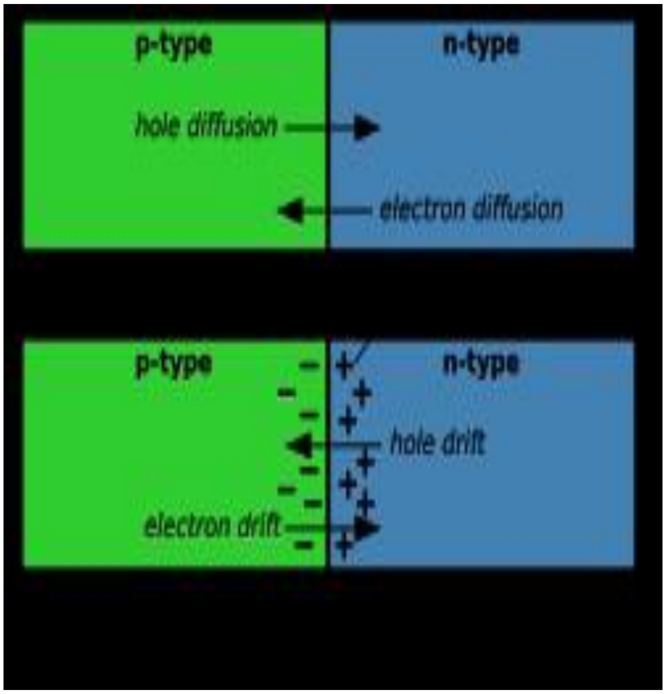
1.1 Solar Photovoltaic (PV):

Historical development: Solar Photo-voltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. It is a device that directly converts solar energy into electricity by photovoltaic effect. Photoelectric effect was first time recognized in 1839 by F.C. Becquerel. In this Phenomenon the electrons are emitted from matter after absorption of energy from radiation. In 1883 – First solar cell was built by coating Selenium with extremely thin layer of gold. In 1958 – Bell laboratories found that Silicon (Si) doped with certain impurities was very sensitive to light. This finding resulted in the production of first practical solar cell with sunlight conversion efficiency ~6% made from materials that emit electrons when exposed to EM radiation. Mainstream materials presently used for photovoltaic include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Due to the increased demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years. The amount of power available from a solar cell depends on

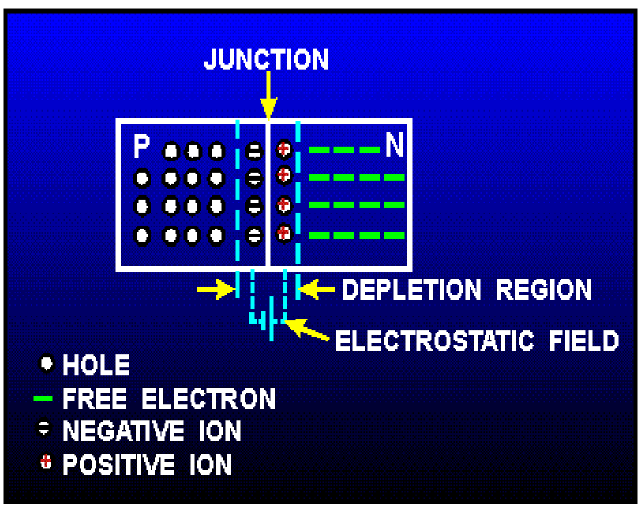
- Type and area of material
- Intensity of sunlight
- Wavelength of sunlight

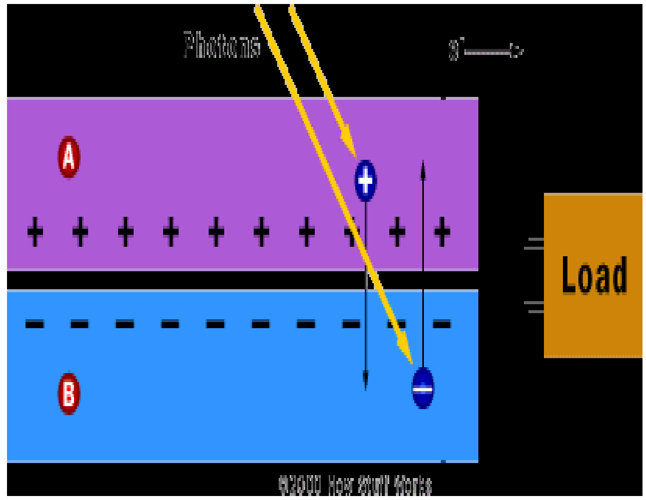
Working principle: Sunlight is made out of tiny energy pockets called photons and that each individual solar cell is designed with a positive and negative layer thus being able to create an electric field (similar to the one in batteries). As photons are absorbed in the cell their energy causes electrons to get free, and they move to the bottom of the cell, and exit through the connecting wire which creates flow of electrons thus generate electricity. The bigger amount of the available sunlight the greater the flow of electrons and the more electricity gets produced in the process. It is a form of photoelectric cell (in that its electrical characteristics e.g. current, voltage, or resistance vary when light is incident upon it) which, when exposed to light, can generate and support an electric current without being attached to any external voltage source, but do require an external load for power consumption. Pure Si is a poor conductor of electricity. Doping – introducing impurities into an intrinsic (pure) semiconductor to change its electrical properties. Examples of n-type dopants – Phosphorus (Ph), Arsenic (As), Antimony (Sb). Examples of p-type dopants –Boron (B), Aluminium (Al). Doping provides with charge carriers (holes and electrons) that can carry electrical current. Electric field to force electrons to flow in a certain direction. This electric field is achieved by bringing together p-type and n-type semiconductors together to make a diode. Holes and electrons from p-region and n-region respectively recombine, creating a depletion region and an electric field. The movement of holes and electrons are represented below. Depletion region continues to grow till the electric field becomes large enough to prevent the flow of charge carriers from one side to the other. Now, if the diode is exposed to light, it frees the electrons in n-region and these electrons, repelled by the electric field, flow through the load to p-region. These electrons constitute current. The flow of electrons and hole can be represented as follows:





The movement of hole and electrons resulting flow of electricity across the cell represented as given below:





Several solar cells are connected together, encapsulated in a glass covered frame to form a module. A solar cell made from a mono-crystalline silicon wafer with its contact grid made from bus bars (the larger strips) and fingers (the smaller ones)

As light hits the solar panels, the solar radiation is converted into direct current electricity (DC). The direct current flows from the panels and is converted into alternating current (AC) used by local electric utilities. Finally, the electricity travels through transformers, and the voltage is boosted for delivery onto the transmission lines so local electric utilities can distribute the electricity to homes and businesses.

