Solar Energy Info-kit
2008

ENVIS Centre
on
Renewable Enerngy and Environment

Solar Energy Info-kit

Contents

Chapter 1: Basics of solar energy

1.1 Introduction

Solar power (also known as solar energy) is the technology of obtaining usable energy from the light of the sun. Solar energy has been used in many traditional technologies for centuries, and has come into widespread use where other power supplies are absent, such as in remote locations and in space. Solar energy can be used in a number of applications including

- Heat (hot water, building heat, cooking)
- Electricity generation (photovoltaics, heat engines)
- Desalination of seawater
- Plant's lifecycle

Indirectly, the sun is responsible for all our energy. Plants use the sun's light to make food, animals eat plants for food, decaying plants hundreds of millions of years ago produced the coal, oil and natural gas that we use today. So, fossil fuels is actually sunlight stored millions and millions of years ago.

1.2 Benefits of solar energy

Solar power is an extremely clean way to generate electricity. There are no air emissions associated with the operation of solar modules or direct application technologies. Residential-scale passive construction, photovoltaic, solar water heating, and other direct applications reduce power generation from traditional sources and the associated environmental impacts.

Solar thermal energy

Solar Thermal is one of the best ways to lower your carbon footprint and help protect the environment. Typically over 20% of a home's Green house gas emissions come from heating water. For many commercial businesses, such as fitness centers, water heating can account for over 50% of green-house emissions.

A solar water heater is one of the most influential and economical ways to reduce your greenhouse gas emissions. For example, a two collector solar thermal system will offset the same amount of greenhouse gasses as a 2.5 KW solar electric system at a fraction of the cost.

Following are a few of the environmental reasons to install a solar thermal system:

- Reduce Greenhouse gas emissions:

- 2-collector domestic hot water system can offset over 2 tons of CO_2 per year or 50 tons over life of system
- 10-collector pool system can offset over 8 tons per year
- On-site generation: Reduce the need to mine and transport fossil-fuel energy
- Local products: Many solar thermal collectors are manufactured locally
- Increased water heater life expectancy

When comparing the relative merits of water heating systems it is important to differentiate capital costs and running costs. The relative importance of capital and running costs to the end user will affect the overall economic merit of each different system. Conventional water heater systems tend to be cheap to install (due to the maturity of the technology and the market), but require the purchase of fuel. Fuel prices are currently low, but trends are upwards. Solar thermal heater systems tend to be more expensive to install (smaller number of manufacturers and installers), but incur no fuel costs.

A solar thermal system will incur very low running costs, and the payback on the capital cost will be even better if the fuel costs for comparative oil or gas systems go up over time.

Photovoltaic systems

Photovoltaics (PV) is an important energy technology for many reasons. As a solar energy technology, it has numerous environmental benefits. As a domestic source of electricity, it contributes to the nation's energy security. As a relatively young, high-tech industry, it helps to create jobs and strengthen the economy. As it costs increasingly less to produce and use, it becomes more affordable and available. And there are many more reasons, as we shall see.

Few power-generation technologies have as little impact on the environment as photovoltaics. As it quietly generates electricity from light, PV produces no air pollution or hazardous waste. It doesn't require liquid or gaseous fuels to be transported or combusted. And because its energy source - sunlight - is free and abundant, PV systems can guarantee access to electric power.

PV frees us from the cost and uncertainties surrounding energy supplies from politically volatile regions. And in addition to reducing our trade deficit, a robust domestic PV industry creates new jobs and strengthens the U.S. economy.

- It's highly reliable and needs little maintenance.
- It costs little to build and operate.
- It has virtually no environmental impact.
- It's produced domestically, strengthening our economy and reducing our trade deficit.
- It's modular and thus flexible in terms of size and applications.
- It meets the demand and capacity challenges facing energy service providers.
- It helps energy service providers manage uncertainty and mitigate risk.
- It serves both form and function in a building.

Solar thermal power vs PV power

Solar water heating has 4 to 5 times the power density of PV. An average 40 square foot Skyline water heater produces thermal energy in an amount equal to the energy of a 2kW Photovoltaic system at a fraction of the cost. Solar water heating is a perfect complement to a photovoltaic system because it doubles the energy output of an average 2kW system, at a fraction of the cost.

1.3 History and development of solar energy

Although the sun has always been the ultimate source of most of the earth's energy, until very recently plants did the job of capturing its power--in wood, coal, natural gas, and oil. Inventions like Nicholas de Saussure's 18th-century solar oven were no more than scientific curiosities; the direct use of solar energy was limited mainly to such commonsense ploys as positioning houses to catch the sun's rays.

That prediction stumbled on formidable obstacles: solar energy's own underdeveloped technology and manufacturing, distribution, and maintenance systems; the coal, oil, and natural gas industries, suppliers of cheap energy; and the developing nuclear power industry, backed by the Atomic Energy Commission. Solar energy could not compete, and nobody seemed interested in investing big money for research to lower the cost and improve the performance of solar devices.

This chronology lists the milestones in the historical development of solar technology:

Table-1: Chronology of solar energy development

Time	Activities
7th Century B.C.	A magnifying glass is used to concentrate the sun's rays on a fuel and light a fire for light, warmth, and cooking.
3rd Century B.C.	Greeks and Romans use mirrors to light torches for religious purposes.
2nd Century B.C.	As early as 212 B.C., Greek scientist Archimedes makes use of the reflective properties of bronze shields to focus sunlight and set fire to Rome's wooden ships, which were besieging Syracuse. (Although there is no proof that this actually happened, the Greek navy recreated the experiment in 1973 and successfully set fire to a wooden boat 50 meters away).
A.D. 20	The Chinese report using mirrors to light torches for religious purposes.
1st to 4th Century	In the first to the fourth centuries, Roman bathhouses are built with large, south-facing windows to let in the sun's warmth.
6th Century	Sunrooms on houses and public buildings are so common that the Justinian Code establishes "sun rights" to ensure that a building has access to the sun.
13th Century	In North America, the ancestors of Pueblo people known as *Anasazi* build south-facing cliff dwellings that capture the warmth of the winter sun. This timeline lists many milestones in the historical development of solar technology from 1767 to

	1891.
1767	Swiss scientist Horace de Saussure is credited with building the world's first solar collector, later used by Sir John Herschel to cook food during his South African expedition in the 1830s.
1816	On September 27, 1816, Robert Stirling applies for a patent for his economiser at the Chancery in Edinburgh, Scotland. A minister in the Church of Scotland until. the age of 86, Stirling builds heat engines in his home workshop in his spare time. Lord Kelvin uses one of the working models in some of his university classes. This engine is later used in the dish/Stirling system, a solar thermal electric technology that concentrates the sun's thermal energy to produce electric power.
1839	French scientist Edmond Becquerel discovers the photovoltaic effect while experimenting with an electrolytic cell made up of two metal electrodes placed in an electricity-conducting solution; the electricity generation increases when exposed to light.
1860	French mathematician August Mouchet proposes an idea for solar-powered steam engines. In the next two decades, he and his assistant, Abel Pifre, will construct the first solar-powered engines for a variety of uses. The engines are the predecessors of modern parabolic dish collectors.
1873	Willoughby Smith discovers the photoconductivity of selenium.
1876	William Grylls Adams and Richard Evans Day discover that selenium produces electricity when exposed to light. Although selenium solar cells fail to convert enough sunlight to power electrical equipment, they prove that a solid material can change light into electricity without heat or moving parts.
1880	Samuel P. Langley invents the bolometer, used to measure light from the faintest stars and the sun's heat rays. It consists of a fine wire connected to an electric circuit. When radiation falls on the wire, it becomes slightly warmer, and this increases the electrical resistance of the wire.
1883	American inventor Charles Fritts describes the first solar cells made of selenium wafers.
1887	Heinrich Hertz discovers that ultraviolet light alters the lowest voltage capable of causing a spark to jump between two metal electrodes.
1891	Baltimore inventor Clarence Kemp patents the first commercial solar water heater.
1860s	French mathematician August Mouchet proposes an idea for solar-powered steam engines. In the next two decades, he and his assistant, Abel Pifre, will construct the first solar-powered engines for a variety of uses. The engines are the predecessors of modern parabolic dish collectors.
1904	Wilhelm Hallwachs discovers that a combination of copper and cuprous oxide is photosensitive.
1905	Albert Einstein publishes his paper on the photoelectric effect, along with a paper on his theory of relativity.
1908	William J. Bailley of the Carnegie Steel Company invents a solar collector with copper coils and an insulated box, which is roughly the same collector design used today.
1914	The existence of a barrier layer in photovoltaic devices is noted.
1916	Robert Millikan provides experimental proof of the photoelectric effect.
1918	Polish scientist Jan Czochralski develops a way to grow single-crystal silicon.
1921	Albert Einstein wins the Nobel Prize for his theories explaining the photoelectric effect.

1932	Audobert and Stora discover the photovoltaic effect in cadmium sulfide.
1947	Because energy had become scarce during the long Second World War, passive solar buildings in the United States are in demand; Libbey-Owens-Ford Glass Company publishes a book titled, Your Solar House, which profiles 49 of the nation's greatest solar architects.
1953	Dr. Dan Trivich of Wayne State University makes the first theoretical calculations of the efficiencies of various materials of different band-gap widths based on the spectrum of the sun.
1954	Photovoltaic technology is born in the United States when Daryl Chapin, Calvin Fuller, and Gerald Pearson develop the silicon photovoltaic (or PV) cell at Bell Labs — the first solar cell capable of generating enough power from the sun to run everyday electrical equipment. Bell Telephone Laboratories then produces silicon solar cell with 6% efficiency and later, 11% efficiency.
1955	Western Electric begins to sell commercial licenses for silicon photovoltaic technologies. Early successful products include PV-powered dollar bill changers and devices that decode computer punch cards and tape.
Mid-1950s	Architect Frank Bridgers designs the world's first commercial office building featuring solar water heating and passive design. The solar system has operated continuously since then; the Bridgers-Paxton Building is listed in the National Historic Register as the world's first solar-heated office building.
1956	William Cherry of U.S. Signal Corps Laboratories approaches RCA Labs' Paul Rappaport and Joseph Loferski about developing photovoltaic cells for proposed Earth-orbiting satellites.
1957	Hoffman Electronics achieves 8% efficient photovoltaic cells.
1958	T. Mandelkorn of U.S. Signal Corps Laboratories fabricates n-on-p (negative layer on positive layer) silicon photovoltaic cells, making them more resistant to radiation; this is critically important for cells used in space. Hoffman Electronics achieves 9% efficient photovoltaic cells. A small PV array (less than one watt) on the Vanguard I space satellite powers its radi Later that year, Explorer III, Vanguard II, and Sputnik-3 will be launched with PV-powered systems on board. Silicon solar cells become the most widely accepted energy source for space applications, and remain so today.
1959	Hoffman Electronics achieves a 10% efficient, commercially available photovoltaic cell. Hoffman also learns to use a grid contact, significantly reducing the series resistance. On August 7, the Explorer VI satellite is launched with a PV array of 9600 solar cells, each measuring 1 cm x 2 cm. On October 13, Explorer VII is launched.
1960	Hoffman Electronics achieves 14% efficient photovoltaic cells. Silicon Sensors, Inc., of Dodgeville, Wisconsin, is founded and begins producing selenium and silicon photovoltaic cells.
1962	Bell Telephone Laboratories launches Telstar, the first telecommunications satellite; its initial power is 14 watts.
1963	Sharp Corporation succeeds in producing practical silicon PV modules. Japan installs a 242-watt photovoltaic array, the world's largest to date, on a lighthouse.
1964	NASA launches the first Nimbus spacecraft—a satellite powered by a 470-watt photovoltaic array.
1965	Peter Glaser conceives the idea of the satellite solar power station.
1966	NASA launches the first Orbiting Astronomical Observatory powered by a 1-kilowatt photovoltaic array; it provides astronomical data in the ultraviolet and X-ray wavelengths filtered out by Earth's atmosphere.

1969	A "solar furnace" is constructed in Odeillo, France; it features an eight-story parabolic mirror.
1970s	With help from Exxon Corporation, Dr. Elliot Berman designs a significantly less costly solar cell, bringing the price down from $100 per watt to $20 per watt. Solar cells begin powering navigation warning lights and horns on offshore gas and oilrigs, lighthouses, and railroad crossings. Domestic solar applications are considered good alternatives in remote areas where utility-grid connections are too costly.
1972	French workers install a cadmium sulfide photovoltaic system at a village school in Niger. The Institute of Energy Conversion is established at the University of Delaware to do research and development on thin-film photovoltaic and solar thermal systems, becoming the world's first laboratory dedicated to PV R&D.
1973	The University of Delaware builds "Solar One," a PV/thermal hybrid system. Roof-integrated arrays feed surplus power through a special meter to the utility during the day; power is purchased from the utility at night. In addition to providing electricity, the arrays are like flat-plate thermal collectors; fans blow warm air from over the array to heat storage bins.
1976	The NASA Lewis Research Center starts installing the first of 83 photovoltaic power systems on every continent except Australia. They provide power for vaccine refrigeration, room lighting, medical clinic lighting, telecommunications, water pumping, grain milling, and classroom television. The project takes place from 1976 to 1985 and then from 1992 to completion in 1995. David Carlson and Christopher Wronski of RCA Laboratories produce the first amorphous silicon photovoltaic cells, which could be less expensive to manufacture than crystalline silicon devices.
1977	In July, the U.S. Energy Research and Development Administration, a predecessor of the U.S. Department of Energy, launches the Solar Energy Research Institute (today's National Renewable Energy Laboratory), a federal facility dedicated to finding and improving ways to harness and use energy from the sun. Total photovoltaic manufacturing production exceeds 500 kilowatts; 1 kilowatt is enough power to light about ten 100-watt light bulbs.
1978	NASA's Lewis Research Center installs a 3.5-kilowatt photovoltaic system on the Papago Indian Reservation in southern Arizona—the world's first village PV system. It provides power for water pumping and residential electricity in 15 homes until 1983, when grid power reaches the village. The PV system is then dedicated to pumping water from a community well.
1980	ARCO Solar becomes the first company to produce more than 1 megawatt (a thousand kilowatts) of photovoltaic modules in one year. At the University of Delaware, the first thin-film solar cell exceeds 10% efficiency; it's made of copper sulfide and cadmium sulfide.
1981	Paul MacCready builds the first solar-powered aircraft — the Solar Challenger — and flies it from France to England across the English Channel. The aircraft has more than 16,000 wing-mounted solar cells producing 3,000 watts of power.
1982	The first megawatt-scale PV power station goes on line in Hisperia, California. The 1-megawatt capacity system, developed by ARCO Solar, has modules on 108 dual-axis trackers. Australian Hans Tholstrup drives the first solar-powered car — the Quiet Achiever — almost 2,800 miles between Sydney and Perth in 20 days — 10

	days faster than the first gasoline-powered car to do so. Tholstrup is the founde of a world-class solar car race, Australia's World Solar Challenge. In California the U.S. Department of Energy and an industry consortium begin operating Solar One, a 10-megawatt central-receiver demonstration project. It establishes the feasibility of power-tower systems, a solar-thermal electric or concentrating solar power technology. In 1988, the final year of operation, the system could be dispatched 96% of the time.
1983	ARCO Solar dedicates a 6-megawatt photovoltaic substation in central California. The 120-acre, unmanned facility supplies Pacific Gas & Electric Company's utility grid with enough power for up to 2,500 homes. Solar Design Associates completes a home powered by an integrated, stand-alone, 4-kilowatt photovoltaic system in the Hudson River Valley. Worldwide, photovoltaic production exceeds 21.3 megawatts, and sales top $250 million.
1984	The Sacramento Municipal Utility District commissions its first 1-megawatt photovoltaic electricity generating facility.
1985	Researchers at the University of South Wales break the 20% efficiency barrier for silicon solar cells.
1986	The world's largest solar thermal facility is commissioned in Kramer Junction, California. The solar field contains rows of mirrors that concentrate the sun's energy onto a system of pipes circulating a heat transfer fluid. The heat transfer fluid is used to produce steam, which powers a conventional turbine to generate. This solar power plant in Kramer Junction, California, is the largest of nine built in the 1980s. Oil in the receiver tubes collects the concentrated solar energy as heat and is pumped to the power plant to generate electricity. ARCO Solar releases the G-4000 — the world's first commercial thin-film module.
1988	Dr. Alvin Marks receives patents for two solar power technologies: Lepcon and Lumeloid. Lepcon consists of glass panels covered with millions of aluminum or copper strips, each less than a thousandth of a millimeter wide. As sunlight hits the metal strips, light energy is transferred to electrons in the metal, which escape at one end in the form of electricity. Lumeloid is similar but substitutes cheaper, film-like sheets of plastic for the glass panels and covers the plastic with conductive polymers.
1991	President George Bush announces that the U.S. Department of Energy's Solar Energy Research Institute has been designated the National Renewable Energy Laboratory.
1992	Researchers at the University of South Florida develop a 15.9% efficient thin-film photovoltaic cell made of cadmium telluride, breaking the 15% barrier for this technology. A 7.5-kilowatt prototype dish system that includes an advanced stretched-membrane concentrator begins operating.
1993	Pacific Gas & Electric installs the first grid-supported photovoltaic system in Kerman, California. The 500-kilowatt system is the first "distributed power" PV installation.
1994	The first solar dish generator to use a free-piston Stirling engine is hooked up to a utility grid. The National Renewable Energy Laboratory develops a solar cell made of gallium indium phosphide and gallium arsenide; it's the first one of its kind to exceed 30% conversion efficiency.
1996	The world's most advanced solar-powered airplane, the Icare, flies over

	Germany. Its wings and tail surfaces are covered by 3,000 super-efficient solar cells, for a total area of 21 square meters. The U.S. Department of Energy and an industry consortium begin operating Solar Two — an upgrade of the Solar One concentrating solar power tower. Until the project's end in 1999, Solar Two demonstrates how solar energy can be stored efficiently and economically so power is produced even when the sun isn't shining; it also spurs commercial interest in power towers.
1998	On August 6, a remote-controlled, solar-powered aircraft, "Pathfinder," sets an altitude record of 80,000 feet on its 39th consecutive flight in Monrovia, California — higher than any prop-driven aircraft to date. Subhendu Guha, a scientist noted for pioneering work in amorphous silicon, leads the invention of flexible solar shingles, a roofing material and state-of-the-art technology for converting sunlight to electricity on buildings.
1999	Spectrolab, Inc., and the National Renewable Energy Laboratory develop a 32.3% efficient solar cell. The high efficiency results from combining three layers of photovoltaic materials into a single cell, which is most efficient and practical in devices with lenses or mirrors to concentrate the sunlight. The concentrator systems are mounted on trackers to keep them pointed toward the sun. Researchers at the National Renewable Energy Laboratory develop a record-breaking prototype solar cell that measures 18.8% efficient, topping the previous record for thin-film cells by more than 1%. Cumulative installed photovoltaic capacity reaches 1000 megawatts, worldwide.
2000	Industry Researchers develop a new inverter for solar electric systems that increases safety during power outages. Inverters convert the direct current (DC) electrical output of solar systems to alternating current (AC) — the standard for household wiring as well as for power lines to homes. Two new thin-film solar modules developed by BP Solarex break previous performance records. The company's 0.5-square-meter module has a 10.8% conversion efficiency — the highest in the world for similar thin-film modules. Its 0.9-square-meter module achieves 10.6% efficiency and a power output of 91.5 watts — the highest in the world for a thin-film module. The 12-kilowatt solar electric system of a Morrison, Colorado, family is the largest residential installation in the United States to be registered with the U.S. Department of Energy's Million Solar Roofs program. The system provides most of the electricity for the family of eight's 6,000-square-foot home.