The operation of a photovoltaic (PV) cell requires 3 basic attributes:

- Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
- Electrons (negatively charged) are excited from their current molecular/atomic orbital. Once excited the electron can either dissipate the energy, and return to its orbital or travel through the cell until it reaches an electrode. Current starts flowing through the material to cancel the potential and this electricity is captured. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction.
- An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.

Essential requirements for solar energy generation are as follows:

1. High solar radiation at that particular site.
2. Adequate land availability.
3. Suitable terrain and good soil condition.
4. Proper approach to site.
5. Suitable power grid nearby.
6. Techno-economic selection of solar panels.
7. Scientifically prepared layout.

Main Components of Solar PV:

Solar cell: In order to make a Monocrystalline solar cell, a silicon ingot, also known as a silicon boule (crystal), must first be produced. Once a silicon ingot has been made, it is thinly sliced and semiconductors are imbedded in the disk. The silicon disk will have positive and negative leads, which serve as connection points to tie multiple cells in series. Once multiple cells are connected in series, the formation of a photovoltaic module begins..

Photovoltaic modules: Due to the low voltage of an individual solar cell, several cells are wired in series in the manufacture of a "laminate". The laminate is assembled into a protective weatherproof enclosure, thus making a photovoltaic module or solar panel. Modules may then be strung together into a photovoltaic array.

Photovoltaic arrays: A photovoltaic array (or solar array) is a linked collection of solar panels. The power that one module can produce is seldom enough to meet requirements of a home or a business, so the modules are linked together to form an array. Most PV arrays use an inverter to convert the DC power produced by the modules into alternating current that can power lights, motors, and other loads. The modules in a PV array are usually first connected in series to obtain the desired voltage; the individual strings are then connected in parallel to allow the system to produce more current. The array rating consists of a summation of the panel ratings, in watts, kilowatts, or megawatts.

Mounting systems: Modules are assembled into arrays on some kind of mounting system, which may be classified as ground mount, roof mount or pole mount. For solar parks a large rack is mounted on the ground, and the modules mounted on the rack. For buildings, many different racks have been devised for pitched roofs. For flat roofs, racks, bins and building integrated solutions are used. Solar panel racks mounted on top of poles can be stationary or moving. Side-of-pole mounts are suitable for situations where a pole has something else mounted at its top, such as a light fixture or an antenna. Pole mounting raises what would otherwise be a ground mounted array above weed shadows and livestock, and may satisfy electrical code requirements regarding inaccessibility of exposed wiring. Pole mounted panels are open to more cooling air on their underside, which increases performance. A multiplicity of pole top racks can be formed into a parking carport or other shade structure. A rack which does not follow the sun from left to right may allow seasonal adjustment up or down.

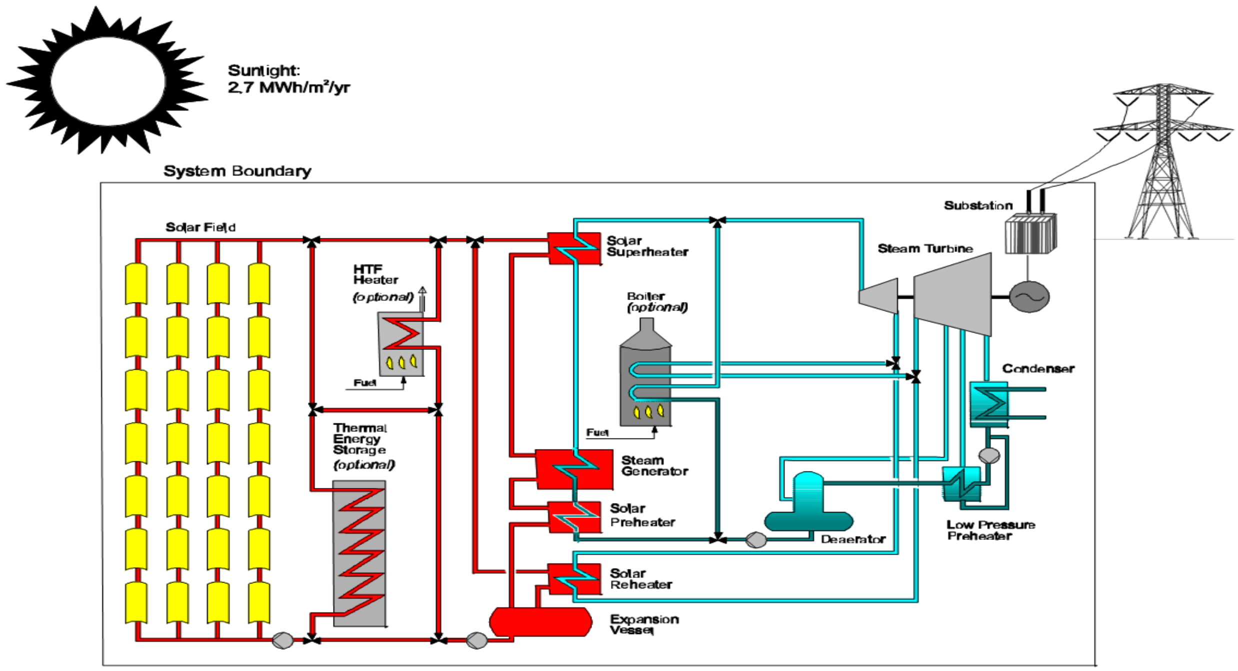
Tracker: A solar tracker tilts a solar panel throughout the day. Depending on the type of tracking system, the panel is either aimed directly at the sun or the brightest area of a partly clouded sky. Trackers greatly enhance early morning and late afternoon performance, increasing the total amount of power produced by a system by about 20–25% for a single axis tracker and about 30% or more for a dual axis tracker, depending on latitude. Trackers are effective in regions that receive a large portion of sunlight directly. In diffuse light (i.e. under cloud or fog), tracking has little or no value. Because most concentrated photovoltaic systems are very sensitive to the sunlight's angle, tracking systems allow them to produce useful power for more than a brief period each day. Tracking systems improve performance for two main reasons. First, when a solar panel is perpendicular to the sunlight, it receives more light on its surface than if it were angled. Second, direct light is used more efficiently than angled light. Special Anti-reflective coatings can improve solar panel efficiency for direct and angled light, somewhat reducing the benefit of tracking.

Inverters: Systems designed to deliver alternating current (AC), such as grid-connected applications need an inverter to convert the direct current (DC) from the solar modules to AC. Grid connected inverters must supply AC electricity in sinusoidal form, synchronized to the grid frequency, limit feed in voltage to no higher than the grid voltage and disconnect from the grid if the grid voltage is turned off. Islanding inverters need only produce regulated voltages and frequencies in a sinusoidal wave shape as no synchronization or co-ordination with grid supplies is required. A solar inverter may connect to a string of solar panels. In some installations a solar micro-inverter is connected at each solar panel. For safety reasons a circuit breaker is provided both on the AC and DC side to enable maintenance. AC output may be connected through an electricity meter into the public grid.

1.1 SOLAR THERMAL:

Concentrated solar power : This systems use mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area. Electrical power is produced when the concentrated light is converted to heat, which drives a heat engine (usually a steam turbine) connected to an electrical power generator or powers a thermo chemical reaction. Solar thermal power technologies are of three types namely Parabolic trough, Dish engine and Power tower.

Parabolic trough technology is the Most proven and mature technology. It consists of a field of single axis tracking parabolic trough solar collectors. Linear receiver located at the focus of parabola. The Heat transfer fluid (HTF) circulates through the receiver and returns to a series of heat exchangers. High-pressure superheated steam generated is fed to turbine. It designed to use solar energy as primary energy source. Fossil fuel based capability can also be used to supplement the solar output during periods of low solar radiation. Modularity, Heat transfer fluid – molten salt, synthetic oil etc. It Operate at temperatures ranging between 1000C-4000C. This technology Used to design power generation systems in the range of 30MW – 150MW. The water requirement is 17,500 cubic metre/MW-yr. Schematic of solar parabolic trough system is as follows:



Working principle: The common basic principle of solar thermal power plants is the use of concentrating parabolic dish systems in large-scale solar fields that concentrate the solar radiation onto a receiver. All systems must track the sun in order to be able to concentrate the direct radiation. This radiation is first converted into thermal energy at temperatures in the range of about 200 to over 1,000 °C (depending on the system). The thermal energy can then be converted to power, as in a conventional power plant, using steam or gas turbines; if needed, it can also be used in other industrial processes, for example, water desalination, cooling or – in the near future – for hydrogen production. Power plants based on concentrated solar power use the sun's energy to generate electricity on an industrial scale. Solar radiation is optically concentrated, thus generating very high temperatures for the power plant process. This high-temperature heat can be stored, thus allowing electricity to be generated on demand an important advantage of this technology.

Components of Solar Thermal:

High-temperature collectors: During the day the sun has different positions. For low concentration systems (and low temperatures) tracking can be avoided (or limited to a few positions per year) if non-imaging optics are used. For higher concentrations, however, if the mirrors or lenses do not move, then the focus of the mirrors or lenses changes (but also in these cases non-imaging optics provides the widest acceptance angles for a given concentration). Therefore it seems unavoidable that there needs to be a tracking system that follows the position of the sun (for solar photovoltaic a solar tracker is only optional). The tracking system increases the cost and complexity. With this in mind, different designs can be distinguished in how they concentrate the light and track the position of the sun.

Parabolic trough designs: Parabolic trough power plants use a curved, mirrored trough which reflects the direct solar radiation onto a glass tube containing a fluid (also called a receiver, absorber or collector) running the length of the trough, positioned at the focal point of the reflectors. The trough is parabolic along one axis and linear in the orthogonal axis. For change of the daily position of the sun perpendicular to the receiver, the trough tilts east to west so that the direct radiation remains focused on the receiver. However, seasonal changes in the in angle of sunlight parallel to the trough does not require adjustment of the mirrors, since the light is simply concentrated elsewhere on the receiver. Thus the trough design does not require tracking on a second axis. The receiver may be enclosed in a glass vacuum chamber. The vacuum significantly reduces convective heat loss. A fluid (also called heat transfer fluid) passes through the receiver and becomes very hot. Common fluids are synthetic oil, molten salt and pressurized steam. The fluid containing the heat is transported to a heat engine where the heat is converted to electricity.

Power tower designs: Power towers (also known as 'central tower' power plants or 'heliostat' power plants) capture and focus the sun's thermal energy with thousands of tracking mirrors (called heliostats) in roughly a two square mile field. A tower resides in the center of the heliostat field. The heliostats focus concentrated sunlight on a receiver which sits on top of the tower. Within the receiver the concentrated sunlight heats molten salt to over 1,000 °F (538 °C). The heated molten salt then flows into a thermal storage tank where it is stored, maintaining 98% thermal efficiency, and eventually pumped to a steam generator. The steam drives a standard turbine to generate electricity. This process, also known as the "Rankine cycle" is similar to a standard coal-fired power plant, except it is fueled by clean and free solar energy. The advantage of this design above the parabolic trough design is the higher temperature. Thermal energy at higher temperatures can be converted to electricity more efficiently and can be more cheaply stored for later use. Furthermore, there is less need to flatten the ground area. In principle a power tower can be built on the side of a hill. Mirrors can be flat and plumbing is concentrated in the tower. The disadvantage of this system is that each mirror must have its own dual-axis control, while in the parabolic trough design single axis tracking can be shared for a large array of mirrors.