2001	The National Space Development Agency of Japan, NASDA, announces plans to develop a satellite-based solar power system that beams energy back to Earth. A satellite with large solar panels would use laser technology to transmit solar power to an airship at an altitude of about 12 miles; the airship would then transmit power to Earth. TerraSun LLC develops a unique method of using holographic films to concentrate sunlight onto a solar cell. Fresnel lenses or mirrors are usually used to concentrate sunlight, but TerraSun claims that holographic optics are more selective, allowing light not needed for power production to pass through the transparent modules so they can be used as skylights. PowerLight Corporation connects the world's largest hybrid solar-wind power system to the grid in Hawaii. Its solar energy capacity — 175 kilowatts — is larger than its wind energy capacity — 50 kilowatts; this is somewhat unusual for hybrid power systems. British Petroleum and BP Solar announce the opening of a service station in Indianapolis that features a solar-electric canopy. The station is the first U.S. "BP Connect" store, a model that BP intends to use for new or revamped BP service stations. The canopy contains translucent photovoltaic modules made of thin films of silicon deposited on glass.
2002	NASA conducts two successful tests of a solar-powered, remote-controlled aircraft called Pathfinder Plus. In July, researchers demonstrate the aircraft's use as a high-altitude platform for telecommunications technologies. In September, it's tested for use as an aerial imaging system for coffee growers. The Union Pacific Railroad installs 350 blue-signal rail yard lanterns, which incorporate energy-saving light-emitting diode (LED) technology and solar cells, at the large North Platt, Nebraska, rail yard. ATS Automation Tooling Systems Inc. in Canada begins commercializing spheral solar technology. Employing tiny silicon beads bonded between two sheets of aluminum foil, this solar-cell technology uses much less silicon than conventional multi-crystalline silicon solar cells, thus potentially reducing costs. The technology was first championed in the early 1990s by Texas Instruments, but TI later discontinued work on it. For more, see the DOE Photovoltaic Manufacturing Technology Web site. The largest solar power facility in the Northwest — the 38.7-kilowatt White Bluffs Solar Station — goes online in Richland, Washington. PowerLight Corporation installs the largest rooftop solar power system in the United States — a 1.18-megawatt system at the Santa Rita Jail in Dublin, California.

1.4 Solar energy applications

The following table shows some applications of solar energy, who uses it and how the energy is obtained. Not all applications listed exist in Canada and this is not a complete list of all solar energy applications in use around the world.

Table-2: Solar technology applications

What is solar energy used for?	Where is it used?	Which solar technologies are used?	Which secondary technologies are used? (where applicable)
Heating - Water	Homes	Glazed flat plate collectors Batch collectors Vacuum tube collectors	Heat exchanger Hot water tank
	Commercial	Liquid-based collectors	Heat exchanger Medium-large water tank
	Agriculture	Glazed flat plate collectors Unglazed flat plate collectors	Heat exchanger Medium-large water tank
	Aquaculture	Unglazed flat plate collectors	Medium-large water tank
Heating - Swimming Pools	Outdoor pools	Unglazed flat plate collectors	
	Indoor pools	Glazed flat plate collectors	Heat exchanger
Heating - Ventilation Air	All building types	all Air-based collectors	By-pass dampers Make-up air handling units
Heating - Buildings	Homes / Commercial	Advanced windows Transparent insulation	Appropriate building materials Building design
		Trombe wall	
		Liquid-based collectors with home heating system	Heat exchanger Advanced thermal storage
	Community-wide	Liquid-based collectors large-scale arrays	Seasonal thermal storage District heating network
	Greenhouses	Transparent insulation	
Cooling - Buildings	Commercial	Vacuum tube collectors Glazed flat plate collectors	Cooling cycles - various
Daylighting - Buildings	Homes & Commercial	Advanced windows Transparent insulation	Building design
Crop Drying	Agricultural	all Air-based collectors	
Electricity Generation - Off Grid	Cottages / Seasonal homes	Photovoltaics – small arrays	Batteries Power Invertors Small wind turbines or microhydro

	Power for remote equipment	Photovoltaics – small-medium arrays	
Electricity Generation - Distributed Power	All building types	Photovoltaics – building integrated medium-scale arrays	Power Invertors
	Remote communities	Photovoltaics – medium-scale arrays in a hybrid system	▫ combined with diesel generators on local grid
	Electric Utilities	Photovoltaics - large-scale arrays	Power Invertors Sun trackers
		▫ Power tower ▫ Parabolic trough	▫ Steam turbine ▫ High temperature thermal storage
▫ Detoxifying - Water	▫ Industrial / Municipal	▫ Photocatalysts for oxidation	▫ UV lamps for backup
		▫ Thermal catalysts for oxidation with concentrating collectors	
▫ Detoxifying - Air	▫ Commercial / Homes	▫ Photocatalysts for oxidation	▫ UV lamps for backup
▫ Cooking food & H2O treatment	▫ Homes	▫ Solar cookers	

Chapter 2: Environmental impact & barriers in solar technologies use

It is known by all that the use of solar energy is going to increase in many different applications in the coming years. There are several reasons for this trend. Firstly, solar energy is an inexpensive, clean and inexhaustible resource. In addition, sustainable development, which is a goal of many governments and industries for the near future, implies a change in the operation and running of industrial processes, for a significant reduction in their environmental impact.

2.1 Environmental impact

Solar Energy technologies (SETs) and mitigation process

Solar energy technologies (SETs) provide obvious environmental advantages in comparison to the conventional energy sources, thus contributing to the sustainable development of human activities their main advantage is related to the reduced CO2 emissions, and, normally, absence of any air emissions or waste products during their operation.

Concerning the environment, the use of SETs has additional positive implications such as:

- Reduction of the emissions of the greenhouse gases (mainly CO2,NO x) and prevention of toxic gas emissions (SO2,particulates)
- Reclamation of degraded land;
- Reduction of the required transmission lines of the electricity grids; and
- Improvement of the quality of water resources

In regard the socio-economic viewpoint the benefits of the exploitation of SETs comprise:

- Increase of the regional/national energy independency;
- Provision of significant work opportunities;
- Diversification and security of energy supply;
- Support of the deregulation of energy markets; and
- Acceleration of the rural electrification in developing countries.

Solar thermal heating systems

The production of solar thermal (ST) systems requires reasonable quantities of materials, insignificant amounts are also consumed during their operation; at that time the only potential environmental pollutant arises from the coolant change, which can be easily controlled by good working practice. The accidental leakage of coolant systems can cause .re and gas releases from vaporized coolant, unfavorably affecting public health and safety.

Land Use

In the case of single-dwelling hot water or space heating/cooling, no land will be required since the system will usually be added to the roof of the existing building. Communal low-temperature systems might use some land, though again the collection surfaces might well be added on already existing buildings. For high temperature systems, the land-use requirements of concentrating collectors providing process heat are more problematical.

Routine and accidental discharges of pollutants

Higher temperature applications would use more complex substances, such as aromatic alcohols, oils, CFCs, etc. The large-scale adoption of SETs might well require control on the disposal of these substances. Except for the normal use, there may be the risk of accidental water pollution through leaks of heat transfer fluid.

Visual Impact

Architects have discovered that solar elements can be used to enhance the aesthetic appeal of a building, and their clients have discovered the positive effects of advertising the fact that they are using solar energy. The solar elements are used as architectural elements in attractive and visible ways.

Effect on buildings

Theoretically the ST placement in the shell of the buildings could increase fire risk and water intrusion into the roof. This can be easily avoided, since only four holes per panel on the roof will be integral part of the roof.

Other Burdens

Other burdens applicable to central power systems only (e.g. noise—during the construction period, visual intrusion, etc.) are likely to prove insignificant (provided areas of scenic beauty are avoided), be cause such schemes are likely to be situated in those areas of low population density.

Therefore, all the impacts of suitably located large ST schemes are expected to be small and reversible.

Photovoltaic power generation

Photovoltaic (PV) are seen to be generally of benign environmental impact, generate no noise or chemical pollutants during use. It is one of the most viable renewable energy technologies for use in an urban environment, replacing existing building cladding materials.

Land Use

An application of a PV system in once-cultivable land is possible to damnify soil productive areas. The ‘‘sentimental bind’’ of the cultivator and his cultivable land is likely to be the reason of several social disagreements and displeasure.

Routine and accidental discharges of pollutants

During their normal operation PV systems emit no gaseous or liquid pollutants, and no radioactive substances. In the case of CIS and CdTe modules, which include small quantities of toxic substances, there is a potential slight risk that a .re in an array might cause small amounts of these chemicals to be released into the environment.

Air Pollution

PV systems also assist to create a supportive environment within which to encourage other means of energy saving by the building promoters, owner s and users. PV energy services are particularly obvious where only low levels of power are needed, such as in rural electrification applications, and where the users are able to benefit directly from the very high reliability of having their own PV generator.

Noise Intrusion

As with all types of construction activity, there will be little noise. Manufacturers should be encouraged to produce systems that are easily recyclable. Options for energy demand reduction must always be considered along with the assessment of PV applications.

Visual Impacts

Visual intrusion is highly dependent on the type of the scheme and the surroundings of the PV systems. It is obvious that, if we apply a PV system near an area of natural beauty, the visual impact would be significantly high. In case of modules integrated into the facade of buildings, there may be positive aesthetic impact on modern buildings in comparison to historic buildings or buildings with cultural value.

Depletion of natural resources

The Cd emissions attributed to CdTe production amount to 0.001% of Cd used (corresponding to 0.01 g/GWh). Furthermore Cd is produced as a byproduct of Zn production and can either be put to beneficial uses or discharged into the environment schemes during the operational phase.

Waste management

A life cycle analysis of batteries for stand-alone PV systems indicates that the batteries are responsible for most of the environmental impacts, due to their relatively short life span and their heavy metal content.

Solar thermal electricity

ST electricity systems present the basic environmental benefit of the displacement or the avoidance of emissions associated with conventional electricity generation. During their operation, these systems have no emissions. Some emissions do arise from other phases of their life cycle (primarily materials processing and manufacture), but they are lower, compared to those avoided by the systems operation.

Materials processing and manufacture

Energy use and gas emissions (CO2, SO2, NO x) in materials' processing and manufacture of ST systems are noticeable. The impacts of these emissions vary according to location, and are fewer than those of conventional fossil fuel technologies.

Construction

These projects have the usual environmental impacts associated with any engineering scheme during the construction phase—impact on landscape, effects on local ecosystems and habitats, noise, virtual intrusion, and topical vexation such as noise and temporally pollutant emissions due to increased traffic because of transportation of workers and of material, occupational accidents,temporal blindness.

Land Use
ST electric systems are amongst the most efficient SETs when it comes to land use (they produce annually about 4–5GWh/ha). To date, most sites used or considered for ST systems are in arid desert areas, which typically have fragile soil and plant communities.

Ecosystem, flora and fauna

Attention during the planning, construction and operation phases can minimize the effects on vegetation, soil and habitat Central concentrator power systems could pose a danger to birds, but operational experience shows that Birds avoid any danger areas (possibly by being sensitive to air turbulence) Flying insects can also be burnt when flying close to the reflector's area.

Visual Impact

The main visual impact would come from the tower of the central receiver systems. However, the atmospheric requirements for these systems point to their deployment in areas of low population densities, so provided that areas of outstanding natural beauty are avoided, visual intrusion is unlikely to be significant.

Noise

Noise is insignificant in comparison to any other power option, such as the conventional, the wind power generation, and the gas turbines The noise from the generating plant of large-scale schemes is unlikely to cause any disturbance to the public. Noise would be generated primarily only during the day; at night, when people are more sensitive to noise, the system is unable to operate.

Water Resources

There may be some pollution of water resources, through thermal discharges and accidental release of plant chemicals.

Health and safety (occupational hazards)

The accidental release of heat transfer fluids (water and oil) from parabolic trough and central receiver systems could form a health hazard. The hazard could be substantial in some central tower systems, which use liquid sodium or molten salts as a heat-transfer medium. Indeed a fatal accident has occurred in a system using liquid sodium.

Social Impacts

There will be some employment benefits during the construction and operational phase.

2.2 Other types of barriers

Renewable potential can be realized at a reasonable cost. Market research shows that many customers will purchase renewable power even if it costs somewhat more than conventional power. However, both economic theory and experience point to significant market barriers and market failures that will limit the development of renewable unless special policy measures are enacted to encourage that development. Some of the important barriers are listed below-

Price distortions

Active solar systems have to compete with conventional energies for which the environmental costs are not fully reflected in the overall energy costs. Conventional energy therefore appears to be cheap compared with active solar heating, because a simple economic comparison does not reflect the environmental advantages of using active solar in comparison to the cheap conventional fuels.

Information

The importance of this barrier varies from country to country, depending (as would be expected) on the promotion of the technology within the individual country. There is also a lack of public awareness of the technology.

Environmental benefits

Solar thermal heating produces no emissions during operation, but some very small levels of emissions are produced during the manufacture and installation of components and systems.

2.3 Solar products and barriers

Photovoltaic Cell or Solar cell

The barriers hindering the market development of PV technology can be divided into five types- technological, financial, institutional, regulatory and structural.

Technological

Technological barriers are common for new technologies such as PVs. For instance, standardization is an important factor for market penetration of any technological product.

With PVs there is a wide range of products available from a variety of manufacturers. A significant level of technological know-how is therefore required of system installers who must pick from a range of products to meet the needs of their system, which in most instances are one-off systems. A degree of standardization would improve the penetration of PVs, it would enable PVs to become more user friendly.

Financial

High costs in comparison to conventional forms of electricity provision are a barrier in themselves but are exacerbated by other financial barriers. It is often argued that there are policy distortions in favour of other energy sources, subsidies for conventional electricity sources. Limited accessibility to affordable credit reduces private sector participation in renewable energy development. This has also been constrained by the absence of appropriate incentives and financial intermediaries for small scale decentralized energy services.

Institutional

Institutional barriers in the form of power utilities unwillingness to adopt innovative approaches to energy service delivery has hindered the growth of the PV industry. Historically based on large-scale plant, power utility preferences for large centrally managed energy projects are clear. Due to rigidities in the infrastructure of the electricity industry, such as low capital stock turnover, changes in energy supply are not likely to be dramatic or quick

Regulatory

Regulatory barriers hinder the development and dissemination of PV technology through inadequate regulations, designed through their historic evolution to meet primarily the requirements of conventional energy systems. These include utility grid connection regulations and electrical safety standards.

Structural

Since PVs is still a young industry, service structures required for the promotion, distribution, sales, technical assistance and maintenance are still poorly developed. Interested purchasers have to undertake lengthy investigations to find out where to obtain what they need. Information dissemination structures are not yet fully developed; there is a lack of awareness and confidence among the general public and decision-makers. There is a lack of information about potential uses and specific advantages of PV technology, hindering the diffusion of the use of the technology.

Solar Water Heater

A multitude of barriers impede the broader adoption of SWH systems in markets around the world.

Financial

Financial barriers to SWH adoption are most common. Low conventional fuel costs can also perpetuate the low demand for SWH technology. Limited capacity in the local private sector to manufacture, distribute, install, and maintain high quality SWH systems, coupled with a dependence on expensive imported systems, virtually ensures that SWH technology costs remain high in many developing countries.

Institutional

Institutional practices also commonly hinder growth in SWH markets. With conventional water heaters overwhelmingly dominating the market in most locations, consumers wishing to adopt SWH technology often encounter difficulty in finding retail outlets or system design and installation businesses with adequate knowledge to properly size, install, and maintain solar water heating systems. Linkages between the various parties involved in the SWH industry are often underdeveloped, and there is little or no coordination between the public and private sectors to promote alternative energy technologies.

Information

A lack of awareness about the favorable lifecycle economics of SWH technology vis à vis conventional water heaters, and a lack of quality control, which often undermines consumer confidence as people associate SWH with mediocre or low quality equipment.

Solar Cooker

Technical

The solar cooker technology is still in its developing stage. The solar cookers being disseminated often fail to offer the reliability a user expects from a resource-technology combination for cooking. Many times, the technical quality of the solar cooker available in the market is found to be poor.

Sunlight

A commonly cited impediment is slow cooking and inability to cook outside of sunshine hours. This may be real in some homes where the routine of work does not permit cooking during daytime but not all homes are in this category. Also access to sunlight may be difficult in some homes, which also is understandable.

Financial

The major impediment is the initial high as cost - in relation to income levels. The commercially available box cooker in India is good enough but it costs at the very least Rs.1500.

Information

Lack of publicity for the awareness of potential users may also be one of the reasons for poor dissemination of the technology.

Compatibility

Cooking with a solar cooker may be incompatible with traditional ways of cooking.

Chapter 3: Solar energy technologies

Solar energy technologies convert the sun's light into usable electricity or heat. Solar energy systems can be divided into two major categories: photovoltaic and thermal. Photovoltaic cells produce electricity directly, while solar thermal systems produce heat for buildings, industrial processes or domestic hot water. Thermal systems can also generate electricity by operating heat engines or by producing steam to spin electric turbines. Solar energy systems have no fuel costs, so most of their cost comes from the original investment in the equipment.

3.1 Solar thermal energy

Direct-use thermal systems are usually located on individual buildings, where they use solar energy directly as a source of heat. The most common systems use sunlight to heat water for houses or swimming pools, or use collector systems or passive solar architecture to heat living and working spaces. These systems can replace electric heating for as little as three cents per kilowatt-hour, and utility and state incentives reduce the costs even further in some cases.

Concentrating solar power

Concentrating solar power (CSP) technologies use mirrors to reflect and concentrate sunlight onto receivers that collect the solar energy and convert it to heat. This thermal energy can then be used to produce electricity via a steam turbine or heat engine driving a generator.

One way to classify concentrating solar power technologies is by how the various systems collect solar energy. These include basic CSP operations of the three main technology systems, as well as thermal storage related to CSP technologies

- Linear Concentrator Systems
- Dish/Engine Systems
- Power Tower Systems
- Thermal Storage

Linear concentrator systems

Linear CSP collectors capture the sun's energy with large mirrors that reflect and focus the sunlight onto a linear receiver tube. The receiver contains a fluid that is heated by the sunlight and then used to create superheated steam that spins a turbine that drives a generator to produce electricity. Alternatively, steam can be generated directly in the solar field, eliminating the need for costly heat exchangers. Linear concentrating collector fields consist of a large number of collectors in parallel rows that are typically aligned in a north-south orientation to maximize both annual and summertime energy collection. With a single-axis sun-tracking system, this configuration enables the mirrors to track the sun from east to west during the day, ensuring that the sun reflects continuously onto the receiver tubes.

Parabolic Trough Systems

The predominant CSP systems currently in operation in the United States are linear concentrators using parabolic trough collectors. In such a system, the receiver tube is positioned along the focal line of each parabola-shaped reflector. The tube is fixed to the mirror structure and the heated fluid—either a heat-transfer fluid or water/steam—flows through and out of the field of solar mirrors to where it is used to create steam (or, for the case of a water/steam receiver, it is sent directly to the turbine).

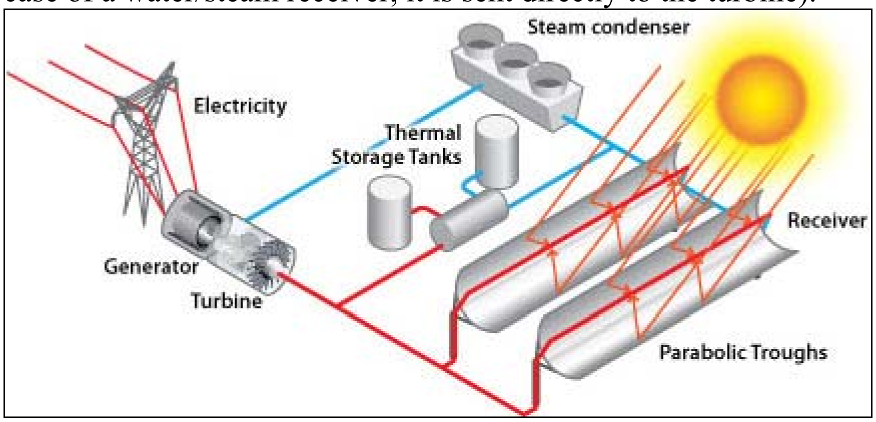


Figure-1: Concentrator power plant using parabolic trough collectors.

Trough designs can incorporate thermal storage. In such systems, the collector field is oversized to heat a storage system during the day that can be used in the evening or during cloudy weather to generate additional steam to produce electricity.

Linear Fresnel Reflector Systems

A second linear concentrator technology is the linear Fresnel reflector system. Flat or slightly curved mirrors mounted on trackers on the ground are configured to reflect sunlight onto a receiver tube fixed in space above these mirrors. A small parabolic mirror is sometimes added atop the receiver to further focus the sunlight.