Dish designs: A parabolic solar dish concentrates the sun's rays on the heating element of a Stirling engine. The entire unit acts as a solar tracker. This CSP-Stirling is known to have the highest efficiency of all solar technologies around 30% compared to solar PV approximately 15%, and is predicted to be able to produce the cheapest energy among all renewable energy sources in high scale production and hot areas, semi deserts etc. A dish Stirling system uses a large, reflective, parabolic dish (similar in shape to satellite television dish). It focuses all the sunlight that strikes the dish onto a single point above the dish, where a receiver captures the heat and transforms it into a useful form. Typically the dish is coupled with a Stirling engine in a Dish-Stirling System, but also sometimes a steam engine is used. These create rotational kinetic energy that can be converted to electricity using an electric generator. Dish systems convert thermal energy in solar radiation to mechanical energy and then to electrical energy. These dishes track sun in two axes. Use mirror array to reflect and concentrate incoming solar radiation on to a receiver. The concentrated radiation is then transferred to an engine. The engine transfers the heat energy into mechanical energy. An alternator converts mechanical energy into electrical energy. This system has high efficiency, modularity and autonomous operation. It also has Inherent ability to operate on fossil fuels and have a wide range of potential applications. Land requirement for this system is – 3 to 4 acres per MW.

Fresnel reflector: A linear Fresnel reflector power plant uses a series of long, narrow, shallow-curvature (or even flat) mirrors to focus light onto one or more linear receivers positioned above the mirrors. On top of the receiver a small parabolic mirror can be attached for further focusing the light. These systems aim to offer lower overall costs by sharing a receiver between several mirrors (as compared with trough and dish concepts), while still using the simple line-focus geometry with one axis for tracking. This is similar to the trough design (and different from central towers and dishes with dual-axis). The receiver is stationary and so fluid couplings are not required (as in troughs and dishes). The mirrors also do not need to support the receiver, so they are structurally simpler. When suitable aiming strategies are used (mirrors aimed at different receivers at different times of day), this can allow a denser packing of mirrors on available land area. Rival single axis tracking technologies include the relatively new linear Fresnel reflector (LFR) and compact-LFR (CLFR) technologies. The LFR differs from that of the parabolic trough in that the absorber is fixed in space above the mirror field. Also, the reflector is composed of many low row segments, which focus collectively on an elevated long tower receiver running parallel to the reflector rotational axis. Prototypes of Fresnel lens concentrators have been produced for the collection of thermal energy by International Automated Systems. No full-scale thermal systems using Fresnel lenses are known to be in operation, although products incorporating Fresnel lenses in conjunction with photovoltaic cells are already available.

Enclosed parabolic trough: The enclosed parabolic trough solar thermal system encapsulates the components within a greenhouse-like glasshouse. The glasshouse protects the components from the elements that can negatively impact system reliability and efficiency. Lightweight curved solar-reflecting mirrors are suspended from the ceiling of the glasshouse by wires. A single-axis tracking system positions the mirrors to retrieve the optimal amount of sunlight. The mirrors concentrate the sunlight and focus it on a network of stationary steel pipes, also suspended from the glasshouse structure. Water is pumped through the pipes and boiled to generate steam when intense sun radiation is applied. The steam is available for process heat. Sheltering the mirrors from the wind allows them to achieve higher temperature rates and prevents dust from building up on the mirrors as a result from exposure to humidity.

Working of Solar Thermal: A solar thermal power plant in principle works no differently than a conventional Steam power plant. However, there is one important difference. No harm is done to the environment by burning coal, oil, natural gas or by splitting uranium to produce steam. It is produced solely by the energy that comes from the sun. In order to achieve the high temperatures required, solar radiation must be concentrated. Parabolic trough collectors represent the most advanced technology for use in doing this. These troughs are more than 1,300 feet (400 meters) in length and are made up of parabolically shaped mirror segments. The troughs track the sun over the course of the day and focus the resulting radiation along the caustic line of the mirrors onto specially coated, evacuated absorber tube receivers. Solar radiation heats up the thermo-oil that flows through the receiver to a temperature of 400° Celsius so that a downstream heat exchanger is able to generate steam. As in a conventional power plant, the steam is pressurized inside the turbine that drives the generator. Heat storage systems can allow electricity output even if the sun isn't shining.

IV. TECHNOLOGICAL DEVELOPMENT

Nanopillars: A material with a novel nanostructure developed at the University of California, Berkeley could lead to lower-cost solar cells and light detectors. It absorbs light just as well as commercial thin-film solar cells but uses much less semiconductor material. The new material consists of an array of nanopillars that are narrow at the top and thicker at the bottom. The narrow tops allow light to penetrate the array without reflecting off. The thicker bottom absorbs light so that it can be converted into electricity. The design absorbs 99 percent of visible light, compared to the 85 percent absorbed by an earlier design in which the nanopillars were the same thickness along their entire length. An ordinary flat film of the material would absorb only 15 percent of the light. Structures such as nanowires, microwires, and nanopillars are excellent at trapping light, reducing the amount of semiconductor material needed. Nanowires and nanopillars use half to a third as much of the semiconductor material required by thin-film solar cells made of materials such as cadmium telluride, and as little as 1 percent of the material used in crystalline silicon cells. Overall, these improvements could make solar cheaper. "Reducing material costs while achieving the same amount of light absorption and hence efficiency is very important for solar cells.

Nanonets: One problem with solar cells is that they only produce electricity during the day. A promising way to use the sun's energy more efficiently is to enlist it to split water into hydrogen gas that can be stored and then employed at any time, day or night. A cheap new nanostructured material could prove an efficient catalyst for performing this reaction. Called a nanonet because of its two-dimensional branching structure, the material is made up of a compound that has been demonstrated to enable the water-splitting reaction. Because of its high surface area, the nanonet enhances this reaction. The nanonet consists of, structures made up of branching wires of titanium and silicon. Recently the researchers in Germany, showed that titanium disilicide, which absorbs a broad spectrum of visible light, splits water into hydrogen and oxygen–and can store the hydrogen, which it absorbs or releases depending on the temperature. Other semiconducting materials have been tested as water-splitting catalysts but have proved unstable. The nanonets, made up of flexible wires about 15 nanometres thick, grow spontaneously from titanium and silicon flowing through a reaction chamber at high temperatures. The material is 10 times more electrically conductive than its bulk form. Conductivity is an important property for water-splitting catalysts. In preliminary tests, the nanostructured version of the material performs about 100 times better than bulk titanium disilicide.

Powerful solar cells: A new solar cell is 27 percent more efficient without being more expensive to make. Technologies the company which created this technology, claims that it improves the efficiency–a measure of the electricity generated from a given amount of light–of multicrystalline silicon solar cells by 27 percent compared with conventional ones. Such improvement will bring multicrystalline cells to efficiencies about the same as single-crystal cells–around 19.5 percent–at the lower costs. There are 3 methods which improves the efficiency. The first is a method for adding texture to the surface of the cells that allows the silicon to absorb more light, a trick that's been used before with single-crystalline devices but has been difficult to implement with multicrystalline silicon. The rough surface causes light to bend as it enters the cell so that when it encounters the back of the cell, it doesn't reflect right back out; rather, it bounces off at a low angle and remains inside the slab of silicon. The longer the light remains within the silicon, the greater the chance that it will be absorbed and converted into electricity.

Flexible solar cells: A new method for making flexible arrays of tiny silicon solar cells could produce devices that don't suffer this trade-offs. Arrays of these microcells are as efficient as conventional solar panels and may be cheaper to manufacture because they use significantly less silicon. They use a stamp made of a soft polymer to pick up the microbars and place them on a substrate, which may be glass or a flexible plastic, and then fabricate interconnects. A cell thickness of 15 to 20 micrometers struck a good balance: thin enough to be flexible, but thick enough to be mechanically stable and efficient. Arrays of the flexible cells have about 12 percent efficiency.

Solar collectors: Looking to make solar panels cheaper, the glass coated sheets with advanced organic dyes that more efficiently concentrate sunlight have used. The glass sheets can reduce the amount of expensive semiconducting material needed in solar panels and provide a cheap way to extract more energy from high-energy photons, such as those at the blue end of the spectrum. The simple, flat sheets of glass have a number of advantages over previous solar concentrators, devices that gather sunlight over a large area and focus it onto a small solar cell that converts the light into electricity. Solar concentrators in use now employ mirrors or lenses to focus the light. Because the new glass sheets are lighter and flat, they can easily be incorporated into solar panels on roofs or building facades. They could also be used as windows, which, connected to solar cells, could generate electricity. What's more, mirrors and lenses require mechanical systems for tracking the sun to keep the light focused on a small solar cell. These tracking systems add cost and can break down over the decades that solar panels are made to be in service. The flat glass concentrators don't require a tracking system. Instead of using optics, the glass sheets concentrate light using combinations of organic dyes. Light is absorbed by the organic dyes coating one side of the glass sheet. The dyes then emit the light into the glass. The glass channels the light emitted by the dye to the edges of the glass, in the same way that fibre-optic cables channel light over long distances. Narrow solar cells laminated to the edges of the glass collect the light and convert it into electricity. The amount of light concentration depends on the size of the sheet–specifically, the ratio between the size of the surface of the glass and the edges. To a point, the greater the concentration, the less semiconductor material is needed, and the cheaper the solar power.

Nanowire solar cells: They have grown light-absorbing nanowires made of high-performance photovoltaic materials on thin but highly durable carbon-nanotube fabric. They've also harvested similar nanowires from reusable substrates and embedded the tiny particles in flexible polyester film. Both approaches, they argue, could lead to solar cells that are both flexible and cheaper than today's photovoltaics. It is possible to achieve 40 percent efficiency, given the superior ability of such materials to absorb energy from sunlight and the light-trapping nature of nanowire structures. By comparison, current thin-film technologies offer efficiencies of between 6 to 9 percent. The technology relies on nanowires containing multiple layers of exotic Group III-V materials, such as gallium arsenide, indium gallium phosphide, aluminium gallium arsenide, and gallium arsenide phosphide. "It creates tandem or multi-junction solar cells that can absorb a greater range of the [light] spectrum, compared to what you could achieve with silicon. Each nanowire is 10 to 100 nanometres wide and up to five microns long. Their length maximizes absorption, but their nanoscale width permits a much freer movement and collection of electrons.

V. BENEFITS OF SOLAR POWER

i. Solar energy is a clean, renewable resource that is continuously supplied to the earth by the sun.
ii. Solar resources are available everywhere in the world. It gives out no emissions i.e. environmentally safe.
iii. Energy security to the country. No dependency on foreign resources for electricity generation.
iv. Can be permitted and installed faster than other traditional or renewable power plants.
v. Produces local, on-site energy, which reduces the need for extensive high-voltage transmission lines or a complex infrastructure.
vi. Reliable over the long term. With no moving parts, fixed photovoltaic systems last longer than other energy sources.

vii. Clean, quiet and visually unobtrusive in nature. Solar energy plants do not have any polluting emissions, do not make any sound, and are not considered to be an "eyesore."
viii. Uses little to no water in the production of zero-emission electricity.
ix. Has a predictable energy curve and is most efficient when utility rates are at their highest.
x. Can be placed in virtually every geographical region because the sun is available everywhere.
xi. Offsets the need for polluting, expensive and inefficient power plants designed exclusively to meet peak demand.
xii. Creates clean, renewable energy that will sustain and support the health of future generations.
xiii. Is a distributed generation ("DG") energy source that can mitigate national security concerns about energy disruption.
xiv. Supports national energy independence because solar electricity is used where it is generated.
xv. Creates good, local jobs for the new energy economy. In fact, solar energy creates more jobs per megawatt hour than any other energy type.