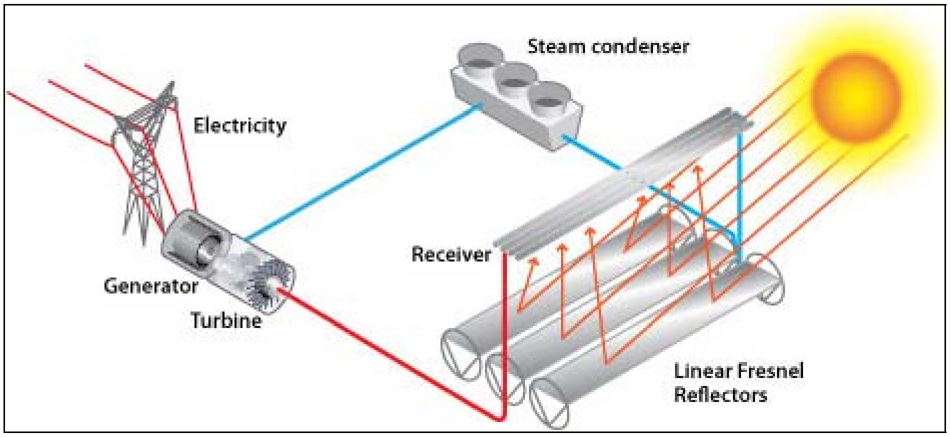


Figure-2: A linear Fresnel reflector power plant.

Dish/engine systems

The dish/engine system is a concentrating solar power (CSP) technology that produces relatively small amounts of electricity compared to other CSP technologies—typically in the range of 3 to 25 kilowatts. Here you will learn about the basic operation of dish/engine systems. A parabolic dish of mirrors directs and concentrates sunlight onto a central engine that produces electricity. The two major parts of the system are the solar concentrator and the power conversion unit.

The solar concentrator, or dish, gathers the solar energy coming directly from the sun. The resulting beam of concentrated sunlight is reflected onto a thermal receiver that collects the solar heat. The dish is mounted on a structure that tracks the sun continuously throughout the day to reflect the highest percentage of sunlight possible onto the thermal receiver. The power conversion unit includes the thermal receiver and the engine/generator. The thermal receiver absorbs the concentrated beams of solar energy, converts them to heat, and transfers the heat to the engine/generator. The engine/ generator system is the subsystem that takes the heat from the thermal receiver and uses it to produce electricity.

Power tower systems

Power tower systems are numerous large, flat, sun-tracking mirrors, known as heliostats, focus sunlight onto a receiver at the top of a tower. A heat-transfer fluid heated in the receiver is used to generate steam, which, in turn, is used in a conventional turbine generator to produce electricity.

Thermal storage

One challenge facing the widespread use of solar energy is the reduced or curtailed energy production when the sun sets or is blocked by clouds. Thermal energy storage provides a workable solution to this challenge. In a CSP system, the sun's rays are reflected onto a receiver, creating heat that is then used to generate electricity. If the receiver contains oil or molten salt as the heat-transfer medium, then the thermal energy can be stored for later use. This allows CSP systems to be a cost-competitive option for providing clean, renewable energy. Presently, steam-based receivers cannot store thermal energy for later use.

Solar water heating

Solar water heating systems and solar electric systems usage have become quite popular across the globe. The solar water heating collectors on the roof look like skylights.
One of the most cost-effective ways to include renewable technologies into a building is by incorporating solar hot water. A typical residential solar water-heating system reduces the need for conventional water heating by about two-thirds. It minimizes the expense of electricity or fossil fuel to heat the water and reduces the associated environmental impacts.

Solar water heating for buildings

Most solar water-heating systems for buildings have two main parts: (1) a solar collector and (2) a storage tank. The most common collector used in solar hot water systems is the flat-plate collector. Solar water heaters use the sun to heat either water or a heat-transfer fluid in the collector. Heated water is then held in the storage tank ready for use, with a conventional system providing additional heating as necessary. The tank can be a modified standard water heater, but it is usually larger and very well insulated. Solar water heating systems can be either active or passive, but the most common are active systems.

Active solar water heaters

Active solar water heaters rely on electric pumps, and controllers to circulate water, or other heat-transfer fluids through the collectors. These are the three types of active solar water-heating systems:

<u>Direct-circulation systems</u> use pumps to circulate pressurized potable water directly through the collectors. These systems are appropriate in areas that do not freeze for long periods and do not have hard or acidic water.

<u>Indirect-circulation systems</u> pump heat-transfer fluids through collectors. Heat exchangers transfer the heat from the fluid to the potable water. Some indirect systems have "overheat protection," which is a means to protect the collector and the glycol fluid from becoming super-heated when the load is low and the intensity of incoming solar radiation is high. The two most common indirect systems are Antifreeze and Drainback systems.

Passive solar water heaters

Passive solar water heaters rely on gravity and the tendency for water to naturally circulate as it is heated. Passive systems are generally more reliable, easier to maintain, and possibly have a longer work life. The two most popular types of passive systems are:

<u>Integral-collector storage systems</u> consist of one or more storage tanks placed in an insulated box with a glazed side facing the sun. These solar collectors are suited for areas where temperatures rarely go below freezing.

<u>Thermosyphon systems</u> are an economical and reliable choice, especially in new homes. These systems rely on the natural convection of warm water rising to circulate water through the collectors and to the tank (located above the collector). As water in the solar collector heats, it becomes lighter and rises naturally into the tank above. Meanwhile, the cooler water flows down the pipes to the bottom of the collector, enhancing the circulation.

Space heating

A solar space-heating system can consist of a passive system, an active system, or a combination of both. Passive systems are typically less costly and less complex than active systems. However, when retrofitting a building, active systems might be the only option for obtaining solar energy.

Passive solar space heating

Passive solar space heating takes advantage of warmth from the sun through design features, such as large south-facing windows, and materials in the floors or walls that absorb warmth during the day and release that warmth at night when it is needed most. A sunspace or greenhouse is a good example of a passive system for solar space heating. Passive solar design systems usually have one of three designs:

<u>Direct gain</u> stores and slowly releases heat energy collected from the sun shining directly into the building and warming materials such as tile or concrete.

<u>Indirect gain</u> uses materials that hold, store, and release heat; the material is located between the sun and living space typically the wall.

<u>Isolated gain</u> collects solar energy remote from the location of the primary living area. For example, a sunroom attached to a house.

Active Solar Space Heating

Active solar space-heating systems consist of collectors that collect and absorb solar radiation combined with electric fans or pumps to transfer and distribute that solar heat.

Active systems also generally have an energy-storage system to provide heat when the sun is not shining. The two basic types of active solar space-heating systems use either liquid or air as the heat-transfer medium in their solar energy collectors.

Liquid-based systems heat water or an antifreeze solution in a hydronic collector. Air-based systems heat air in an air collector. Air-based solar heating systems usually employ an air-to-water heat exchanger to supply heat to the domestic hot water system, making the system useful in the summertime. Both of these systems collect and absorb solar radiation, then transfer the solar heat directly to the interior space or to a storage system, from which the heat is distributed. An auxiliary or backup system provides heat when storage is discharged. Liquid systems are more often used when storage is included.

Space cooling

Cooling and refrigeration can be accomplished using thermally activated cooling systems (TACS) driven by solar energy. These systems can provide year-round utilization of collected solar heat, thereby significantly increasing the cost effectiveness and energy contribution of solar installations. These systems are sized to provide 30% to 60% of building cooling requirements using solar, with the remainder usually dependent on TACS fueled by natural gas. The TACS available for solar-driven cooling include absorption systems and desiccant systems.

3.2 PV Systems

Photovoltaics (PVs) convert sunlight directly into electricity, using semiconductors made from silicon or other materials. A photovoltaic (PV) or solar cell is the basic building block of a PV (or solar electric) system. An individual PV cell is usually quite small, typically producing about 1 or 2 watts of power. To boost the power output of PV cells, we connect them together to form larger units called modules. Modules, in turn, can be connected to form even larger units called arrays, which can be interconnected to produce more power, and so on.

Figure-3: A photovoltaic cell, the most basic building block of a PV system.

Figure-4: Two silicon modules generate power

By themselves, modules or arrays do not represent an entire PV system. Structures are required to put them on that point them toward the sun, and components that take the direct-current electricity produced by modules and "condition" that electricity, usually by converting it to alternate-current electricity. Some electricity can be stored usually in batteries, for later use. All these items are referred to as the "balance of system" (BOS) components. Combining modules with the BOS components creates an entire PV system.

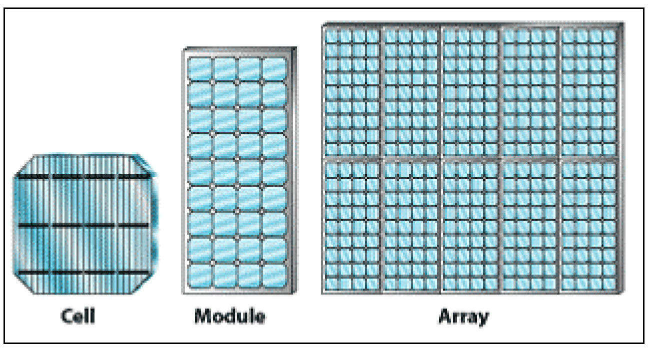


Figure-5: Photovoltaic systems

The basic photovoltaic or solar cell typically produces only a small amount of power. To produce more power, cells can be interconnected to form modules, which can in turn be connected into arrays to produce yet more power. Because of this modularity, PV systems can be designed to meet any electrical requirement, no matter how large or how small.

PV systems can be classified into two general categories: flat-plate systems or concentrator systems.

Flat-plate PV systems

The most common array design uses flat-plate PV modules or panels. These panels can either be fixed in place or allowed to track the movement of the sun. They respond to sunlight that is either direct or diffuse. Even in clear skies, the diffuse component of sunlight accounts for between 10% and 20% of the total solar radiation on a horizontal surface. On partly sunny days, up to 50% of that radiation is diffuse. And on cloudy days, 100% of the radiation is diffuse.

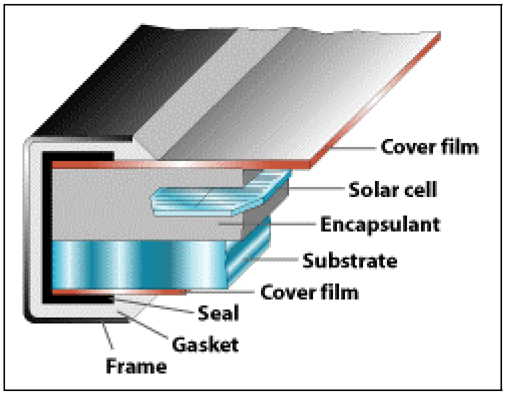


Figure-6: Flat bed PV systems

One typical flat-plate module design uses a substrate of metal, glass, or plastic to provide structural support in the back; an encapsulant material to protect the cells; and a transparent cover of plastic or glass. The simplest PV array consists of flat-plate PV panels in a fixed position. The advantages of fixed arrays are that they lack moving parts, there is virtually no need for extra equipment, and they are relatively lightweight. These features make them suitable for many locations, including most residential roofs. Because the panels are fixed in place, their orientation to the sun is usually at an angle that practically speaking is less than optimal. Therefore, less energy per unit area of array is collected compared with that from a tracking array. However, this drawback must be balanced against the higher cost of the tracking system.

Concentrator PV systems

The primary reason for using concentrators is to be able to use less solar cell material in a PV system. PV cells are the most expensive components of a PV system, on a per-area basis. A concentrator makes use of relatively inexpensive materials such as plastic lenses and metal housings to capture the solar energy shining on a fairly large area and focus that energy onto a smaller area, where the solar cell is. One measure of the effectiveness of this approach is the concentration ratio—in other words, how much concentration the cell is receiving.

Several advantages of concentrator PV systems, as compared to flat-plate systems, can be enumerated. Concentrator systems increase the power output while reducing the size or number of cells needed. An additional advantage is that a solar cell's efficiency increases under concentrated light. How much that efficiency increases depends largely on the design of the solar cell and the material used to make it. Another advantage is that a concentrator can be made of small individual cells. This is an advantage because it is harder to produce large-area, high-efficiency solar cells than it is to produce small-area cells.

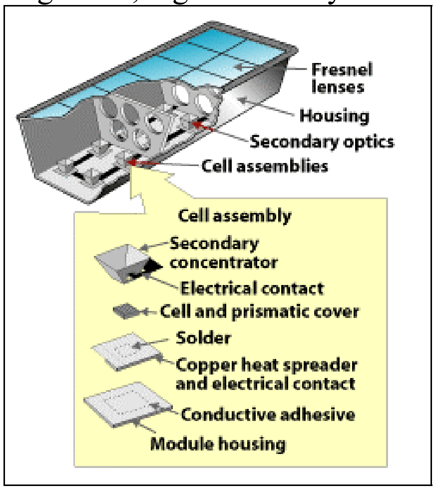


Figure-7: Concentrator PV systems

A typical basic concentrator unit consists of a lens to focus the light, cell assembly, housing element, secondary concentrator to reflect off-center light rays onto the cell, mechanism to dissipate excess heat produced by concentrated sunlight, and various contacts and adhesives. Notice that the module depicted uses 12 cell units in a 2x6 matrix. These basic units may be combined in any configuration to produce the desired module.
However, several challenges exist to using concentrators. For example, the required concentrating optics are significantly more expensive than the simple covers needed for flat-plate solar systems, and most concentrators must track the sun throughout the day and year to be effective. Thus, achieving higher concentration ratios means using not only expensive tracking mechanisms, but also, more precise controls than those of flat-plate systems with stationary structures.

Both reflectors and lenses have been used to concentrate light for PV systems. The most promising lens for PV applications is the Fresnel lens, which uses a miniature sawtooth design to focus incoming light. When the teeth run in straight rows, the lenses act as line-focusing concentrators. And when the teeth are arranged in concentric circles, light is focused at a central point. However, no lens can transmit 100% of the incident light. The best that lenses can transmit is only 90% to 95%, and in practice, most transmit less. Furthermore, concentrators cannot focus diffuse sunlight, which makes up about 20% of the solar radiation available on a clear day.

Chapter 4: Solar energy products

4.1 Solar collectors

Solar collectors are the key component of active solar-heating systems. Solar collectors gather the sun's energy, transform its radiation into heat, then transfer that heat to water, solar fluid, or air. The solar thermal energy can be used in solar water-heating systems, solar pool heaters, and solar space-heating systems. There are several types of solar collectors:

- Flat-plate collectors
- Evacuated-tube collectors
- Integral collector-storage systems

Flat-plate collectors

Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar space heating. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorber plate. These collectors heat liquid or air at temperatures less than 180°F.

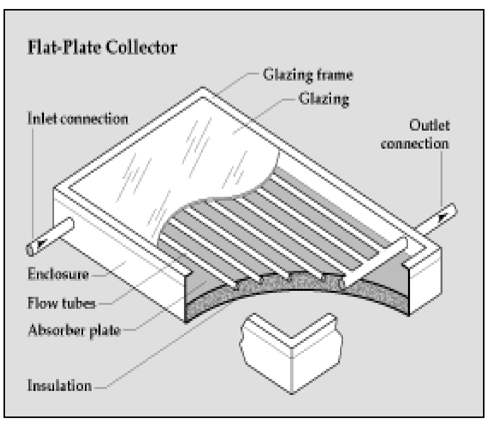


Figure-1: Flat-plate collectors

Liquid flat-plate collectors heat liquid as it flows through tubes in or adjacent to the absorber plate. The simplest liquid systems use potable household water, which is heated as it passes directly through the collector and then flows to the house. Solar pool heating also uses liquid flat-plate collector technology, but the collectors are typically unglazed as in figure below.

Air flat-plate collectors are used primarily for solar space heating. The absorber plates in air collectors can be metal sheets, layers of screen, or non-metallic materials. The air flows past the absorber by using natural convection or a fan. Because air conducts heat much less readily than liquid does, less heat is transferred from an air collector's absorber than from a liquid collector's absorber, and air collectors are typically less efficient than liquid collectors.

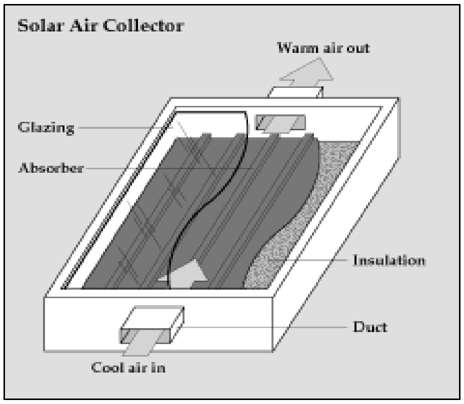


Figure-2: Air flat-plate collectors are used for space heating

Evacuated-tube collectors

Evacuated-tube collectors can achieve extremely high temperatures (170°F to 350°F), making them more appropriate for cooling applications and commercial and industrial application. However, evacuated-tube collectors are more expensive than flat-plate collectors, with unit area costs about twice that of flat-plate collectors.

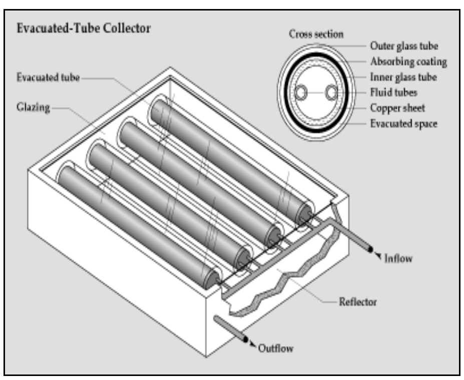


Figure-3: Evacuated-tube collectors are efficient at high temperatures

The collectors are usually made of parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin is covered with a coating that absorbs solar energy well, but which inhibits radiative heat loss. Air is removed, or evacuated, from the space between the two glass tubes to form a vacuum, which eliminates conductive and convective heat loss.

Integral collector-storage systems

Integral collector-storage systems, also known as ICS or "batch" systems, are made of one or more black tanks or tubes in an insulated glazed box. Cold water first passes through the solar collector, which preheats the water, and then continues to the conventional backup water heater. ICS systems are simple, reliable solar water heaters. However, they should be installed only in climates with mild freezing because the collector itself or the outdoor pipes could freeze in severely cold weather. Some recent work indicates that the problem with freezing pipes can be overcome in some cases by using freeze-tolerant piping in conjunction with a freeze-protection method.

4.2 Solar water heater

Solar water heaters—also called solar domestic hot water systems—can be a cost-effective way to generate hot water for your home. They can be used in any climate, and the fuel they use—sunshine—is free. Water heater can constitute 15% to 25%, or more, of the energy use of home. Solar water heaters are available that can reduce annual operating costs by 50% to 80% or more using "free energy" from the sun. These systems typically are cost-competitive with electric water heaters and also can be cost-competitive with natural gas-fired water heaters. Solar water heaters come in two distinct designs: active and passive systems. In many climates, a solar heating system can provide a very high percentage (50 to 75%) of domestic hot water energy. In many northern European countries, combined hot water and space heating systems (solar combisystems) are used to provide 15 to 25% of home heating energy.

Structure

In an "active" system, when sunlight heats one or more solar collectors sufficient for water heating, sensors and a controller activate a pump to circulate a fluid: either potable water from the storage tank or a food-grade antifreeze solution in climates exposed to freezing conditions. The fluid is drawn from the colder bottom portion of the storage tank up to the collector for solar heating, and then circulated back to the top of the storage tank. Where antifreeze solutions are used, the solar heat is transferred to water in the storage tank through a heat exchanger.

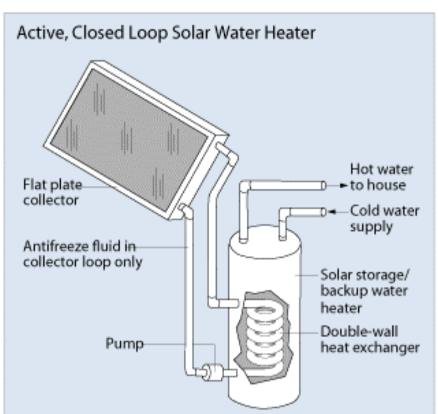


Figure-4: Functioning of solar water heater

When the water in the storage tank is warmer than the collector, the controller and sensor switch off the pump. In many active systems, the solar system has its own water storage tank, allowing it to serve as a "pre-heater" for the primary water heater (gas or electric). A "passive" system combines the solar collector and storage in one complete unit separate from the conventional gas or electric water heater storage tank. The storage can be directly coupled with the collector or located above the collector using the natural flow of heated water upwards to drive fluid circulation (thermosiphon system).