VI. Bottlenecks of Solar Power Projects:

i. The major disadvantage of solar or any renewable energy is availability. The weather conditions on which the availability is dependent is a major factor. So, we can't say if in a particular time the energy from solar will be available to us or not.
ii. The high capital cost is another factor. Though the cost of setting up of a PV plant has come down considerably, but in comparison to fossil fuel power generation it's still high.
iii. Large land area requirement, which sometimes is not feasible.
iv. Solar thermal needs a considerable amount of water, so, basically to be located near a large water source.
v. Storage problem, suppose the demand of power is not so high, now the electricity produced by the solar plant will have to be stored somewhere to supply it at the time of demand. This increases the cost of the project.

VII. Incentives And Promotional Policies:

- **Incentive mechanisms:** Because the point of grid parity has not yet been reached in many parts of the country, solar generating stations need some form of financial incentive to compete for the supply of electricity. Many stateshave introduced such incentives to support the deployment of solar power stations.
- **Feed-in tariffs:** Feed in tariffs are designated prices which must be paid by utility companies for each kilowatt hour of renewable electricity produced by qualifying generators and fed into the grid. These tariffs normally represent a premium on wholesale electricity prices and offer a guaranteed revenue stream to help the power producer finance the project.
- **Renewable portfolio standards and supplier obligations:** These standards are obligations on utility companies to source a proportion of their electricity from renewable generators. In most cases, they do not prescribe which technology should be used and the utility is free to select the most appropriate renewable sources.
- **Renewable Energy Certificate Mechanism:** The concept of Renewable Energy Certificate (REC) concept seeks to address the mismatch between availability of RE sources and the requirement of the obligated entities to meet their renewable purchase obligation. Renewable Energy Certificate (REC) mechanism is a market based instrument to promote renewable energy and facilitate renewable purchase obligations (RPO). Cost of electricity generation from renewable energy sources is classified as cost of electricity generation equivalent to conventional energy sources and the cost for environmental attributes.
- **Loan guarantees and other capital incentives:** Some government financial institutions offered less targeted financial incentives, available for a wide range of infrastructure investment, such as loan guarantee scheme, which stimulated a number of investments in the solar power plant.
- **Tax credits and other fiscal incentives:** Another form of indirect incentive which has been used to stimulate investment in solar power plant was tax credits available to investors. In some cases the credits were linked to the energy produced by the installations, such as the Production Tax Credits. In other cases the credits were related to the capital investment such as the Investment Tax Credits.

VIII. SOLAR ENERGY STORAGE

Energy storage can be defined as "Storing of energy in a viable form for use later in production of electricity or any other purposes deemed necessary." Energy storage is accomplished by devices or physical media that store energy to perform useful processes at a later time. A device that stores energy is sometimes called an accumulator. Many renewable energy sources (most notably solar and wind) produce infirm or intermittent power. Wherever intermittent power sources reach high levels of grid penetration, energy storage becomes one option to provide firm and reliable energy supplies. Individual energy storage projects augment electrical grids by capturing excess electrical energy during periods of low demand and storing it in other forms until needed on an electrical grid. The energy is later converted back to its electrical form and returned to the grid as needed. (10). Common forms of renewable energy storage include pumped-storage hydroelectricity, which has long maintained the largest total capacity of stored energy worldwide, as well as rechargeable battery systems, thermal energy storage including molten salts which can efficiently store and release very large quantities of heat energy, and compressed air energy storage. Less common, specialized forms of storage include flywheel energy storage systems, the use of cryogenic stored energy, and even superconducting magnetic coils. Solar energy can be stored at high temperatures using molten salts. Salts are an effective storage medium because they are low-cost, have a high specific heat capacity and can deliver heat at temperatures compatible with conventional power systems. The Solar PV used this method of energy storage, allowing it to store 1.44 TJ in its 68 m^3 storage tank with an annual storage efficiency of about 99%. Off-grid PV systems have traditionally used rechargeable batteries to store excess electricity. With grid-tied systems, excess electricity can be sent to the transmission grid, while standard grid electricity can be used to meet shortfalls. Net metering programs give household systems a credit for any electricity they deliver to the grid. The storage of solar energy can be classified in following forms:

Mechanical:
- Compressed air energy storage
- Flywheel energy storage
- Gravitational potential energy storage
- Pumped hydroelectric storage (PHS),

Thermal:
- Cool water, hot water or ice thermal storage.
- Liquid air or liquid nitrogen energy storage or Cryogenic energy storage.
- Molten salt storage.

Chemical:
- Battery, Battery Energy Storage System (BESS), flow battery, secondary battery.
- Hydrogen storage.
- Power to gas.

Electromagnetic:
Storage coil, superconducting storage coil or Superconducting magnetic energy storage

Some types of Solar Energy Storage facilities:

a) **Cryogenic energy storage (CES)** is the use of low temperature (cryogenic) liquids such as liquid air or liquid nitrogen as energy storage. When it is cheaper (usually at night), electricity is used to cool air from the atmosphere to -195 °C using the Claude Cycle to the point where it liquefies. The liquid air, which takes up one-thousandth of the volume of the gas, can be kept for a long time in a large vacuum flask at atmospheric pressure. At times of high demand for electricity, the liquid air is pumped at high pressure into a heat exchanger, which acts as a boiler. Air from the atmosphere at ambient temperature, or hot water from an industrial heat source, is used to heat the liquid and turn it back into a gas. The massive increase in volume and pressure from this is used to drive a turbine to generate electricity.

b) **Molten salt storage** can be employed as a thermal energy storage method to retain thermal energy collected by a solar tower or solar trough so that it can be used to generate electricity in bad weather or at night. It was demonstrated in the Solar Two project from 1995-1999. The system is predicted to have an annual efficiency of 99%, a reference to the energy retained by storing heat before turning it into electricity, versus converting heat directly into electricity. The molten salt mixtures vary. The most extended mixture contains sodium nitrate, potassium nitrate and calcium nitrate. It is non-flammable and non-toxic, and has already been used in the chemical and metals industries as a heat-transport fluid, so experience with such systems exists in non-solar applications. The salt melts at 131 °C. It is kept liquid at 288 °C in an insulated "cold" storage tank. The liquid salt is pumped through panels in a solar collector where the focused sun heats it to 566 °C. It is then sent to a hot storage tank. This is so well insulated that the thermal energy can be usefully stored for up to a week. When electricity is needed, the hot salt is pumped to a conventional steam-generator to produce superheated steam for a turbine/generator as used in any conventional coal, oil or nuclear power plant. A 100-megawatt turbine would need a tank of about 9.1 metres tall and 24 metres in diameter to drive it for four hours by this design.

c) **Battery System:**Without batteries to store energy we would only have power when the sun was shining or the generator was running.