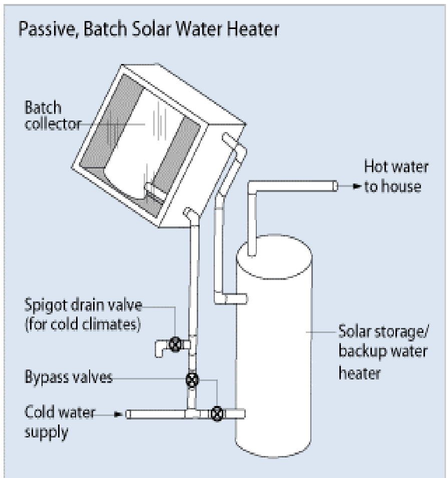


Figure-5: Types of solar water heater

Passive system design requires no pumps or controls for operation as sunlight heats water all day. When hot water is used in the home, water from the passive solar storage tank is drawn into the conventional gas or electric water heater storage tank, thereby avoiding the need for electric or gas fired heat to turn on. Providing energy-efficient houses with solar water heating systems provides peace-of-mind that homeowners are contributing to environmental stewardship while helping their bottom-line expenses.

Applications

Solar water heating can be used to heat water and/or provide space heating in domestic, commercial, agricultural and industrial premises. It is currently used mainly in households to supply hot water and in leisure facilities to heat swimming pools. However, it is increasingly being used in multi-occupancy premises (e.g. hotels) and office buildings. Solar heat may also be used in low temperature industrial applications including drying, food preparation and laundries.

Benefits

There are many benefits to owning a solar water heater, and number one is economic. Many homebuilders choose electric water heaters because they are easy to install and relatively inexpensive to purchase. Solar water heaters offer long-term benefits that go beyond simple economics. The National Remodelers Association reports that adding a solar water heater to an existing home raises the resale value of the home by the entire cost of the system. You may be able to recoup your entire investment when you sell your home. Solar water heaters do not pollute. By investing in one, you will be avoiding carbon dioxide, nitrogen oxides, sulfur dioxide, and the other air pollution and wastes created when your utility generates power or you burn fuel to heat your household water.

4.3 Solar Cell

Solar cells are materials that turn sunlight into electricity. E. Becquerel first recorded this effect, in 1839. The first solid-state device was recorded to show such an effect in 1877. However, it was in 1954 at Bell Labs when the solar electric effect was demonstrated in silicon that the idea of producing useable amounts of electricity from solar cells began. Solar electricity is measured in kilowatt-hours, a unit of energy. Solar cells convert sunlight directly into electricity. Most cells are made of silicon, a material that comprises 28 percent of the Earth's crust. One solar cell measuring four inches across can produce one watt of electricity on a clear, sunny day.

Structure

Modern solar cells are based on semiconductor physics -- they are basically just P-N junction photodiodes with a very large light-sensitive area. The photovoltaic effect, which causes the cell to convert light directly into electrical energy, occurs in the three energy-conversion layers.

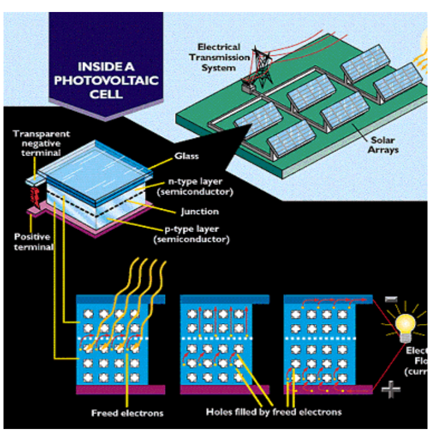


Figure-6: Photovoltaic cell

The first of these three layers necessary for energy conversion in a solar cell is the top junction layer (made of N-type semiconductor). The next layer in the structure is the core of the device; this is the absorber layer (the P-N junction). The last of the energy-conversion layers is the back junction layer (made of P-type semiconductor).

As may be seen in the above diagram, there are two additional layers that must be present in a solar cell. These are the electrical contact layers. There must obviously be two such layers to allow electric current to flow out of and into the cell. The electrical contact layer on the face of the cell where light enters is generally present in some grid pattern and is composed of a good conductor such as a metal. The grid pattern does not cover the entire face of the cell since grid materials, though good electrical conductors are generally not transparent to light. Hence, the grid pattern must be widely spaced to allow light to enter the solar cell but not to the extent that the electrical contact layer will have difficulty collecting the current produced by the cell. The back electrical contact layer has no such diametrically opposed restrictions. It need simply function as an electrical contact and thus covers the entire back surface of the cell structure. Because the back layer must be a very good electrical conductor, it is always made of metal.

Energy efficiency

A solar cell's energy conversion efficiency (η, "eta"), is the percentage of power converted (from absorbed light to electrical energy) and collected, when a solar cell is connected to an electrical circuit. This term is calculated using the ratio of P_m, divided by the input light irradiance under "standard" test conditions (E, in W/m^2) and the surface area of the solar cell (A_c in m^2).

$$\eta = \frac{P_m}{E \times A_c}$$

Another defining term in the overall behavior of a solar cell is the fill factor (*FF*). This is the ratio of the maximum power point divided by the open circuit voltage (V_{oc}) and the short circuit current (I_{sc}):

$$FF = \frac{P_m}{V_{oc} \times I_{sc}} = \frac{\eta \times A_c \times E}{V_{oc} \times I_{sc}}$$

Applications

Solar cells have many applications. They have long been used in situations where electrical power from the grid is unavailable, such as in remote area power systems, Earth-orbiting satellites and space probes, consumer systems, e.g. handheld calculators or wrist watches, remote radiotelephones and water pumping applications. More recently, they are starting to be used in assemblies of solar modules (photovoltaic arrays) connected to the electricity grid through an inverter, often in combination with a net metering arrangement.

Benefits

Solar cells have many benefits. It has no fuel costs, low operating and maintenance costs, and produce virtually no air emissions or waste. It can be built quickly and in many sizes.

They are well suited to rural areas, developing countries, and other communities that do not have access to centrally generated electricity.

4.4 Solar Panel

Solar Panels are a form of active solar power, a term that describes how solar panels makes use of the sun's energy: solar panels harvest sunlight and actively convert it to electricity. Solar Cells, or photovoltaic cells, are arranged in a grid-like pattern on the surface of the solar panel. These solar voltaic cells collect sunlight during the daylight hours and covert it into electricity.

Figure-7: Solar panel

Structure

Solar panels collect solar radiation from the sun and actively convert that energy to electricity. Solar panels are comprised of several individual solar cells. These solar cells function similarly to large semiconductors and utilize a large-area p-n junction diode. When the solar cells are exposed to sunlight, the p-n junction diodes convert the energy from sunlight into usable electrical energy. The energy generated from photons striking the surface of the solar panel allows electrons to be knocked out of their orbits and released, and electric fields in the solar cells pull these free electrons in a directional current, from which metal contacts in the solar cell can generate electricity. The more solar cells in a solar panel and the higher the quality of the solar cells, the more total electrical output the solar panel can produce. The conversion of sunlight to usable electrical energy has been dubbed the Photovoltaic Effect.

Energy efficiency

In direct sunlight at the surface of the equator, a maximally efficient photovoltaic cell about 1/5m in diameter creates a current of approximately 2 amps at 2 volts, however, due to the Earth's atmospheric interference, terran solar panels will never perform as well as solar panels exposed directly to the sun's rays. Years of overheating and physical wear can, however, reduce the operation efficiency of the photovoltaic unit. Solar cells become less efficient over time, and excess energy is released into its thermally conductive substrate as infrared heat.

Applications

Solar panels are used to power all sorts of electronic equipment, from solar-powered handheld calculators that will function as long as sunlight is available, to remote solar-powered sensor arrays in bouys, and even some experimental vehicles and boats. Solar panels are also placed on outdoor lighting structures - the solar cell is charged during daylight hours, and at night, we get free electricity to keep our streets well lit and secure. Solar panels are used extensively on satellites, where array of solar cells provide reliable power for the satellite's electrical systems.

Benefits & drawbacks

Solar panels are clean - while generating electricity from sunlight, solar panels produce virtually no pollution, whereas burning fossil fuels releases large quantities of toxic gases into the atmosphere. For the consumer, solar panels can free the individual from reliance on the power grid and the monopolistic energy supplier. Once you make the initial investment in hardware, you will have free electricity for years to come.

Admittedly, while solar power is certainly much cleaner than the burning of fossil fuels, and moderately cleaner than the production of nuclear power, solar panels are very pricey and in many years demand for solar panels exceeds supply. Solar Panels also require squarer yardage per kilowatt for the power-generating facility than fossil fuel power plants or nuclear power.

4.5 Solar cooker

A solar cooker is a device, which cooks food with the help of solar energy and can save the conventional fuels to a significant amount. It, however, supplements the cooking fuel and cannot replace it in total. Solar energy is abundantly available in India. Solar cookers work because direct sunlight carries lots of power: on bright days, about 1,000 watts fall on each square meter of surface that it strikes (compare this to your toaster oven, which is likely to use about 1,000 watts). In a solar cooker, sunlight is concentrated into a cooking area that gets hot enough to cook food. The Solar Cooker stands 1.4 m (~ 4 ft 6 in) tall and is 1 m (~ 3 ft 3 in) wide. The cooker can be spun just above the base to face any direction. The parabolic dish has a diameter of 90 cm (~ 3 ft) and is about a 20 cm (~ 4 in) deep at its center. The parabolic dish pivots on a horizontal axis and is covered with a shiny aluminum paper. The focus ring on the Solar Cooker is 48 cm (~ 19 in) above the center of the dish. This is the point where the light is concentrated and converted to heat energy.

Solar cooker types

(i) <u>Box cookers</u> - Box cookers are the most common type made for personal use. Despite the name "box" cooker, they are made in both circular and rectangular shapes. Figure 1 illustrates the basic box cooker design. They consist of an enclosed inner box covered with clear glass or plastic, a reflector, and insulation. There is a wide variety of patterns and plans that can be adapted to work with available materials. While they do not heat quickly, they provide slow, even cooking. Box cookers are very easy and safe to use, and fairly easy to construct.

Figure-8: Box type solar cooker

(ii) Parabolic cookers-Parabolic cookers reach higher temperatures and cook more quickly than solar box cookers, but are harder to make and use. Most commercial ovens, such as the Solar Chef oven pictured in Figure 2, are a form of parabolic cooker. Parabolic cookers require more precision to focus the sunlight on the cooking vessel. If the sunlight is not focused exactly on the cooking vessel, the food will not cook. When the parabolic oven is used, the temperature must be watched so the vessel does not overheat, burning the food. The risk of burns and eye injury is greater with homemade parabolic designs. While they provide excellent results when used correctly, they are not easy to build at home and require great care to use.

Figure-9: Parabolic type solar cooker

(iii) Panel Cooker- Panel cookers are flat reflective panels which focus the sunlight on a cooking vessel without the inner box common in box cookers. Panel cookers are the easiest and least costly to make, requiring just four reflective panels and a cooking vessel, but they are unstable in high winds and do not retain as much heat when the sun is hidden behind clouds. Figure 3 shows a panel cooker with dark cooking vessel and thermometer wrapped in a plastic oven bag.

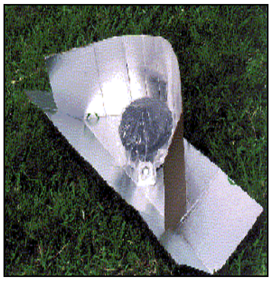


Figure-10: Panel type solar cooker

Structure

The Solar Cooker works on the basic principle of reflection. The sun's light rays are collected by the parabolic bowl and are bounced off the shiny aluminum that covers the dish. These light rays reflect at various angles and are concentrated to a single point.

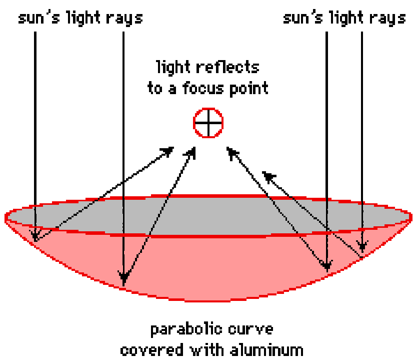


Figure-11: Functioning of solar cooker

When an object (such as a marshmallow or hot dog) is placing at the focus point, it will heat up and cook. The light rays are converted in to heat energy. The darker the object (like a black pot) placed at the focus point, the better the light is converted to heat.

Benefits & barriers

Moderate cooking temperatures in simple solar cookers help preserve nutrients. It is smoke-free. Solar cooker "fuel" — is free and abundant. Money saved can be used for food, education, health care, etc. These are pollution-free, and, when used in large numbers, may help curb global warming. Electric companies that have trouble meeting peak hour demand because of heavy use of stoves and air conditioners can reduce that demand by promoting use of solar cookers. It includes a slow cooking process due to low temperatures.

Chapter 5: Global status of solar energy

5.1 Introduction

Renewable energy supplies 17 percent of the world's primary energy consumption, counting traditional biomass, large hydropower and "new" renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels). Traditional biomass, primarily for cooking and heating, represents about 9 percent [*Table-1*] and is growing slowly or even declining in some regions as biomass is used more efficiently or replaced by more modern energy forms. Large hydropower is slightly less than 6 percent and growing slowly, primarily in developing countries. New renewables are 2 percent and growing very rapidly in developed countries and in some developing countries.

Table-1: Renewable Energy Contribution to Global Primary Energy, 2004

Renewable energy types	**Contribution**	
Large hydro power	5.7%	--
New Renewables	2.0%	Hot waster heating – 0.7% Biofuels – 0.2% Power generation – 1.2%
Traditional biomass	9.0%	--

Renewable energy competes with conventional fuels in four distinct markets: power generation, hot water and space heating, transport fuels, and rural (off-grid) energy. In power generation, renewable energy comprises about 4 percent of power-generating capacity and supplies about 3 percent of global electricity production (excluding large hydropower). Hot water and space heating for tens of millions of buildings is supplied by solar, biomass, and geothermal. Solar thermal collectors alone are now used by an estimated 40 million households worldwide. Biomass and geothermal also supply heat for industry, homes, and agriculture. Biomass transport fuels make small but growing contributions in some countries and a very large contribution in Brazil, where ethanol from sugar cane now supplies 44 percent of automotive (non-diesel) fuel consumption for the entire country. In developing countries, 16 million households cook and light their homes from biogas, displacing kerosene and other cooking fuel; more than 2 million households light their homes with solar PV; and a growing number of small industries, including agro-processing, obtain process heat and motive power from small-scale biogas digesters.

The fastest growing energy technology in the world has been grid-connected solar PV, with total existing capacity increasing from 0.16 GW at the start of 2000 to 1.8 GW by the end of 2004, for a 60 percent average annual growth rate during the five-year period. During the same period, other renewable energy technologies grew rapidly (annual average) as well: wind power 28 percent, biodiesel 25 percent, solar hot water/heating 17 percent, off-grid solar PV 17 percent, geothermal heat capacity 13 percent, and ethanol 11 percent. Other renewable energy power generation technologies, including biomass, geothermal, and small hydro, are more mature and growing by more traditional rates of 2–4 percent per year. Biomass heat supply is likely to grow by similar amounts. These growth rates compare with annual growth rates of fossil fuel-based electric power capacity of typically 3–4 percent (higher in some developing countries), a 2 percent annual growth rate for large hydropower, and a 1.6 percent annual growth rate for nuclear capacity during the three year period 2000–2002.

Table-2: Renewable Energy Indicators

Indicator Power generation	**Existing capacity by 2004** (GW)	**Comparison Indicators** (GW)
Large hydropower	720	World electric power capacity =3,800
Small hydropower	61	
Wind turbines	48	
Biomass power	39	
Geothermal power	8.9	
Solar PV, off-grid	2.2	
Solar PV, grid-connected	1.8	
Solar thermal power	0.4	
Ocean (tidal) power	0.3	
Total renewable power generation capacity (excluding large hydropower)	160	

Existing renewable electricity capacity worldwide totaled 160 GW in 2004, excluding large hydro has been shown in the [*Table-2*]. Small hydro and wind power account for two-thirds of this capacity. This 160 GW compares to 3,800 GW installed capacity worldwide for all power generation, is truly marginal. Developing countries as a group, including China, have 70 GW (44 percent) of the 160 GW total, primarily biomass and small hydro power. The European Union has 57 GW (36 percent), a majority of which is wind power.

During 2006 renewable energy consumption reached its highest level since 1997, which was a record year for hydropower due to water availability. Hydropower is the second largest source of renewable energy consumption. The electric power sector continued to be the largest consumer of renewable energy in 2006 (55 percent of total), primarily due to the very large contribution of conventional hydroelectric power. The industrial sector was second (29 percent of the total), due to that sector's major consumption of wood and derived fuels. Geothermal and conventional hydropower played only minor roles in the industrial sector. The residential sector also consumed wood for space heating and solar energy for water heating and electricity. The commercial sector accounted for just 2 percent of total renewable energy consumption. The transportation sector was the fastest growing sector, consuming 40 percent more renewable fuel between 2005 and 2006. This is mainly due to increased ethanol consumption, by far the larger component of biofuels during those years.

5.2 World renewable energy targets

Policies to promote renewable energy existed in a few countries in the 1980s and early 1990s, but renewable energy policy began to emerge in many more countries, states, provinces, and cities during the late 1990s and early 2000s. Many of these policies have exerted substantial influence on the market development.

Policy targets for renewable energy exist in at least 45 countries worldwide. By mid-2005, at least 43 countries had a national target for renewable energy supply, including all 25 EU countries [*Table-3*]. The EU has Europe-wide targets as well: 21 percent of electricity and 12 percent of total energy by 2010. In addition to these 43 countries, 18 U.S. states (and the District of Columbia) and 3 Canadian provinces have targets based on renewables portfolio standards (although neither the United States nor Canada has a national target). An additional 7 Canadian provinces have planning targets. Most national targets are for shares of electricity production, typically 5–30 percent. Electricity shares range from 1 percent to 78 percent. Other targets are for shares of total primary energy supply, specific installed capacity figures, or total amounts of energy production from renewables, including heat. Most targets aim for the 2010–2012 timeframe.

Table-3: Worldwide renewable energy targets

Country	RE target (%) by 2020		Country	RE target (%) by 2020
Total (EU-25)	21.0		Latvia	49.3
Hungary	3.6		Sweden	60.0
Malta	5.0		Austria	78.0
Estonia	5.1		Australia	9.5 TWh of electricity annually by 2010
Luxembourg	5.7		Brazil	3.3 GW added by 2006
Belgium	6.0		Canada	3.5% to 15%
Cyprus	6.0		China	10% of electric power capacity by 2010
Lithuania	7.0		Dominican Republic	500 MW wind power capacity by 2015
Poland	7.5		Egypt	14%
Czech Republic	8.0		India	10% during 2003–2012
United Kingdom	10.0		Israel	5% of electricity by 2016
Netherlands	12.0		Japan	1.35% of electricity by 2010 besides Geothermal and Large hydro
Germany	12.5		Korea	7% of electricity by 2010
Ireland	13.2		Malaysia	5% of electricity by 2005-6
Greece	20.1		Mali	15% of energy by 2020
France	21.0		New Zealand	30 PJ of added capacity by 2012
Italy	25.0		Norway	7 TWh from heat and wind by 2010
Denmark	29.0		Philippines	4.7 GW total existing capacity by 2013
Spain	29.4		Singapore	50,000 m2 of solar thermal by 2012
Slovak Republic	31.0		South Africa	10 TWh added final energy by 2013
Slovenia	33.6		Switzerland	3.5 TWh from electricity and heat by 2010
Finland	35.0		Thailand	8% of total primary energy by 2011
Portugal	45.6		United States	5% to 30%

A few other developing countries are likely to announce targets in the near future. China's target of 10 percent of total power capacity by 2010 (excluding large hydropower) implies 60 GW of renewables capacity given projected electric-power growth. China also has targets for 2020, including 10 percent of primary energy and 12.5 percent of power capacity, 270 million square meters of solar hot water, and 20 GW each of wind and biomass power. Thailand is targeting 8 percent of primary energy by 2011 (excluding traditional biomass). India is expecting 10 percent of added electric power capacity, or at least 10 GW of renewables, by 2012. The Philippines is targeting nearly 5 GW total by 2013, or a doubling of existing capacity. South Africa in 2003 set a target of 10 TWh of additional final energy from renewables by 2013, which would represent about 4 percent of power capacity. The Mexican legislature was considering in 2005 a new law on renewable energy that would include a national target.

5.3 International solar energy market

Overall, renewable power capacity expanded to 182 GW in 2004, up from 160 GW in 2004, excluding large hydro power. The top six countries were China (42 GW), Germany (23 GW), USA (23 GW), Spain (12 GW), India (7 GW), and Japan (6 GW). India's renewable power capacity exceeded that of Japan for the first time.

As per the latest available data from IEA, solar energy contributes very little towards overall RE power generation and use *(Table-4)*. The following table shows usage of solar energy (thermal and photovoltaic) in residential and electric power generation sectors.

Table-4: Renewable energy consumption by energy use 2002-2006 (Quadrillion Btu)

Sector and Source	2002	2003	2004	2005	2006
Total	5.893	6.150	6.261	6.444	6.922
Solar/PV	0.065	0.063	0.065	0.067	0.072
Residential					
Solar/PV[h]	0.059	0.058	0.059	0.061	0.067
Electric Power					
Solar/PV	0.006	0.005	0.006	0.006	0.005

[h] *Includes small amounts of distributed solar thermal and photovoltaic energy used in the commercial, industrial and electric power sectors.*
Source: IEA, 2008

When compared the overall ranking of countries in terms of solar energy generation, the following table *(Table-5)* was generated from IEA data. The countries were ranked based on their annual amounts of capacity additions in 2005 in the mentioned areas.

Table-5: Top Five Countries with Solar Technologies

	1	2	3	4	5
Solar PV (grid connected)	Germany	Japan	USA	Spain	France
Solar Hot Water	China	Turkey	Germany	India	Austria / Greece/ Japan/ Australia

Source: IEA, 2006

The global solar photovoltaic market

Grid connected SPV continued to be the fastest-growing power generation technology in 2005, with a 55% increase in cumulative installed capacity to 3.1 GW, up from 2.0GW in 2004. More than half of the annual global increase occurred in Germany, which saw over 600 MW of PV installed in one year. Grid connected SPV increased by about 300 MW in Japan for the first time. Including off-grid applications, total PV capacity existing worldwide increased to 5.4 GW in 2005, up from 4.0 GW. In 2006, the SPV sector has register an average of 36.1% annual growth with Germany achieved highest growth of 61.9%.

Existing Solar hot water capacity increased by 14% to reach 88 GWth in 2005, up from 77 GWth in 2004, excluding unglazed swimming pool heating. Solar hot water in Europe increased by more than 1.3 GWth. India and several other countries saw an acceleration of solar hot water installations.

The global solar thermal market

Solar thermal electricity generation decreased on worldwide basis from 663 GW in 1990 to 550 GW in 2006. While most of production is taking place in USA, the Spain has initiated activities to generate solar thermal electricity during the year 2007-08.

New opportunities are opening up for solar thermal power as a result of the global drive for clean energy solutions. Both national and international initiatives are supporting the technology, encouraging the commercialization of production. The Concentrating Solar Power Global Market Initiative was launched in October 2003. A number of countries have introduced legislation that forces power suppliers to source a rising percentage of their supply from renewable fuels. Bulk power, high-voltage transmission lines from high-insolation sites, such as in northern Africa, could encourage European utilities to finance large solar plants, power from which would be utilized in Europe.

These and other factors have led to significant consideration of plant construction in the sunbelt regions of the world. In addition, interest rates have drastically fallen worldwide, increasing the viability of capital-intensive renewable energy projects. The 'race to be first' in this sector is demonstrated by the range of specific, large solar thermal projects currently planned *(Table-6).*

Table-6: Large solar thermal projects planned by different countries

Country	**Power generation activities**
Algeria	140 MW ISCC plant with 35 MW solar capacity
Australia	35 MW compact linear Fresnel reflector (CLFR)-based array to preheat steam at a 2000 MW coal-fired plant
Egypt	127 MW ISCC plant with 29 MW solar capacity
Greece	50 MW solar capacity using steam cycle
India	140 MW ISCC plant with 35 MW solar capacity

Israel	100 MW solar hybrid operation
Italy	40 MW solar capacity using steam cycle
Mexico	300 MW ISCC plant with 29 MW solar capacity
Morocco	230 MW ISCC plant with 26 MW solar capacity
Spain	Two 50 MW solar capacity using steam cycle and storage in solar-only mode
USA	50 MW solar capacity using steam cycle; 1 MW parabolic trough using Organic Rankine Cycle (ORC) engine

A scenario prepared by Greenpeace International and the European Solar Thermal Power Industry Association (ESTIA) projects what could be achieved by the year 2020 given the right market conditions. This scenario is based on expected advances in solar thermal technology, coupled with the growing number of countries supporting projects in order to achieve both climate change and power supply objectives.

Other notable features of the scenario (2005-2020) include the following:

Box 1: Global solar thermal highlights

- By 2020, the total installed capacity of solar thermal power around the world will have reached 21,540 MW
- Solar thermal power will have achieved an annual output of more than 54,000,000 MWh
- Capital investment in solar thermal plant will rise from US$375 million in 2005 to almost $5.4 billion in 2020
- The total investment would amount to $41.8 billion
- Expansion in the solar thermal power industry will result in the creation of 200,000 jobs worldwide
- The five most promising countries are Spain, USA, Mexico, Australia and South Africa
- Over the period up to 2020, a total of 154 million tonnes of CO_2 emissions into the atmosphere would be prevented

Source: ESTIA, 2005

Over the period encompassed by the scenario, it is predicted that solar thermal technology will have emerged from a relatively marginal position in the hierarchy of renewable energy sources to achieve a more substantial status, alongside the current market leaders such as hydro and wind power. From a current level of just 354 MW, the total installed capacity of solar thermal power plants will have passed 5000 MW by 2015, according to the Greenpeace-ESTIA projections. By 2020, additional capacity would be rising at a level of almost 4500 MW each year. Following table shows estimated solar thermal power generation, CO2 emission control and investment required for achieving the targeted growth.

Table-7: Overall projections for solar thermal power (2002-2020)

Total capacity (MW)	Total annual electricity generation (MWh)	Total CO2 emission avoided (tonnes)	Total investment (USD million)
2002	354	708000	424800
2005	505	1058000	634800
2010	1,550	60,95,000	3657300
2015	5,990	1,52,08,000	91,24,800
2020	21,540	5,45,83,000	3,27,49,300

Source: Enersol EU report

A further projection is also made for the potential expansion of the solar thermal power market over the subsequent two decades, up to 2040. This shows that, by 2030, worldwide capacity will have reached 106,000 MW, and by 2040 a level of almost 630,000 MW will have been achieved.

Increased availability of plant, because of the greater use of efficient storage technology, will also increase the amount of electricity generated from a given installed capacity. The result is that, by 2040, more than 5% of the world's electricity demand could be satisfied by solar thermal power.

5.4 Solar Energy markets in India

The Indian solar energy market is divided mainly under two heads depending ion the types of technologies used for product manufacturing. These are solar photovoltaics and solar thermal. Although in terms of present usage solar thermal power generation is much more than the corresponding photovoltaics counterpart, but the latter technology is developing very fast.

Growth of solar photovoltaics (SPV)

The solar PV program was begun in the mid 70's in India. While the world has progressed substantially in production of basic silicon mono-crystalline photovoltaic cells, India has fallen short to achieve the worldwide momentum. In early 2000, nine Indian companies were manufacturing solar cells. During 1997-98 it was estimated that about 8.2 MW capacity solar cells were produced in the country. The total installed manufacturing capacity was estimated to be 19 MW per year. The major players in Solar PV are Bharat Heavy Electricals Ltd. (BHEL) (http://www.bhel.com/bhel/home.php); Central Electrtonics Ltd., and Rajasthan Electricals & Instruments Ltd., as well as by several companies in the private sector. The latest, 100 million dollars investment from Tata BP Solar in India is the pointer towards the booming solar market in India. Of late, the market is growing for SPV applications based products with the active encouragement of the government.

The Ministry of New and Renewable Energy (www.mnes.nic.in) have initiated innovative schemes to accelerate utilization and exploitation of the solar energy. Number of incentives like subsidy, soft loan, 80 percent accelerated depreciation, confessional duty on import of raw materials and certain products, excise duty exemption on certain devices/systems etc. are being provided for the production and use of solar energy systems.

The Indian Renewable Energy Development Agency (IREDA) a Public Limited Company established in 1987- provides revolving fund to financing and leasing companies offering affordable credit for the purchase of PV systems. As a result, the Renewable Energy Sector is increasingly assuming a greater role in providing grid power to the Nation as its total capacities reached about 9,013 MW. This apart, the Electricity Act 2003, National Electricity Policy 2005 and National Tariff Policy 2006 provide a common framework for the regulation of renewable power in all States/UTs through quotas, preferential tariffs, and guidelines for pricing 'non-firm' power. However, in the Draft New and Renewable Energy Policy Statement 2005, which is yet be approved, the federal government is very cautious about the status of renewable energy in the future. It says, "despite the fact that the biomass-solar- hydrogen economy is some decades away, it should not make industry and the scientific & technical community of the country unduly complacent into believing that necessary steps for expected changes can wait."

The MNES has been implementing installation of solar PV water pumping systems for irrigation and drinking water applications through subsidy since 1993-94. Typically, a 1,800 Wp PV array capacity solar PV water pumping system, which cost about Rs. 3.65 lakh, is being used for irrigation purposes. The Ministry is providing a subsidy of Rs.30 per watt of PV array capacity used, subject to a maximum of Rs. 50,000 per system. The majority of the pumps fitted with a 200 watt to 3,000 watt motor are powered with 1,800 MWp PV array which can deliver about 140,000 liters of water/day from a total head of 10 meters. By 30th September, 2006, a total of 7,068 solar PV water pumping systems have been installed.

State-wise details of cumulative achievements under various non-conventional energy programmes, as on 31.03.2006 are shown in the *Table-8* below:

Table-8: Cumulative achievements under non-conventional energy programmes

MINISTRY OF NON-CONVENTIONAL ENERGY FUNDED PHOTOVOLTAIC OUTPUT BY STATE

	Energy Generated (Megawatt-Years)		
States	2003	2004	2005
Andhra Pradesh	0.21	0.25	0.26
Arunachal Pradesh	0.02	0.03	0.04
Assam	0.03	0.04	0.05
Bihar	0.11	0.11	0.14
Chhatisgarh	0.08	0.19	0.21
Goa	0.00	0.00	0.01
Gujarat	0.10	0.11	0.12
Haryana	0.17	0.21	0.26
Himachal Pradesh	0.14	0.14	0.15
Jammu & Kashmir	0.13	0.22	0.24
Jharkhand	0.03	0.03	0.07
Karnataka	0.13	0.14	0.22
Kerala	0.33	0.43	0.43
Madhya Pradesh	0.16	0.16	0.17
Maharashtra	0.01	0.13	0.14
Manipur	0.02	0.01	0.13
Meghalaya	0.03	0.03	0.06
Mizoram	0.03	0.05	0.05
Nagaland	0.01	0.01	0.01
Orissa	0.11	0.12	0.27
Punjab	0.14	0.41	0.42
Rajasthan	0.38	0.40	0.44
Sikkim	0.01	0.01	0.01
Tamil Nadu	0.21	0.22	0.23
Tripura	0.07	0.07	0.10
Uttar Pradesh	0.56	0.56	0.65
Uttaranchal	0.28	0.33	0.43
West Bengal	0.35	0.67	0.68
Andaman & Nicobar Islan	0.05	0.05	0.06
Chandigarh	0.02	0.02	0.02
Delhi	0.02	0.02	0.03
Lakshadweep	0.13	0.13	0.14
Pondicherry	0.01	0.01	0.01
Others	0.07	0.11	0.12
Total	4.14	5.42	6.37

Source: MNRE

A total of 32 grid interactive solar PV power plants have been installed in the country with financial assistance from the Federal Government. These plants, with aggregate capacity of 2.1 MW, are estimated to generate about 2.52 million units of electricity in a year. In 1995, an aggregate area of 4 lakh square meters of solar collectors were installed in the country for thermal applications such as water heating, drying cooking etc. The thermal energy generated from these devices was assessed at over 250 million kwh per year. In addition, solar PV systems with an aggregate capacity of 12 MW were installed for applications such as lighting, water pumping, communications, etc. These systems are capable of generating 18 million kwh of electricity per year. In 2003 alone, India added 2.5 MW of solar PVs. For rural electrification as well as employment and income generation, about 16,530 solar photovoltaic lighting systems were installed during 2004-05. Over 150,000 square meters of collector area has been installed in the country for solar water heating in domestic, industrial and commercial sectors making the cumulative installed collector area over one million square meters. Government-funded solar energy in India only accounted for about 6.4 megawatt-years of power as of 2005.

Similarly, India's Integrated Rural Energy Program using renewable energy had served 300 districts and 2,200 villages by early 2006 *(Table-9)*. More than 250 remote villages in seven states were electrified under the program during 2005, with additional projects under implementation in over 800 villages and 700 hamlets in 13 states and federal territories (see table below). Rural applications of solar PV had increased to 340,000 home lighting systems, 540,000 solar lanterns, and 600,000 solar cookers in use.

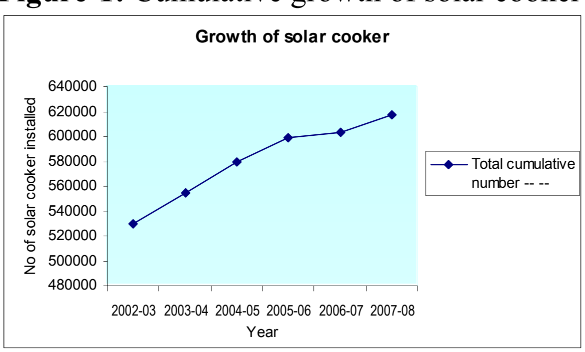
Table-9: India's integrated rural energy program remote villages selected for solar electrification

State	#
Andhra Pradesh	168
Assam	33
Gujarat	38
Haryana	45
Jammu & Kashmir	50
Jharkhand	341
Karnataka	20
Madhya Pradesh	50
Maharashtra	174
Manipur	40
Mizoram	20
Rajasthan	230
Tamil Nadu	152
Tripura	518
Uttaranchal	164
Uttar Pradesh	97
West Bengal	265
	2,405

Source: MNRE

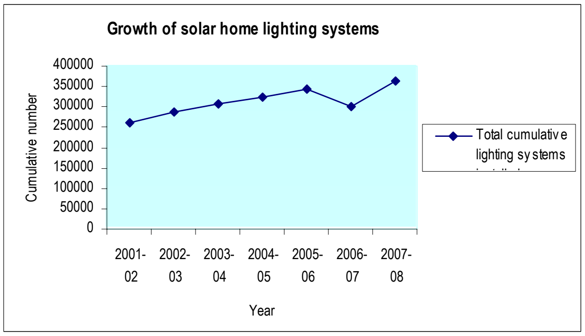
By 2006 over 2,400 off-grid villages in India had received solar thermal and photovoltaic systems. Growth of solar cooker, solar home and street lighting, and solar lantern system have been shown in the following diagrams and tables.

Figure-1: Cumulative growth of solar cooker



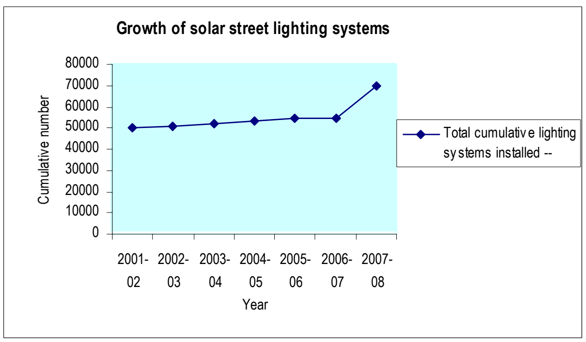
Source: MNRE

Figure-2: Cumulative growth of solar home lighting system



Source: MNRE

Figure-3: Solar street lighting system



Source: MNRE

Table-10: Solar photovoltaic pumps installations in India

Year	**Total cumulative pumps installed**
2001-02	4208
2002-03	5113
2003-04	6414
2004-05	6780
2005-06	7002
2006-07	7046
2007-08	7068

Source: Annual Report, MNRE

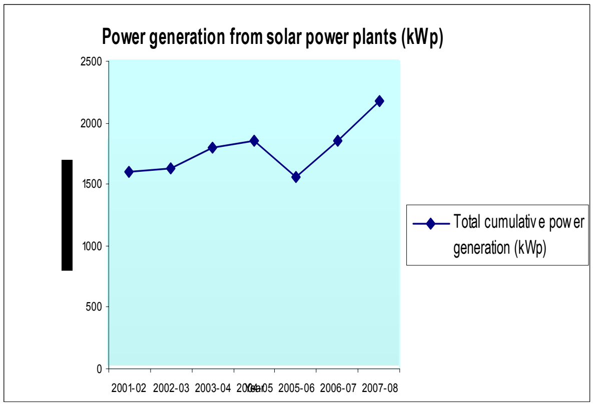
Table-11: Cumulative growth of solar lantern system

Year	Total cumulative lighting systems installed
2005-06	538718
2006-07	463058
2007-08	585001

Source: MNRE

Besides, solar power plant systems are also installed in large number and their number has grown over the years. Their cumulative installed capacity is represented below in the graph.

Figure-4: Solar power plant system



Source: MNRE

5.5 Growth of solar thermal technologies

In India, solar thermal systems are used both in the domestic as well as commercial and industrial applications. In the industrial sector, solar thermal energy is utilized for supplying process heat requirements. The resultant savings are used to meet hot water requirements in hotels, hospitals, and hostels. In the domestic sector, the replacement of electric geysers by solar water-heating systems has resulted in saving of electrical energy.

Solar thermal technologies have a special relevance in India with high availability of sunlight as resource, average radiation is 4.5 - 6 kwh/m2/day for 280 days. According to a conservative estimate, the potential for the deployment of solar water heaters is around 140 million m^2 of collector area. With increasing energy demand in all the sectors, there is immense potential especially in domestic and industrial sector.

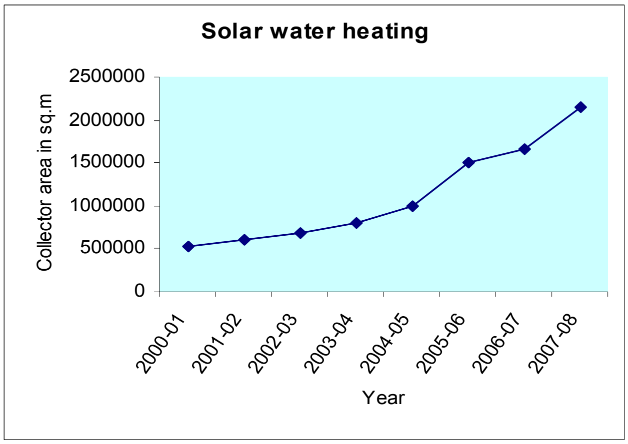
Since its inception in 1992, the MNES had continued supporting solar thermal technologies with various promotional programmes, research, policy initiatives, subsidies and campaigns. At present, following solar thermal technologies are in different stages of commercialization or R&D:

- Solar water heating using flat plate collector
- Solar process heating using concentrating collectors
- Solar thermal power generation
- Solar pond
- Solar cooker
- Solar desalination
- Solar detoxification

The focus is mainly on the solar water heating systems as it is the most commercialised technology in India as well as in Europe and the objective of this study is to identify areas of co-operation between India and Europe.

As a result of various promotional efforts such as national level programmes, government financing, innovative research and policy initiatives, subsidies and campaigns, there has been a steady growth in the cumulative collector area installed as shown in Figure 1.

Figure-5: Cumulative installations of solar water heating systems in India



Source: MNRE

In 2007-08, the total potential collector area was recorded as 140 million m^2 with 6.0 lakh sq m as annual target. A total of about 2.5 lakh sq. m. of collector area has been installed so far during the year, taking the cumulative figure to about 2.15 million sq.m in the country for solar water heating. The total collector area installed has increased from 525000 m^2 in 2001 to 2150000m2 in 2007.