Marine type deep cycle batteries are basically for boats & campers and are suitable for only very small systems. They can be used but do not really have the capacity for continuous service with many charge/discharge cycles for many years. Regular or Car type batteries should not be used at all because they cannot be discharged very much without internal damage. A very popular battery for small systems is the Golf Cart battery. They are somewhat more expensive than deep cycle recreational batteries but are probably the least expensive choice for a small system on a budget.

Flooded type These are Lead acid batteries that have caps to add water. Many manufacturers make these types for Solar Energy use. They are reasonably priced and work well for many years. All flooded batteries release gas when charged and should not be used indoors. If installed in an enclosure, a venting system should be used to vent out the gases which can be explosive.

Gel type Not to be confused with maintenance free batteries, sealed gel batteries have no vents and will not release gas during the charging process like flooded batteries do. Venting is therefore not required and they can be used indoors. This is a big advantage because it allows the batteries to maintain a more constant temperature and perform better.

Absorbed Glass Mat batteries are the best available for Solar Power use. A woven glass mat is used between the plates to hold the electrolyte. They are leak/spill proof, do not out gas when charging, and have superior performance. They have all the advantages of the sealed gel types and are higher quality, maintain voltage better, self discharge slower, and last longer. The Sun Xtender series by Concorde Battery is an excellent example of AGM batteries. They are more expensive, but usually get what pay for it. This type of battery used in airplanes, hospitals, and remote telephone/cell tower installations.

Steam accumulators: A Steam accumulator is an insulated steel pressure tank containing hot water and steam under pressure. It is a type of energy storage device. It can be used to smooth out peaks and troughs in demand for steam. Steam accumulators may take on significance for energy storage in solar thermal energy projects. A solar power tower stores heat in tanks as pressurized steam at 50 bar and 285 °C. The steam condenses and flashes back to steam, when pressure is lowered. Storage is for one hour. The longer storage is possible, but that has not been proven yet in an existing power plant.

Phase change material: A phase-change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage (LHS) units. Phase Change Material (PCMs) offers an alternative solution in energy storage. Using a similar heat transfer infrastructure, PCMs have the potential of providing a more efficient means of storage. PCMs can be either organic or inorganic materials. Advantages of organic PCMs include no corrosives, low or no under cooling, and chemical and thermal stability. Disadvantages include low phase-change enthalpy, low thermal conductivity, and flammability. Inorganics are advantageous with greater phase-change enthalpy, but exhibit disadvantages with under cooling, corrosion, phase separation, and lack of thermal stability. The greater phase-change enthalpy in inorganic PCMs make hydrate salts a strong candidate in the solar energy storage field.

Solar pond: A solar pond is a pool of saltwater which acts as a large-scale solar thermal energy collector with integral heat storage for supplying thermal energy. A solar pond can be used for various applications, such as process heating, desalination, refrigeration, drying and solar power generation. A solar pond is simply a pool of saltwater which collects and stores solar thermal energy. The saltwater naturally forms a vertical salinity gradient also known as a "halocline", in which low-salinity water floats on top of high-salinity water. The layers of salt solutions increase in concentration (and therefore density) with depth. Below a certain depth, the solution has a uniformly high salt concentration. When solar energy is absorbed in the water, its temperature increases, causing thermal expansion and reduced density. If the water were fresh, the low-density warm water would float to the surface, causing convection current. The temperature gradient alone causes a density gradient that *decreases* with depth. However the salinity gradient forms a density gradient that *increases* with depth, and this counteracts the temperature gradient, thus preventing heat in the lower layers from moving upwards by convection and leaving the pond. This means that the temperature at the bottom of the pond will rise to over 90 °C while the temperature at the top of the pond is usually around 30 °C. The main features of solar pond energy storage system are as follows:

- The approach is particularly attractive for rural areas in developing countries. Very large area collectors can be set up for just the cost of the clay or plastic pond liner.
- The evaporated surface water needs to be constantly replenished.
- The accumulating salt crystals have to be removed and can be both a valuable by-product and a maintenance expense.
- No need of a separate collector for this thermal storage system
- The power can be used when it needed.

IX. BENEFITS OF STORAGE SYSTEMS:

- **Security:** A more efficient grid that is more resistant to disruptions.
- **Environment:** Decreased carbon dioxide emissions from a greater use of clean electricity.
- **Economy:** Increase in the economic value of solar power and strengthened competitiveness in the clean energy race.
- **Jobs:** New income sources for rural landowners and tax revenues for solar development areas. More jobs in supporting sectors such as manufacturing, engineering, construction, transportation and finance.
- Peak Demand Reductions.
- Improved asset utilization.
- Air emission reductions.
- Improved reliability.

X. BARRIERS TO THE DEVELOPMENT AND UTILIZATION OF SOLAR ENERGY TECHNOLOGIES

There are so called barriers that tend to weaken the adoption of solar energy technologies for electricity generation and thermal utilization purposes. These barriers are classified broadly as technical, economic, and institutional.