5.6 Indian market segments

Indian markets in terms of growth are performing quite well in both types of solar power generation and their applications, particularly in rural sectors. The government's pro-investment policies also found favour among the Indian renewable energy companies. The enthusiastic Indian entrepreneurs has started investing in RE power generation in recent years. Many new players such as Moser Bayer, Tata BP Solar, Reliance, etc are making conscious efforts towards RE market development.

There are two distinct market segments for solar water heating systems (SWHS) in India, namely, (i) domestic and (ii) commercial & industrial. In domestic sector, SWHS are used to meet household hot water requirements. Whereas, in commercial sector, SWHS are used to meet the hot water demand e.g. in hotels and hospitals etc. while in industrial sector, these systems are used for preheating boiler feed water or to meet the process heating requirements.

So far, the majority of installations in India are in the commercial and industrial sector, with 80% of the collector area installed in commercial and industrial sector, But as a result of improved economics of solar systems thanks to increase in electrical prices, the domestic market is increasing in India. As per MNRE, the potential of solar water heating systems in the country is around 30 million m^2 of collector area. The MNES policy (draft) has set the goal of installing 5-million m^2 collector area during 2000-2012, with equal distribution of collector area in domestic as well as commercial and industrial sector. Various policy incentives have been suggested to achieve this target.

Although, the total collector area installed has increased substantially over the last few years, but this market penetration is still too small comparing to the European countries like Greece, Germany, and Spain etc., especially when compared in terms of collector area installed per unit population. The installations per 1000 inhabitants are 5.1, 15.2 and 0.52 in Greece, Germany and India respectively. In case of Indian market, the marketing, installation of systems and after sales service are responsibility of the manufacturer as the chain of dealers and installers has not been developed, which is very important for market penetration.

India has a strong industrial base for manufacturing of PV systems, which not only caters to the local market, which not only caters to the local market, but also exports. Development of the Indian PV industry started with the setting up of a public sector company called CEL (Central Electronics Ltd) and, subsequently, the start of PV operation by BHEL (Bharat Heavy Electricals Ltd.).Private companies entered this field in the early 1990s. In the Indian PV Industry today, 8 companies manufacture modules while about 45 are in the business of system integration with most of them manufacturing their balance-of-systems as well.

Typically the Indian market has been divided in to

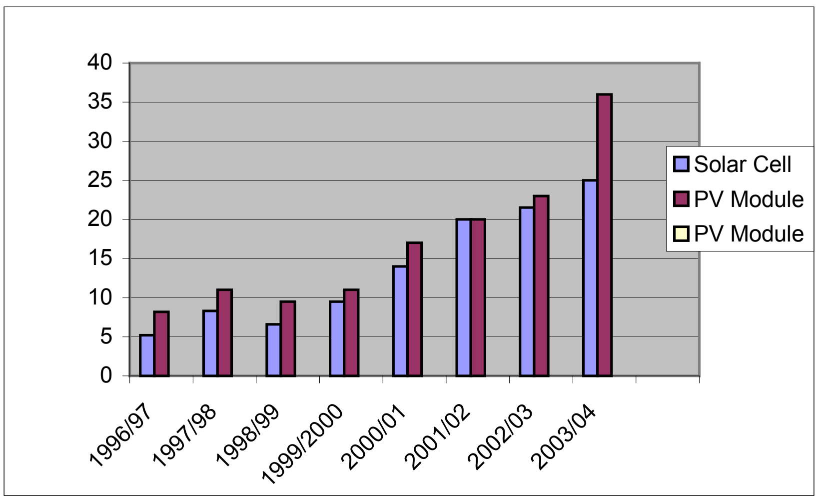
(1) MNES- supported subsidy market primarily for socially-driven schemes;
(2) Commercial market for specialized applications such as in railways, telecommunications, and exports; and
(3) Consumer-oriented market primarily driven by availability of finance.

The first segment of market consists of approximately 30% of the aggregate system installed capacity. Market share for commercial segment has been 46%, and remaining 24% is accommodated in the consumer-oriented market. In view of the current emphasis and commitment on deploying PV technology through commercially sustainable routes, it is estimated that the market segment in the commercial and consumer segments will grow fast.

Based on the experience and success of the Ninth Plan, the pattern of PV demonstration and utilization programme has been modified for the Tenth Plan period. Accordingly, targets have been set as 250 000 home lighting systems, 10 000 solar generators, and 5-MW capacity power plants and other including BIPV applications. A total of 5000 villages are proposed to be electrified during the Tenth Plan out of which 4000 are likely to use PV technology. Additionally, a target for selling 600 000 solar lanterns through the interest subsidy has also been set. For grid interactive power, the plan proposes a total of 15 MW_p additional capacities out of which 5 MW_p is more captive use by the industry.

There is also an annual manufacturing capacity of about 2 million silicon wafers. The industry produced 25 MW_p of solar cells and 36 MW_p of modules during 2003/04, while production of these during 2002/03 was 21.5 MW_p and 23 MW_p, respectively. The cumulative production of the Indian PV industry was around 191 MW_p till 31 December 2004, out of which over 105 MW_p was exported. The target for 11th Five Year Plan is to add about 50 MWp of SPV systems including both off grid and grid connected SPV systems. Following *Figure-6* shows the details of the annual production of solar cells and modules in India.

Figure-6: Annual production of solar cells and modules



Source: MNRE

5.7 Markets for the future

Most of the thermal energy requirements in the Indian industrial sector lies in the range of 100-250 ^{0}C, which corresponds to the medium temperature range of solar thermal systems. This is supplied either as high temperature, pressurized water or as low-pressure steam. These medium temperature requirements are primarily met by the combustion of fossil fuels, such as coal. Ignite, and furnace oil. There are 22 major industries where boilers supply process heat in the form of either steam or hot air up to a maximum temperature of 150 C. These industries include dairy, food processing, textiles, hotels, edible oil, chemical, bulk drug, breweries, and distilleries.

Solar thermal Systems can be employed to meet this demand in a complementary manner. It is estimated that about 60% of the thermal energy consumed in the industry is used to process and products. Even if only 10% of this requirement is met through solar thermal systems, it will lead to savings of about 292 400 Kilolitres of furnace oil (Dr Rao Associates 1991) a year and a reduction in the resultant CO_2.

A major component of household energy requirement in India is cooking. Fuelwood, Kerosene, and LPG are the major sources of cooking energy; however, there is a gradual shift from fuelwood to LPG for cooking. Solar cooking offers a viable option in the domestic sector. At the micro level, solar cookers facilitate financial savings for the consumer, and at the macro level, they help in the conservation of LPG and fuelwood. Of the many types of solar cookers- such as concentrating (dish) type solar cookers, indirect heating type solar cookers, with or without heat storage, and hybrid type solar cookers- the box type solar cookers have reached the commercialization stage.

Considering the vast potential and resource availability, the Government of India, through the MNES, provided various interventions in terms of subsidy and other fiscal benefits to promote solar water-heating systems. These subsidies were abolished in July 1993 when the technology attained a certain level of commercialization. Instead, provisions were made to avail soft loans through IREDA and some designated banks.

Among several applications of PV, BIPV (Building integrated PV) is one of the fastest-growing market segments in Europe. In India, this concept is slowly gaining popularity, pioneered by TERI and followed by a few other projects such as those in IIT (Indian Institute of Technology), Kanpur. Traditionally, PV arrays have been mounted on special support structures; however, they can also be made an integral part of the building envelope. In order to encourage this application and prepare manufacturers and users, the MNES has recently launched a scheme to support BIPV demonstration.

The village electrification programme of the Government of India has opened a significant market segment for PV. There are about 173000 villages in the country of which about 25000 villages are in remote and accessible areas. All these villages are proposed to be electrified using RETs.

The SPV demonstration and utilization programme was reviewed during the year 2004/05. It was found that 74-W_p models of solar home systems (which consist four light points or two light points and a connection of TV/fan) were being purchased by relatively well-off people. Therefore, the subsidy of the 74-W_p module has been reduced to re-introduce solar lanterns under this programme, which was withdrawn from the programme in 2002/03. However, the subsidy level for solar lanterns would be same as it was at the time of its withdrawal (that is 50%).

Chapter 6: Government programmes in solar energy developments in India

6.1 Central policy for renewable energy development

The spread of various renewable energy technologies have been aided by a variety of policy and support measures by Government. Major policy initiatives taken to encourage private/foreign direct investment to tap energy from renewable energy sources include provision of fiscal and financial incentives under a wide range of programmes being implemented by the Ministry and simplification of procedures for private investment, including foreign direct investment, in renewable energy projects. The policy is clearly directed towards a greater thrust on over all development and promotion of renewable energy technologies and applications. The recent policy measures provide excellent opportunities for increased investment in this sector, technology up-gradation, induction of new technologies, market-development and export promotion. A Comprehensive Renewable Energy Policy for all round development of the sector is under preparation.

Policy measures in vogue:

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

- 100% accelerated depreciation for tax purposes in the first year of the installation of projects/systems.
- No excise duty on manufacture of most of the finished products.
- Low import tariffs for capital equipment and most of the materials and components.
- Soft loans to manufacturers and users for commercial and near commercial technologies.
- Five-year tax holiday for power generation projects.
- Remunerative price under alternate power purchase policy by State Government for the power generated through renewable energy systems, fed to the grid by private sector.
- Facility for Banking and wheeling of power.
- Facility for Third party sale of renewable energy power.
- Financial Incentives/Subsidies for devices with high initial cost.
- Involvement of women not only as beneficiaries but also for their active contribution in implementation of renewable energy programmes.
- Encouragement to NGOs and small entrepreneurs.
- Special thrust for renewable energy in North-Eastern region of the country. 10% of Plan funds earmarked for North-East towards enhanced and special subsidies.

- Allotment of land on long term basis at token lease rent and supply of garbage free of cost at project site by State Governments, in respect of projects on energy recovery from municipal waste.

6.2 State Government's Policy for Renewable Energy

For encouraging investment by the private and public sector companies in power generation through renewable energy, a set of guidelines have been issued by the Ministry of Non-Conventional Energy Sources for consideration of the States.
As a result a number of States have announced policy packages including Wheeling, Banking, Third Party sale and Buy-Back which have been outlined.
In addition some of the States are providing concession/exemption in State Sales Tax and Octroi etc.

6.3 Industrial Policy for Renewable Energy Development in India

Ministry of Non-Conventional Energy Sources is promoting medium, small, mini and micro enterprises for manufacturing and servicing of various types of renewable energy systems and devices. Industrial policy measures include:

- Industrial clearance is not required for setting-up of renewable energy industry.
- No clearance is required from Central Electricity Authority for power generation projects upto Rs. 100 crores (Rs. 1000 million).
- A five year Tax holiday allowed for renewable energy power generation projects.
- Soft loan is being made available through IREDA for renewable energy equipment manufacturing.
- Facilities for promotion of export oriented units are available for renewable energy industry also.
- Financial support is available to renewable energy industries for taking up R&D projects in association with technology institutions.
- Power project import allowed.
- Private Sector Companies can set up enterprises to operate as licensee or generating companies.
- Customs duty concession is available for renewable energy parts/equipment, including for machinery required for renovation and modernization of power plants.
- Excise duty on a number of capital goods and instruments in the renewable energy sector has been reduced/exempted.

6.4 Foreign Investment Policy

Following are the major features of the policy:

- Foreign Investors can enter into a joint venture with an Indian partner for financial and/or technical collaboration and also for setting up of renewable energy based Power Generation Projects.

- Liberalized foreign investment approval regime to facilitate foreign investment and transfer of technology through joint ventures.
- The proposals for up to 74% foreign equity participation in a joint venture qualifies for automatic approval.
- 100% foreign investment as equity is permissible with the approval of Foreign Investment Promotion Board (FIPB).
- Various Chambers of Commerce and Industry Associations in India can be approached for providing guidance to the Investors in finding appropriate partners.
- Foreign Investors can also set up a liaison office in India.
- Government of India is also encouraging foreign Investors to set up renewable energy based power generation projects on Built- Own and Operate basis.

6.5 Incentives and Schemes

India is one of the countries most involved in developing the use of renewable energies and is trying to make the opportunity for investors more attractive than costly.

To promote renewable energy technologies in the country, the government has put in place some subsidies & fiscal incentives. The Indian Renewable Energy Development Agency has been set up under Ministry for Non-Conventional Energy Sources and is a specialized financing agency to promote and finance renewable energy projects. Following is a short list of new measures:

- Income tax breaks
- Accelerated depreciation
- Custom duty/duty free import concessions
- Capital/Interest subsidy
- Incentives for preparation of Detailed Project Reports (DPR) and feasibility reports

6.6 Ministry for Non-Conventional Energy Sources mix of fiscal and financial benefits:

- 2/3rd of the project cost subject to a maximum of Rs. 2.00 crore per 100 KW for procurement of modules, structures, power conditioning units, cabling etc. to the implementing agency. The balance cost on land, extension of grid lines, transformers, civil works, foundation and erection and commissioning, etc. is met by the implementing agency.
- Up to Rs.1.0 lakh for the preparation of Detailed Project Report (DPR) for the grid interactive SPV power projects.
- 2.5 percent of its share of project cost, subject to a maximum of Rs.5 lakhs for performance evaluation, monitoring, report writing, etc. to the State Nodal Agency.
- Interest subsidy of up to 4 percent to Financial Institutions including IREDA, Nationalized Banks etc. for captive power projects of maximum capacity 200 KW by industry.

In a bid to encourage private sector participation in the non-conventional energy sector, the Indian government has proposed incentives for promoting medium, small, mini and micro enterprises for manufacturing and servicing of various types of renewable energy systems and devices. The measures include:

- Industrial clearance is not required for setting-up of a renewable energy industry.
- No clearance is required from the Central Electricity Authority for power generation projects up to Rs 1 billion ($21.7 million).
- A five year tax holiday is allowed for renewable energy power generation projects.
- Soft loans are being made available through the Indian Renewable Energy Development Agency (IREDA) for renewable energy equipment manufacturing.
- Facilities for the promotion of export-oriented units are also available for renewable energy industry.
- Financial support is available to renewable energy industries for taking up R&D projects in association with technology institutions.
- Power project imports are allowed.
- Private Sector Companies can set up enterprises to operate as licensee or generating companies.
- Customs duty concession is available for renewable energy parts/equipment, including for machinery required for renovation and modernization of power plants.
- Excise duty on a number of capital goods and instruments in the renewable energy sector has been reduced/exempted.

The Minister for Non-Conventional Energy in the Indian government, Mr M Kannapan has also urged corporate to turn their attention to renewable energy as a business proposition and not just to meet their own energy requirements. He said that his ministry would consider proposals involving even 100 percent foreign equity participation favorably for projects, production facilities and technical services. Opportunities for joint Research and Development (R&D) should be created, the Minister said.

6.7 Programmes and schemes

Following are a few examples of government programmes and schemes initiated in India.

a) Solar hot water system installed in Pune

Solar thermal energy refers to the utilization of solar energy by capturing the available solar radiation and transferring it as heat to perform various useful activities, like, heating, cooling, drying, water purification, industrial process heat and power generation. This technology route also includes solar architecture, which finds utility in designing and construction of energy efficient buildings.

b) Urban, industrial and commercial applications programme

According to the Census of 2001, and data published by the Ministry of Urban Development, India had a population of 1027 million, as on 1st March, 2001. About 285 million people (27.8% of the total population) live in urban areas. While the population in rural areas grew by 17.9% during the decade between 1991 and 2001, that in urban areas grew by as much as 31.2%, indicating a migration from rural to urban areas (besides normal population growth).There are a total of 4378 urban agglomerations and towns in the country (the census data shows 5161 towns). Of these, 423 towns and cities have a population or more than 1 lakh. There are 35 urban agglomerations and cities with a population of over 1 million. The total number of urban households in the country is 53.7 million.

In an effort to mitigate the energy problems of cities and to provide alternative energy solutions for industrial and commercial establishments; it has been decided to focus on the development and application of the renewable energy technologies and energy efficient systems.

c) Solar thermal systems for air heating/ steam generating applications

Under this programme, Solar Flat Plate Collector (FPC) have been found to be very useful specially in agriculture and food industries for air heating. These industries generally require hot air at low temperature (50-80 Deg.C.) as process heat for drying of various products such as tea leaves, coffee beans and also for processing of fruits, spices, cereals, mushroom, papad, vegetables, fish, sea food etc. Hot air is also required in industries such as leather, textile, chemicals, rubber, paper, pharmaceuticals etc. MNES, Govt. of India shall provide 50% of the cost of the system subject to a maximum of Rs.2,500/- per sq. mtr. of collector area for FPC based solar air heating systems/ dryers for non-profit making institutions/ organizations. 35% of the cost of system subject to maximum of Rs.1750/- per sq. mtr. of collector area for FPC based solar air heating systems/ dryers for commercial / industrial organizations (profit making and claiming depreciation).

d) Solar concentrating system for heating air / generating steam directly or through heating of oil

Under this programme, Solar Concentrating systems comprising of parabolic dishes known as “Scheffler” dishes have been found to be useful for generating steam to cook food for 100 and 10000 of people in Community Kitchens specially at religious places. MNES, Govt. of India shall provide 50% of the cost of the system subject to a maximum of Rs.5,000/- per sq. mtr. of dish area for Solar Concentrating Systems for non-profit making institutions/ organizations. 35% of the cost of system subject to maximum of Rs.3500/- per sq. mtr. of dish area for Solar Concentrating Systems for commercial / industrial organizations (profit making and claiming depreciation).

e) Solar cookers and water heaters

The government has been promoting box type solar cookers with subsidies for quite some time with the hopes of saving fuel and meeting the needs of both the rural and urban populace. There are community cookers and large parabolic reflector based systems in operation in some places in India. A conservative estimate of the amount of solar water heating systems installed in the country is over 475,000 sq. meters of conventional flat plate collectors. To date, the largest users of solar water heaters are co-operative dairies, chemical and process units, hostels, hospitals, textile mills, process-houses and individuals.

Chapter 7: Solar energy applications – case studies

7.1 Solar power generating systems, milk collection centers, Gujarat

In Gujarat the milk collection centers in rural areas cannot be operated due to unavailability or lack of electricity. To overcome these difficulties a Solar Photovoltaic Power Generating System can be utilized for providing continuous uninterrupted power and operation of Milk Collection Centres. The total cost of the 525 Wp system is approximately Rs. 1.70 lacs, including installation, commissioning, transportation, operation and one-year maintenance and monitoring. The MNES provides a subsidy of Rs 0.85 lacs for the system. Now, with the uninterrupted power supply they are able to provide better services with the help of Solar Photovoltaic Power Generating System. There is tremendous potential for Solar Photovoltaic Power Generating System as there are about 1000 nos. of milk collection centres per district and about 6 District are eager to install this type of Solar Photovoltaic Power Generating System in the State of Gujarat. All the systems are found to be performing excellent, and revenue is increased.

For details log onto: http://www.geda.org.in/solar/so_slr_casestudy.htm

7.2 Solar modules on the rooftop of the world – the ladakh project

In the Trans Himalayan region of Ladakh, men, women and children living in total absence of grid electricity, life remains unchanged year after year. Until Tata BP Solar and the Ladakh Renewable Energy Development Agency (LREDA) joined hands to transform the lives of thousands living in the Last Shangri La. Tata BP Solar has played a pivotal role in the Rs.166 million LREDA Project to electrify 80 remote and mountainous villages, as the first step towards electrifying the entire region of Ladakh. The Government of India approved the Project in September 2000 and Solar Energy was the natural choice, since Ladakh is blessed with sunshine for more than 300 days in a year. The low ambient temperature ensures that PV Modules operate at optimum efficiency. And the tough mountainous terrain makes other forms of energy unviable.

For details log onto: http://www.tatabpsolar.com/home_light.html

7.3 Greening field with gold and blue in Punjab

Punjab has the distinction of producing the largest wheat crop in the country and also vast quantities of rice and cotton, but by the unavailability of water, farmers were unable to irrigate their fields. Understanding the urgent need to provide alternative energy for water pumping, the Punjab Energy Development Agency, after much deliberation, decided upon a 2 HP DC Surface Pumping System, powered by the sun. And in the year 2000 awarded Tata BP Solar an order for 225 Solar Water Pumping Systems. To make the Systems financially viable to farmers, a complex web of financial engineering was developed. Working closely with the Ministry of Non-Conventional Energy Sources and the State Government, the Punjab Energy Development Agency, offered the Pumping Systems to farmers at an end-user contribution of just Rs.35,000/- . The response was overwhelming. 500 Pumps were booked in just 2 months. During 2003, Tata BP Solar installed 1000 Solar Water Pumping Systems, in Punjab alone. Similar success stories are taking shape in Tamil Nadu, Kerala and Bihar too.

For details log onto: http://www.tatabpsolar.com/water_pump.html

7.4 200kw grid connected solar photovoltaic power plant, Punjab

Village Khatkar Kalan in District Nawanshahr state of Punjab, India's one of the thousands of Indian villages, which are facing electricity shortages. The Ministry of Non conventional Energy Sources (MNES), Government of India in consultation with village Panchayat (the local governance body) identified the village for demonstration of grid connected solar photovoltaic power plant of 200kW capacity, which is the largest Photovoltaic plant in the country. The Power plant also supplies electricity to streetlights in the villages. Demonstration of village electrification through distributed generation by grid connected solar photovoltaic power plant is the main objective of the project. The power plant of this size has not been installed in the country so far. This plant is one of the best examples of demonstration of technology as well as the concept of feeding the renewable electricity into the state grid. It also showcases the arrangements of long-term service-cum- O&M contract with the manufacturer and supplier of the equipments.

For details log onto:

http://indiaenergyportal.org/files/Case%20study_SPV%20Grid_1.doc

7.5 Solar pv pumping systems, Punjab

Punjab government came up with a bold initiative to introduce Solar PV Pumping Systems (SPS) on a large scale. 1000 SPS of 1800 Wp each were installed at rural farms all over the Punjab. Following the initial success, the project is now being repeated on a yearly basis and neighboring states have picked up on the initiative and started their own SPS programmes. The project not only sticks out in terms of its sheer size (nearly 2 MWp of PV power installed in rural areas in just 2 years), but also in terms of some innovative aspects to guarantee the long-term sustainability of the PV pumping systems.

For details log on to: http://www.terienvis.nic.in/casestudies.htm#punb

7.6 Roof-top SPV systems catch-up in Kolkata

During 2001-02 five projects with an aggregate capacity of 275 kWp were commissioned. This brings the total rooftop systems installed up to February 2002 to nine. In addition two rooftop systems are under installation. Among the projects commissioned during the year are those at the Vidyut Saudha Building in Hyderabad and at the Bikalp Shakti Bhavan in Kolkata. The West Bengal Renewable Energy Development Agency (WBREDA) has set up the Kolkata project, which has a capacity of 25 kWp. WBREDA has entered into an Energy Adjustment Agreement with the West Bengal State Electricity Board, under which the WBREDA would pay net energy charges. A bi-directional import-export energy meter keeps a record of the net energy consumption by the WBREDA and the electricity charges are based on net energy consumption at Bikalp Shakti Bhawan.

For details log on to:
http://www.google.co.in/search?hl=en&q=solar+energy+case+studies+in+india&meta

7.7 Village electrification via solar energy, Chattisgarh

Currently, 16000 villages are un-electrified in the state. Of these, 1250 villages are so isolated that the state electricity board has declared them as "inaccessible to grid power". This is because they are not able to connect these villages to conventional grid power due to economic, social and environmental challenges. Chattisgarh State Renewable Energy Development Agency (CREDA), under the department of energy, Chattisgarh, looked at more environment-friendly options like solar power to electrify villages in dense forests. Working with the state electricity board, CREDA will electrify over 1253 villages with priority being given to non-electrified police stations in the naxalite-affected districts. Tata BP Solar has been working closely with CREDA during the last 5-6 years. It has set up over 100 solar power plants in a phased manner, in 107 villages across 5 districts. Ranging from 1 kwp to 6 kwp, these plants provide power for 6 to 22 streetlights and 38 to 220 home lighting systems per village / cluster. The grid quality power from the solar power plants has had a positive impact on the health, education, entertainment and economic activities in these villages, largely populated by poor tribes. After the successful implementation of this project, which was completed on time, with no Health, Safety, Security and Environment (HSSE) violations, Tata BP Solar has received another significant order from CREDA for 112 solar power plants with a total size of 0.5 mw amounting to Rs 216 million.

For details log on to: http://www.tata.com/tata_bp_solar/articles/20070103_arunodaya.htm

7.8 Largest solar water heating systems, Mysore

Sprawled across a 270-acre campus, Infosys' campus in Mysore is home to the Global Education Centre, the largest of its kind in the world. Adding a green touch to this world-class campus is Tata BP Solar, with its solar water heating systems. Tata BP Solar recently bagged an order from Infosys for supply and installation of solar water heating systems totaling a capacity of 2,42,000 litres per day (lpd). It includes 15 systems of 5000 lpd, 33 systems of 4000 lpd and 13 systems of 3000 lpd. These systems will cater to the requirement of inmates in 7000 rooms in the campus with a peak load demand equivalent of 10 mw on an average occupancy of 75 per cent. The running cost of the project is 90 per cent less than that of conventional diesel / electrical modes. Since April 2005, Tata BP Solar has commissioned about 84 solar water-heating systems of 147,000-lpd capacities in the same premises.

For details log on to: http://www.tata.com/tata_bp_solar/articles/20070103_arunodaya.htm

7.9 World's largest solar steam cooking system at tirumala, Andhra Pradesh

The Tirumala Tirupathi Devasthanam (TTD) at Tirumala in Andhra Pradesh has installed the world's largest solar steam cooking system. The system has a capacity to prepare food for 15,000 people/day and employs automatic tracking solar dish concentrators, which convert water into high-pressure steam. The steam thus generated is being used for cooking purposes in the kitchen of TTD. It has been hooked up with the existing boiler working on diesel so as to make the system reliable under all climatic conditions. The system has been designed to generate over 4000 kgs of steam/day at 180 degree centigrade and 10 kg/sqcm, which is sufficient to cook two meals for around 15,000 persons. It is modular in nature and consists of 106 automatic tracked parabolic concentrators arranged in series and parallel combination, each of 9.2 sq meter reflector area. Each unit of concentrators is connected to a central steam pipeline going to the kitchen. The system is made of indigenous components and the reflectors are of acrylic mirrors having reflectivity over 75%. Its installation was completed during September 2002 and was inaugurated on 11th October 2002. The system is expected to save around 1,18,000 litres of diesel per year, valued at Rs. 2.3 million. The total cost of the system is about Rs. 110 million, which includes back up boiler, utensils and annual maintenance contract for five years. A total of 6 such systems have been installed in the country. This technology could be very useful at places where rice is the staple food and cooking is done on a very large scale.

For details log on to:
http://www.google.co.in/search?hl=en&q=solar+energy+case+studies+in+india&meta=

7.10 Remote villages case study: village PV power, Mexico

For 25 years, the village of Xcalak, Mexico, a remote village on the east coast of the Yucatan peninsula, struggled to keep its diesel generators running. The people of Xcalak were dissatisfied with their diesel generators because it was expensive to ship fuel to the village and because the generators kept breaking down. Located 68 miles (110 kilometers) from the nearest utility line, this village of 350 people could not convince the utility to spend $3.2 million for a line extension. But when the villagers turned to their government, a bold new solution emerged: adding solar electric modules and wind generators to the existing diesel system to make a large hybrid power system that generates electricity reliably. For Xcalak, there were many advantages to the hybrid system like; construction costs were a fraction of those required for a line extension and fuel and maintenance expenses for the hybrid system are now lower than those for running the diesels alone. The system itself has greater generating capacity, providing more homes and businesses with electric power. And it is proving to be much more reliable than diesel generators alone, because it includes multiple backup generation devices and a larger battery bank.

For details log on to: http://www1.eere.energy.gov/solar/cs_mexico_village.html

7.11 Grid-connected pv case study: PV power for an energy-efficient home, Massachusetts, USA

Concerned about the environment and rising energy costs, a retired couple in Massachusetts commissioned the design of a PV-powered, energy-efficient, all solar home. Although they wanted to be more self-reliant, they didn't want to maintain a battery bank at their home. Because utility power was available, they specified a utility-connected PV system. The privately financed home incorporates many energy-conserving features. Built largely of masonry, concrete, and steel with earth berms against the north, east, and west sides, it stays warm in winter and cool in summer. The south wall of the house is nearly all glass to soak up the winter sun, and the roof overhang shades the south facing glass in summer. The PV modules occupy 430 square feet (40 square meters) of the south-facing roof. The direct current (dc) electricity from the modules passes through an inverter, which converts it to utility-grade ac power. The PV system generates most of the electricity the couple needs, making the home nearly self-sufficient, energy wise, over the course of the year. During summer, the PV system generates more electricity than the house uses and sends the excess out into the utility grid. In winter, the house uses more electricity than the PV system produces, and so it draws some power from the grid.

For details log on to: http://www1.eere.energy.gov/solar/cs_ma_eehome.html

7.12 Utility applications case study: power for a utility substation, California

Pacific Gas and Electric Company's (PG&E) Kerman substation near Fresno, California, was becoming overloaded on hot summer days. That happened especially when air-conditioning and water-pumping needs were greatest, and the utility experienced its peak demand. Overloading heats up substation components, and that in turn shortens the life of expensive transformers, reduces power quality for customers, and increases line losses during transmission. Analysts in PG&E's research group looked to a PV array to meet the extra demand at Kerman, because it happened on the sunny days when solar cells would be producing power very well. Analysts at PG&E believed that using PV to support a substation during times of peak electrical demand might make economic sense for their utility, But no one knew how much the PV grid support would be worth. Because upgrading the Kerman substation would cost several million dollars, PG&E decided to install a PV system as a research project (as part of the PV for Utility-Scale Applications project) to evaluate the benefits of grid support. They found that the PV system installed at Kerman in 1993 produces the most power on sunny summer afternoons, when PG&E experiences its peak demand and electricity has the highest value to the utility. The system maintains its electrical output close to its rated capacity by having the PV modules mounted on trackers that change the modules' tilt as the sun moves across the sky. The Kerman substation experiment is designed to measure the value to the utility of a 500-kilowatt generating plant that can be quickly (within 6 months) placed where extra power is needed. Monitors record electrical output throughout the day and yield detailed information on system output.

For details log on to: http://www1.eere.energy.gov/solar/cs_ca_substation.html

7.13 Remote homes case study: PV power for a modern home, Florida

When the Chases moved to their PV-powered home in southwest Florida, they brought along all their electrical appliances. And they found out they had enough electricity to use them. Once Joyce and George Chase discovered it would cost $15,000 to extend a utility line to their new home on the Peace River in southwest Florida, they decided instead to use a stand-alone PV system to power their appliances and lights. George, whose weekend cabin on the same site had been powered by a stand-alone PV system and battery, designed the house from scratch with the cooperation of the local building inspector. Today, a visitor to this modern 2,000-square-foot (185-square-meter) home would never guess that it doesn't use utility power. All fixtures, outlets, and electrical appliances are standard. Although most of the Chases' appliances operate on direct current (dc), an inverter converts some of their dc power, which is stored in batteries, to ac for those that require ac power. George put the battery and control rooms in a central spot that shortened the length of wire needed, keeping costs down and increasing efficiency. On the advice of an inspector, George installed larger gauge wire for the dc circuits. Today, the Chases enjoy all the conveniences of the city in their rural home: a hair dryer, washing machine, microwave oven, a TV, and ceiling fans, to name a few.

For details log on to: http://www1.eere.energy.gov/solar/cs_fl_modern_home.html

7.14 Solar thermal energy in Iran

Saving energy, realizing net economic benefits and protecting the environment by investing in energy efficiency and renewables. Iran has considerable human and material resources to moderate its energy supply and to co-ordinate the transition to a sustainable energy system. Moreover, Iran has a high amount of renewable energy sources. Against this background, and as part of the initiative "Climate Policy and Sustainable Development. Opportunities for Iranian- German Co-operation "funded by the Heinrich Böll Foundation, a case study on the use of solar thermal energy in Iran was carried out by a consortium led by the Wuppertal Institute. Its results had been presented in a workshop and press conference in Tehran on 18 May 2005. Partners of this project are the Center for Environment and Energy Research and Studies (CEERS), Tehran and the Wuppertal Institute, the University of Osnabrück and Ö-quadrat, Freiburg. The interesting finding of this study is that the expansion of renewable energy sources would not result in an economic burden but would favour the Iranian economy, save costs and create new domestic jobs and new business sectors. To conclude, this important step towards a sustainable energy supply would not mean an economic disadvantage but would induce an increase in welfare.

For details log on to: http://www.ceers.org/News/index.asp

7.15 A PV-powered telephone signal booster, Nevada, USA

The place: a remote signal station in the mountains of northern Nevada. The situation: Sprint Communications decides to reduce the amount of time the company runs its propane-powered electric generators by adding PV modules. When Sprint Communications built its east-west fiber-optic cable line in the late 1980s, it needed a regenerator station every 22 miles (35 kilometers) to boost the signal. These regenerator stations use electricity 24 hours a day, 7 days a week, to power the transmission equipment and control shelter temperatures. Utility power serves most of the stations, which have 2 hours of backup battery capacity should the power line go down. But at Sand Pass, Nevada, bringing in utility power was prohibitively expensive. When Sprint built a regenerator station there in 1986, it installed two propane-powered electric generators. But to maintain the generators, a mechanic had to drive out to the pass every month, and to provide fuel; a teamster hauled a heavy propane tank over rough dirt roads to the site every 3 months. The solution was to install a PV system at the Sand Pass station. The PV array and propane generators at Sand Pass complement each other well. The PV array charges batteries that power the dc transmission equipment. The generators are used to power the ac motor in the air-conditioning unit only when the shelter thermostat calls for air conditioning. As added backup, the generators can charge the batteries, if necessary. Because relieving the generators of their everyday battery-charging duties has reduced the amount of time they run, the PV system has significantly lowered the station's fuel and maintenance costs.

For details log on to:http://www1.eere.energy.gov/solar/cs_nv_signal_booster.html

Chapter 8: Solar energy directory

8.1 National level

Advanced Radio Masts Ltd (PV Manufacturer)	A-9, Electronics Complex, Kushiguda, Hyderabad 500 062 , India Tel: 91 40 7175100 Fax: 91 40 674400
Agni Electronics (PV Manufacturer)	48, Shahid Mahal D.P. Nagar Calcutta 700 056, India Fax: 91 33 4720905
Airier India (Supply and exporter of solar water heater, solar hot water heaters and wind driven roof ventilators)	No.89, Krishna Complex, Kodigehali, Sahakaranagar, Bangalore - 560 096, India Phone: +(91)-(80)-23636753 Fax: +(91)-(80)-23636753
Amar Enterprises (PV Manufacturer)	12-A, Shivpuri Bulandshahar, UP- 201 001, India Tel: 0091-5732-34666 Fax: 0091-5732-24868 E mail: ajit_sharma@sancharnet.in
Beblec (India) Private Limited (Manufacturer, supplier and distributor of energy conservation systems like three phase P20 energy saving device, ac energy savers, servo controlled voltage stabilizers, street lighting energy savers, cooling tower controllers)	Plot No. 126, Sipcot Indl. Complex, Hosur - 635 126, India Phone: +(91)-(4344)-276358/278658/400687/400688/276958/276959 Fax: +(91)-(4344)-276359/276358 Website: http://www.indiamart.com/beblec
Bharat Electronics Limited (Monocrystalline Cell Manufacturer)	Scope Complex, Core-6, Floor 6,7 Lodhi Road, New Delhi 110 003, India Tel: 91 11 436 0705 Fax: 91 11 436 4401 E mail: cm@del2.vsnl.in
Bharat Heavy Electricals Limited (BHEL) (PV modules, solar water systems, small wind energy)	Integrated Office Complex, Lodhi Road, New Delhi -110003, India Tel: 91 11 51793242 Fax: 91 11 26493021 E mail: query@bhel.com
Bihar State Electronics Dev. Corpn (PV Manufacturer)	Beltron Bhavan, Shahstri Nagar Patna 800 023, India

Caldyne Automatics Limited (Engaged in manufacturing of non-conventional energy systems such as solar energy, wind energy and solar wind hybrid. Also offers thyristorised industrial battery charger and earthing transformer)	Plot No.Y-21, Block EP, Sector-V, Salt lake, Electronics Complex, Bidhannagar, Kolkata – 700 091, India Phone: +(91)-(33)-23575851/23575852/23575853/23575854 Fax: +(91)-(33)-23577062 Website: http://www.caldyneautomatics.com/non-conventional.html
CASE Pvt. Ltd. (Manufacturer, design and installation of solar water heaters)	458 Udyog Vihar, Phase V, Gurgaon, Haryana, India 122016 Tel: 91 124 340941
Central Electronics Limited (CEL) (Manufacturer of Monocrystalline cells, systems and related products)	4 Industrial Area, Ghaziabad, 201 010, Sahibabad, India Tel: 91 120 2895165 Fax: 91 120 2895148 E mail: cel@celsolar.com
Combustion Research Associates (Manufacturers and suppliers of several kinds of energy conservation products, pollution control systems and process automation equipments like waste heat recovery boilers, industrial heat burners, combustion systems and flame arrestors)	A-52, Sector 83, Phase II, Noida - 210 305, India Phone: +(91)-(120)-3078777 Fax: +(91)-(120)-3078781 Website: http://www.indiamart.com/combustionindia
Deep Energy Systems Pvt. Ltd. (Manufacturers and exporters of solar water heating systems such as domestic solar water heater, industrial solar water heaters, hotel solar water heater and hospital solar water heater)	H-203, Dsioc Sector- 1, New Delhi - 110 058, India Phone: +(91)-(11)-25508535 Website: http://www.indiamart.com/deepenergy
Deepa Solar Lighting Systems (Supplier and exporter of solar lighting systems and products such as solar indoor lights, solar wall lights, solar street lights, solar focusing lights, solar inverters, solar mobile chargers, solar grid power units, solar fans and solar fencings)	No 19, 4th "C" Main, Mahalakshi Layout, Opp Bnes College, Bangalore - 560 086, India Phone: +(91)-(80)-23594462 Fax: +(91)-(80)-23596942 Website: http://www.indiamart.com/deepasolarlighting
Electroplast (Engaged in manufacturing all types of solar products such as solar blinker, solar	80, Functional Industrial Estate, Patparganj, New Delhi - 110 092, India Phone: +(91)-(11)-22149568 Fax: +(91)-(11)-22149568

road stud, solar garden light, solar LED lantern, solar lantern light and solar torch)	Website: http://www.indiamart.com/electroplast
Ensemble Systems (Installer of solar water heaters)	6/6, Sinchan Nager, Pune-4110020, Maharastra, India Tel: 91 202 260993 Fax: 91 202 260993 E mail: ensemble@ip.eth.net
Era Lamp Manufacturing (I) Pvt. Ltd. (Manufacturing and supplying solar cell making machine, glass sheet washing machine, glass shett drying machine, glass sheet etching, capping mill, auto-coil feeder, sintering,. packing machines, punching machines and exhaust machine)	28, Sadanand Road, Kolkata - 700 026, India Phone: +(91)-(33)-24545270 Website: http://www.indiamart.com/eralampmanufacturing
Exide Products Ltd (Batteries)	Exide House, 59E Chowringhee Road Calcutta 700 020, West Bengal, India Tel: 91 33 478 320 Fax: 91 33 479 819
Flex Engineering Ltd. (Manufacturer of PV modules)	94 Sector 6, Chiranjiv Vihar, Ghaziabad VP 201002, India Tel: 91 575 766 604
Gitanjali Solar Enterprises (PV Manufacturer)	P/14, Kasba Industrial Estate Phase I, E.M. Bye Pass Calcutta 700 078
Hill Electronics Corporation Ltd (PV Manufacturer)	A-1/26, Vishwas Khand II Gomati Nagar LUCKNOW 226 010, India Tel: 91 11 6827438-43 (Delhi), Fax: 91 11 6827437
Hitech Systems (PV Manufacturer)	A-31, Nirala Nagar LUCKNOW 226 020, India Tel: 91 522 325220
Ind-Tech Services (Manufacturers and exporters of solar heaters, solar water heaters and other products such as force lift deep well hand pumps, threadle irrigation pumps, India mark II deep well handpump.)	2-132/4, Road No. 5, Shobana Colony, Bala Nagar, Hyderabad - 500 042, India Phone: +(91)-(40)-23770220 Fax: +(91)-(40)-23777012 Website: http://www.indiamart.com/indtechpumps
ITI Limited (PV Manufacturer)	Naini Unit Naini, Allahabad - 211 010, India Fax: 91 532 697345
Jaiswal Battery Services	11, Church Building , Hazrat Ganj, Lucknow, U.P.