Technical Barriers

Solar PV

i. The efficiency constraint is one of the main barriers to widespread use. The thin-film and crystalline-silicon modules have efficiency ranges of 7% to 10% and 12% to 18% respectively. Even as PV technologies with significantly higher efficiencies are under development, the present efficiency ranges constitute a barrier.
ii. Strong demand for PV outpaced the supply and partly stalled the growth of solar sector. However, the resulting surge in production combined with the present financial crisis has created an industry wide.
iii. The performance limitations of balance of system components, of solar PV system such as batteries, inverters and other power-conditioning equipment are another area with considerable room for improvement.

iv. Lack of clarity regarding technical limits of exporting power to the grid and network grid protection requirements for PV systems to safely export power.
v. In the case of stand-alone PV systems, storage is an important concern as is the shorter battery life compared to that of the module. Further, safe disposal of batteries becomes difficult in the absence of a structured disposal/recycling process.
vi. Lack of proper information about the utilization of solar electric systems, especially PV, For instance, incorrect charging techniques such as polarity reversal were seen as frequent problems that damaged the junction boxes of the PV panel. It was observed that cracks in the glass of the PV module, water intrusion during rainy season, dust and algal growth accumulating along the lower section of the panels also constituted some of the major problems of PV systems.
vii. When the PV systems are promoted, especially from government sponsored programs, very little care is given to the potential load of the prospective user‘s household. People have been found to install more bulbs than the specified number. In addition, in many cases it was found that the replacement for a fused CFL bulb was a cheaper incandescent one. This resulted in faster drainage of the battery. It has also been observed that in an effort to overcharge‘ the battery, the charge controller is bypassed. Such practices reduce the battery life and require investment in a new battery.

Solar thermal

i. In the case of solar thermal parabolic trough systems, one of the most proven solar power technology, the upper process temperature is limited by the heat carrying capacity of the thermal oil used for heat transfer. Thermal loss from heat storage in such system remains an important technical challenge in solar thermal technologies.
ii. In case of central receiver systems of solar thermal the technologies such as the molten saltin-tube receiver technology and the volumetric air receiver technology, both with energy storage system needs more experience to be put for large-scale application.
iii. With regard to solar thermal application for space and water heating, thermal losses from heat storage is an important challenge. It was observed that the losses were up to five times greater than originally expected. In addition many of solar thermal designs are put to market without assessing appropriateness of people‘s needs and without proper education related to its efficient use. Lack of trained manpower to install and maintain such systems has also been a persistent concern.
iv. Another barrier to solar air and water heating applications especially in industrialized countries is the lack of integration with household appliances.

Economic Barriers

Solar PV

i. While solar PV has zero fuel cost, low O&M costs and is competitive on a life-cycle cost basis, the high initial upfront cost and unavailability of easy and consistent financing options forms a prime barrier.
ii. Cost comparisons are often made against established conventional technologies that benefit from direct and indirect subsidies, accumulated industry experience, economies of scale and uncounted externality costs.
iii. Unusually high risks are assessed in determinations by finance institutions because of their lack of experience with PV projects.
iv. Bias against distributed technology platforms among conventional energy agencies and utilities. Thus, in less wealthy countries, limited sources of investment finance are directed towards conventional energy technologies.
v. The cost of the module may decline but may not be matched by a proportional decline in Balance of System costs.
vi. Power tariffs are subsidized for certain sectors of the economy (e.g. agriculture) and/or certain income groups. As such the use of PV to serve these market segments is at a disadvantage.

Solar Thermal

i. High upfront and maintenance costs constitute significant barriers. This is particularly relevant for poorer potential customers.
ii. The lengthy payback periods and small revenue stream also raises creditworthiness risks of such systems.
iii. The bias against distributed energy technology platforms among conventional energy agencies and utilities
iv. In the case of solar thermal applications, diffusion can be hindered by gaps in technical and financial data needed for accurate planning and implementation of projects.

XI. Recommendations

The capital cost of the solar power system is higher then the conventional source of energy. Efforts are required to be made for reduction of capital cost of solar power projects to make it comparable with conventional source of energy. Most of the State Electricity Regulatory Commissions issued the tariff order for purchase of power from solar power projects. The other States, those having potential of solar energy also required to issue solar energy tariff to accelerate and attract the investment in this field. It may also be concluded that solar energy development is of great importance from the point of view of long term energy supply security, decentralization of energy supply particularly for the benefit of the rural population, environmental benefits and sustainability. For faster development of solar energy, following recommendations are necessary to implement

- A strong need to improve reliability of technologies and introduce consumer-desired features (in terms of services and financial commitments) in the design and sales package.

- Although solar energy is comparatively more expensive than conventional fuels, but it can be used in distributed generation and local distribution networks to counterbalance the transmission & distribution (T&D) losses incurred by states depend on government support for development.
- Incorporation of solar energy strategy into development programmers will promote its decentralized applications.
- The government policies should encourage more private participation and industry collaboration in R&D for rapid commercialization of solar energy and in market infrastructure development.
- Public-private role in solar energy development needs to be redefined. Solar energy deployment could also be enhanced from energy services delivery perspective.

XII. Conclusion

Solar power is infirm power and efforts are required to be made it firm power by developing appropriate storage facilities. The solar power can also make a viable source of energy by announcing the suitable policies incentives. Re-powering has to be a part of any strategy to scale-up solar power capacity as it is vital to optimally utilize high solar radiation sites that remain unused due to less effort by the government and investing companies and to retrofit or replace the old panels with modern, large and higher, more efficient ones. This will have to go along side efforts to develop and facilitate introduction of a new generation of solar panels that can harness the potential from sustained low to medium solar radiation regimes available in abundant measure in large parts of the country. Such efforts may require revisiting role and mandate of Jawahar Lal Nehru Solar Mission (JNNSM) and to position an institution that can lead new initiatives in solar resources assessment and technology development

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Authors

First Author – Ashok Upadhyay has Graduation degree in Electrical Engineering, degree of Master in Engineering in Industrial Engineering and having degree of M. Phil in Renewable Energy. The main author is certified Energy Manager accredited by BEE, Govt. of India. The Author is working as Dy. Director (Generation) in M.P. Electricity Regulatory Commission, Bhopal. The main author is currently pursuing PHD program in electrical engineering from MANIT, Bhopal, Madhya Pradesh, India, PH-09893324160.
E-mail:ashok.upadhyay06@gmail.com

Second Author – Arnab Chowdhury Pursuing MBA (Power Mgmt.), University of Petroleum and Energy Studies., Dehradun, Uttarkhand, chowdhury6698@gmail.com