(PV Manufacturer)	
Joonix India (PV Manufacturer)	SCO 84, Near Sagar Cinema, Sector 16, Faridabad 121 002, India
K. S .Industries, Coimbatore (Manufacturer and supplier of residential solar water heating system, industrial solar water heating system, flat plate heat collector, solar heater evacuated tube collector and solar pool heating system)	195/2, R. M. T., Bungalow Road, Sai Nagar, Industrial Estate (PO), Coimbatore - 641 021, India Phone: +(91)-(422)-2673319 Fax: +(91)-(422)-2673317 Website: http://www.indiamart.com/prosun
Kaynes Energy Systems Ltd (PV modules and sytems, outdoor lighting, solar water)	23-25 Belagola Food Industrial Estate, Metagalli, Mysore, Karnataka, India 517 016 Tel: 91 824 491 967 Fax: 91 824 458 315
M/s A.K.W. Electronics Shop (PV Manufacturer)	No.6, LSC, Site No.42, MORLAND Budh Bazar Subzi Mandi, Kalkaji New Delhi 110 019, India
M/s Alpha Zee Systems (PV Manufacturer)	Ponneth Temple Road , Kadavanthara, Kochi - 691 012, India
M/s Global Solar Energy (India) Ltd (PV Manufacturer)	Plot No.2, EHTP Complex, Sector 34, Delhi Jaipur Highway (NH-8) Gurgaon 122 001 Tel: 91 11 6827438-43 (Delhi), Fax: 91 11 6827437
M/s Photon Energy Systems Ltd. (PV Manufacturer)	Plot No.775-K, Road NO.45, Jubilee Hills, HYDERABAD 500 033, India Tel: 91 40 3546775 Fax: 91 40 3542075
Maharishi Solar Technology (Engage in production and supply of multicry stalline silicon wafers, multicry stalline silicon solar cells, monocry stalline solar cells and solar cooling system)	A-14, M. C. I. E, Mathura Road, New Delhi - 110 044, India Phone: +(91)-(11)-26959529 Fax: +(91)-(11)-26959669
Manasa Electronics (PV Manufacturer)	B-27, Shyam Park Extension Sahibabad, Ghaziabad 201 005 U.P. India
Microsolpower India P Ltd (Mono-crystalline cell Manufacturer)	# 605, 6th Floor Sapthagiri Towers S.P.Road Begumpet Hyderabad - 500 016 Andhra Pradesh, India Tel: 91 40 2776 6917 Fax: 91 40 2776 6916 E mail: info@microsolpower.com
Mitray Power	Shri Sai Siddhi, Liberty Garden Road No 1,

(Supplying and exporting solar air conditioners, slar home systems, solar lighting fencings, solar garden lights, solar emergency lights and solar staircase lights)	Malad (West), Mumbai - 400 064, India Phone: +(91)-(22)-55702431 Website: http://www.indiamart.com/mitraypower
Natural Power & Electronic Systems (PV Manufacturer)	B-272, Okhla Industrial Area, Phase - I New Delhi 110 020, India Tel: 91 11 6815887, 6817369
Omega Electronics T.C. (PV Manufacturer)	9/2449, Athira Judge Lane Sasthamangalam Thiruvananthapuram 695 010, India Tel: 91 471 698 72, 68115
Packwell Industries (PV Manufacturer)	Plot No.201, New GIDC, Gundlav, Valsad, Gujarat - 396 035, India
Param Progressive Group (Engaged in manufacturing and export of solar products such as solar energy lights, solar energy harvestors. Also supply of amorphous metal cores, vacuum tube collectors, electronic energy savings and other electrical fittings)	B- 507, Vardhman Apts, Mayur Vihar Ph I, New Delhi - 110 091, India Phone: +(91)-(11)-22715684 Fax: +(91)-(11)-22719366 Website: http://www.indiamart.com/paramchokes
Pentafour Solec Technology Limited (Manufacturing PV modules, marketing of wind generators)	Chitra Towers, 332-2 Aarcot Road, Kodambakkam, Chennai 600 024, India Tel: 91 44 4334 292 Fax: 91 44 4834 517
Polyplex Corporation Ltd. (Manufacturer of thin film cells and modules)	Plot 2, EHTP, Sector-34, Gurgaon 12001, Haryana, India Tel: 91 124 302 890 Fax: 91 124 302 890
Prabhu Energy Systems (P) Ltd. (Solar water heaters)	2nd Floor, Hameed Complex Kuloor, Ferry Road, Alake, Mangalore, India 575003 Tel: 91 824 491 967 Fax: 91 824 458 315
Prakritik Lighting & Urja Systems Pvt.Ltd (PV Manufacturer)	F-274, Flatted Factory Complex, Okhla Industrial Estate New Delhi 110 020, India
Premier Solar Systems (P) Ltd (PV Manufacturer)	41 & 42, Sri Venkateswara , Co-operative Indl. Estate, Balanagar , Hyderabad, India 500 037 Tel: 91 40 273515, 273525 Fax: 91 40 271879

Purav Safety Engineers (Deals in exporting and supplying of solar energy conservation products that includes solar street lights, solar power plants, solar water heating equipments and biomass power plants. Also offers fire fighting equipments as fire extinguishers)	49, Wishpering Palm Shopping Centre, Lokhandwala Township Akurli Road, Kandivali East, Mumbai - 400 101, India Phone: +(91)-(22)-28876275/28845314/32661924 Fax: +(91)-(22)-28876275 Website: http://www.indiamart.com/puravsafety
Rajasthan Electronics & Instruments Ltd (Manufacturer of PV cells, modules and PV Systems)	2, Kanakpura Industrial Area JAIPUR 302 012, India Tel: 91 141 361883, 361 981 Fax: 91 141 312701
Renewable Energy Systems Ltd. (Manufacturer of PV cells, modules and PV Systems)	D-52 Phase V IDA, Jeedimetla, Hyderabad 500 055, Andhra Pradesh, India Tel: 91 40 896 362 Fax: 91 40 895 807
Right Engineering (Supplier and manufacturer of solar energy products, solar equipments, solar panels, domestic water heaters, industrial water heaters, lantern, street light, solar UPS and electronic relays)	New No.67 & 71, Old No. 29B/1, Bajanai Koil Street, Choolaimedu, Chennai - 600 094, India Phone: +(91)-(44)-42648756 Fax: +(91)-(44)-43540887 Website: http://www.indiamart.com/rightengineering
Ritika Systems Pvt.Ltd (PV Manufacturer)	B-279, Okhla Industrial Area, Phase 1 New Delhi 110 020, India Tel: 91 011 - 6817369
Rose Bud Electro private limited (PV Manufacturer)	I / IA , 4TH Floor, Biplabi Amukul, Ch. Street, Calcutta – 700072
Rowsons Marketing Private Ltd (Engaged in manufacturing and exporting solar cookers, solar air dryers, solar street lighting system, solar power plants and solar power stations)	260/1A Royapetta High Road, Mylapore, Chennai - 600 004, India Phone: +(91)-(44)-24980622/24980603 Fax: +(91)-(44)-24980361 Website: http://www.indiamart.com/rowsons
Savemax Solar Systems Pvt Ltd (Solar flat plate collectors, solar water heating, solar home lighting)	Jayaprabha, Jadhavnagar, Vadgaon Bk, Pune 411041, Maharashtra, India 411041 Tel: 91 20 435 8613 Fax: 91 20 435 8613
Shiv Shakti Electronics Pvt. Ltd (PV Manufacturer)	F-274, Flatted Factories Complex, Okhla Industrial Area New Delhi 110 020, India Tel: 91 11 6840742

Shri Vaishno Enterprises (Deals in export and manufacture of solar water heating systems and other equipments that includes spm & conveyor system, ac frequency drives, crystallized gear boxes and laminated yoke dc motors)	House No. 156, Sector 9, Faridabad - 121 001, India Phone: +(91)-(129)-4081487/3252414/2261487 Website: http://www.indiamart.com/shrivaishnoenterprises
Solaris Systems Pvt. Ltd (PV Manufacturer)	28/2416 (I), Shanti Nagar Kadavanthara Cochin 682 020, India
Solartech India Ltd (PV wafers, cells and modules)	161 Vidyut Nagar B, Ajmer Road, Jaipur, Rajasthan, India 302001 Tel: 91 141 352881 Fax: 91 141 351434
Solker Industries Limited (PV Manufacturer)	37, Jayalakshmipuram Ist, Nungambakkam CHENNAI 600 034, India Tel: 91 44 8264142, 8271819, 8272829 Fax: 91 44 8273435
Spsolar Technologies (Engaged in manufacturing solar energy equipments such as solar lamps, solar lanterns, solar water heater and solar wind energy systems)	No 15, 66th Street Korattur, Chennai - 600 080, India Phone: +(91)-(44)-55873172
SU Solartech Systems (Solar thermal and PV home systems)	Sector 7-C, Chandigarh-160019, India Tel: 91172 2792576 Fax: 91172 2792576 E mail: solartech@susolartech.com
Su-Kam Power Systems Ltd.	196-C, Udyog Vihar, Phase VI, Sector-37, Gurgaon -122001, Haryana, India Tel: +91-124-4030700, 4170500 Fax: +91-124-4038700/1/2 E-mail:info@su-kam.com Web: www.su-kam.com
Sun Energy Systems (PV Manufacturer)	No.15, 2nd Cross Street, Vengata Nagar, Pondicherry - 605 011, India
Sunbeam Energy Private Limited (Manufacturers of solar products such as solar lanterns, solar street light, solar garden light, solar home light, solar energy light, solar energy flasher, street lighting system, home lighting system and energy saving solar lamp)	16, Shriji Shopping Centre, Opposite Bachuram Aashram Smrutimandir Road, Isanpur, Ahmedabad - 382 443, India Phone: +(91)-(79)-25834349

Sunbeam Solar Thermal Co. (Manufacturer of solar water heating systems, water heaters)	1114/11 University Road, Pune, Maharashtra - 411016, India Tel: 91 212 356097 E mail: sushil@giaspn01.vsnl.net.in
SunLine Solar Systems Pvt Ltd (Solar water heating, solar pool heating)	1826 Sadashiv Peth, Deshmukh Wadi, Pune, Maharashtra, India 411030 Tel: 91 20 448 5418 Fax: 91 20 448 5418 E mail: jbhala@hotmail.com
Suntime Energy Limited (PV Manufacturer)	E-3, Lajpat Nagar II New Delhi 110 024, India
Surya Jyoti Devices India (P) Ltd. (PV Manufacturer)	E/3, Lajpat Nagar II New Delhi 110 024, India Tel: 91 11 6834129, 6834822 Fax: 91 11 6839444
Swamy Renewable Energy Systems (Suppliers and exporters of solar products such as solar lanterns, solar home lighting systems, solar street lighting systems, solar power packs, solar refrigerators and solar air dryers)	SRES, Plot No.: 6-26, Dee Nagar, HMT Chintal, Hyderabad - 500 054, India Phone- +(91)-(40)-30725445/23195702 Fax +(91)-(40)-23195702 Website: http://www.indiamart.com/swamysolar
Tata BP Solar India Ltd (Module manufacturer, supplier of PV Systems and PV System components, solar products)	Plot 78, Electronic City, Hosur Road, Bangalore 560 100, India Tel: 91 080 2235 8465 Fax: 91 80 852 0972 E mail: tatabp@tatabp.com
Telemats India Pvt.Ltd (PV Manufacturer)	Plot No. 10, Block 1, F.I.E. Patparganj Industrial Area, New Delhi 110 092
The Energy & Resources Institute (Manufacturer and exporter of solar products such as solar generator, solar power generator, solar energy power generator and solar power generated system)	Darbari Seth Block, I. H. C. Complex, Lodhi Road, New Delhi - 110 003, India Phone: +(91)-(11)-24682100 Fax: +(91)-(11)-24682144 Website: http://www.teriin.org/
Thoshiba Energy and Exports (Manufacturers and exporters of solar products such as solar power heaters, solar portable lanterns, solar lighting systems, solar cooking systems and solar water pumping systems)	7, Manjula Apartment, G. G. Road, Near Vishnunagar Police Station, Dombivli - 421 202, India Phone: +(91)-(251)-2497725 Fax: +(91)-(251)-2497725 Website: http://www.indiamart.com/thoshibaenergy\
Titan Energy Systems Ltd	16, Aruna Enclave, Trimulgherry , Secunderabad 500 015, India

(PV Manufacturer)	Tel: 91 40 7740751 Fax: 91 40 7745629
Udhaya Semiconductors (P) Ltd (PV Manufacturer)	1/482, Avanashi Road, Neelambur COIMBATORE 641 014, India Tel: 91 422 887545, 887003 Fax: 91 422 887504, 572675 E mail: udaya@uslsolar.com
Union Enterprises (PV Manufacturer)	Khoyothong, Imphal -795 001, India
Usha (India) Limited (PV cell Manufacturer)	12/1, Mathura Road Faridabad Haryana,121 003, India Tel: 91 129 5277641-45 Fax: 91 129 5277679 E mail: sales@uslsolar.com
Utility Enterprises (Solar water heaters)	2 Pancharatna Apartments, 43 Vishwas Colony, Alkapuri, Baroda, Gujarat, India 390 007 Tel: 91 265 333 504 Fax: 91 265 314 452 E mail: addition@ad1.vsnl.net.in
Vijay Electronics (PV Manufacturer)	C-30, Flatted Factory's Complex, Rani Jhansi Road, Jhandewalan, New Delhi - 110 055
Vimal Electronics (PV Manufacturer)	Plot No. E-49, GIDC Electronics Estate Sector 26, Gandhinagar 382 044
VK Solar Pvt. Limited (Supply and export of various solar products like solar modules, solar inverters, solar lantern, solar torch, solar security lights, solar grid connected systems, solar power pack, solar air-conditioners, solar mobile chargers, solar water heaters.)	C-38, Greater Kailash -1, New Delhi - 110 048, India Phone: +(91)-(11)-29248176 Fax: +(91)-(11)-41630400 Website: http://www.indiamart.com/vksolar
West Bengal Electronics Industry Development Corporation Limited (PV Manufacturer)	Webel Bhavan, Block EP & GP Sector V, Bidhannagar, Salt Lake Calcutta - 700 091 India Tel: 91 33 357 1702 / 04/ 06 Fax: 91 33 357 1708 / 1739 E mail: ssit@wb.gov.in
XL Telecom Systems (PV Manufacturer)	335, Chandralok, Secunderabad 500 003, India

8.2 International level

Company Name	Address
Aidt Miljö A/S (Denmark)	Kongensbrovej, Aidt 8881 Thorsø. 45 Tel: +45 8696 6700 Fax: +45 86966955 E-mail: hjc□aidt.dk Website: www.aidt.dk/engelsk/headsite.html
Ample (China)	03,3/F,Angye Bldg., Pioneering Park for Overseas Chinese Scholars, Xiamen, Fujian, 361005. China Tel: +86 592 5762128 Fax: +86 592 5760686 E- mail: sales□ample-cn.com Website: www.ample-cn.com
ASS GmbH (Germany)	D-99099 Erfurt, Konrad Zuse Str 15. Germany Tel: +49 3614262505 Fax: +49 3614262506 E-mail: info□ass-gmbh.net Website: www.ass-gmbh.net
Bailixing Solar (China)	D-99099 Erfurt, Konrad Zuse Str 15. Germany Ph- +49 3614262505 Fax: +49 3614262506 E-mail: info□ass-gmbh.net Website: www.ass-gmbh.net
BIC (Egypt)	9 Marouf St., Cairo 11522. Egypt Tel: +20 25798334 Fax: +20 25795744 E-mail: bic□bicegypt.com Website: www.bicegypt.com
Konarca (U.S.A)	116 John Street, Suite 12, 3rd Floor, Lowell, MA 01852. USA Ph- +1 9785691400 Fax: +1 9785691401 Website: www.konarka.com
Living Clean Pty Ltd (Australia)	7 Plane Tree Circuit, Woongarrah, NSW 2259. Australia Tel: +61 243929258 Fax: +61 243922101 E-mail: info□livingclean.com.au Website: www.livingclean.com.au
Motech Industries	Tainan Science-Based Industrial Park No. 2, Da-Shun 9th Road, Hsin-Shi, Tainan 74145,

(Taiwan)	Taiwan. R.O.China Tel: +886 6 505 0789 Fax- +886 6 505 1789 E-mail: solar□motech.com.tw Website: www.motech.com.tw
Pintsch Aben bv (Netherlands)	Herenweg 24A, 3602 AP, Maarssen. Netherlands Tel: +31 346583958 Fax: +31 346554393 E-mail: info□pintschaben.com Website: www.pintschaben.com
Power Master Technology (Taiwan)	8F, 651-3 Chung Cheng Road, Hsin Chuang City, Taipei Hsien, Taiwan Tel: +886 266266660 Fax: +886 266266800 E-mail: sales□powermaster.com.tw Website: www.powermaster.com.tw
PSE (S. Korea)	23-2, palyong-dong, changwon, Kyoungnam. South Korea Tel: +82 552942116 Fax: +82 552942118 E-mail: admin□psec.co.kr Website: www.psec.co.kr
SOCO (Italy)	Via S.Paolo 25, 20041 Agrate Brianza (MI). Italy Tel: +39 039653830 Fax: +39 039650959 E-mail: soco□soco.it Website: www.soco.it
Sol-Lite Manufacturing Company (Hong Kong)	202-5, International Trade Center, 11-19 Sha Tsui Road, Tsuen Wan, N.T., Hong Kong. Tel: +852 23691811 Fax: +852 27240730 E-mail: websales□sol-lite.com Website: www.sol-lite.com
VHF-Technologies SA (Switzerland)	Av. des Sports 18, CH-1400 Yverdon-les-Bains. Switzerland Tel: +41 244230490 Fax: +41 244230499 E-mail: marketing□flexcell.ch Website: www.flexcell.com

References

Publications

1. Renewable Energy Information, 2006. Paris, France: IEA

2. Akshay Urja, 2008, July-August, September-October, November-December
Bi-Monthly newsletter published by MNES

3. TERI Energy Data Directory & Yearbook, 2007. New Delhi, India: The Energy and Resources Institute

4. Ali S, 1999. *Renewable energy- the way forward*. Applied Energy, 64: 23

5. Tsoutsos T, 2005. *Environmental impacts from the solar energy technologies.* Energy Policy, 33(3)

6. Annual Report 2005/06, The Energy and Resources Institute, New Delhi, India.

7. Applied Thermal Engineering: 2007, (27): *Industrial application of PV/T solar energy systems* by Kalogirou, S.A.

8. Goetzberger A. 2002. *Solar cells: past, present, future.* Solar energy and materials and solar cells, (74)

9. Velayudhan S K, 2003. *Dissemination of solar photovoltaics: a study on the government programme to promote solar lantern in India.* Energy policy, (31)

10. Lambert D W H, 2000. *Appropriate battery technology for a new, rechargeable, micro-solar lantern.* Journal of Power Sources, (88)

Web sites

1. Ministry of Non-Conventional Energy Sources, Govt. of India (www.mnes.nic.in)

2. ENVIS Web site (www.envis.nic.in)

3. http://www1.eere.energy.gov/solar

4. The Energy and Resources Institute (www.teriin.org)

5. Tata-BP Solar Web site (http://www.tata.com/tata_bp_solar)

6. Ministry of New and Renewable Energy (http://mnes.nic.in/)

7. National Renewable Energy Association (http://www.nrel.gov/wind/)

8. The Energy and Resources Institute (www.teriin.org)

9. Gujarat Energy Development Agency (http://www.geda.org.in/)

10. http://en.wikipedia.org/wiki/Solar_energy

11. http://intranet.daiict.ac.in/~ranjan/rer/presentation/200231019.pdf

12. http://ec.europa.eu/energy/library/599fi_en.pdf

13. http://www.ren21.net/pdf/RE2005_Global_Status_Report.pdf

14.http://www.geni.org/globalenergy/library/energytrends/currentusage/renewable/Renewable-Energy-Potential-for-India.pdf

15. http://www.clintonglobalinitiative.org/NETCOMMUNITY/Document.Doc?&id=44

16. http://www.cleanedge.com/reports/trends2006.pdf

17. http://mnes.nic.in/list/spv-manufacturers.pdf