Renewable Energy

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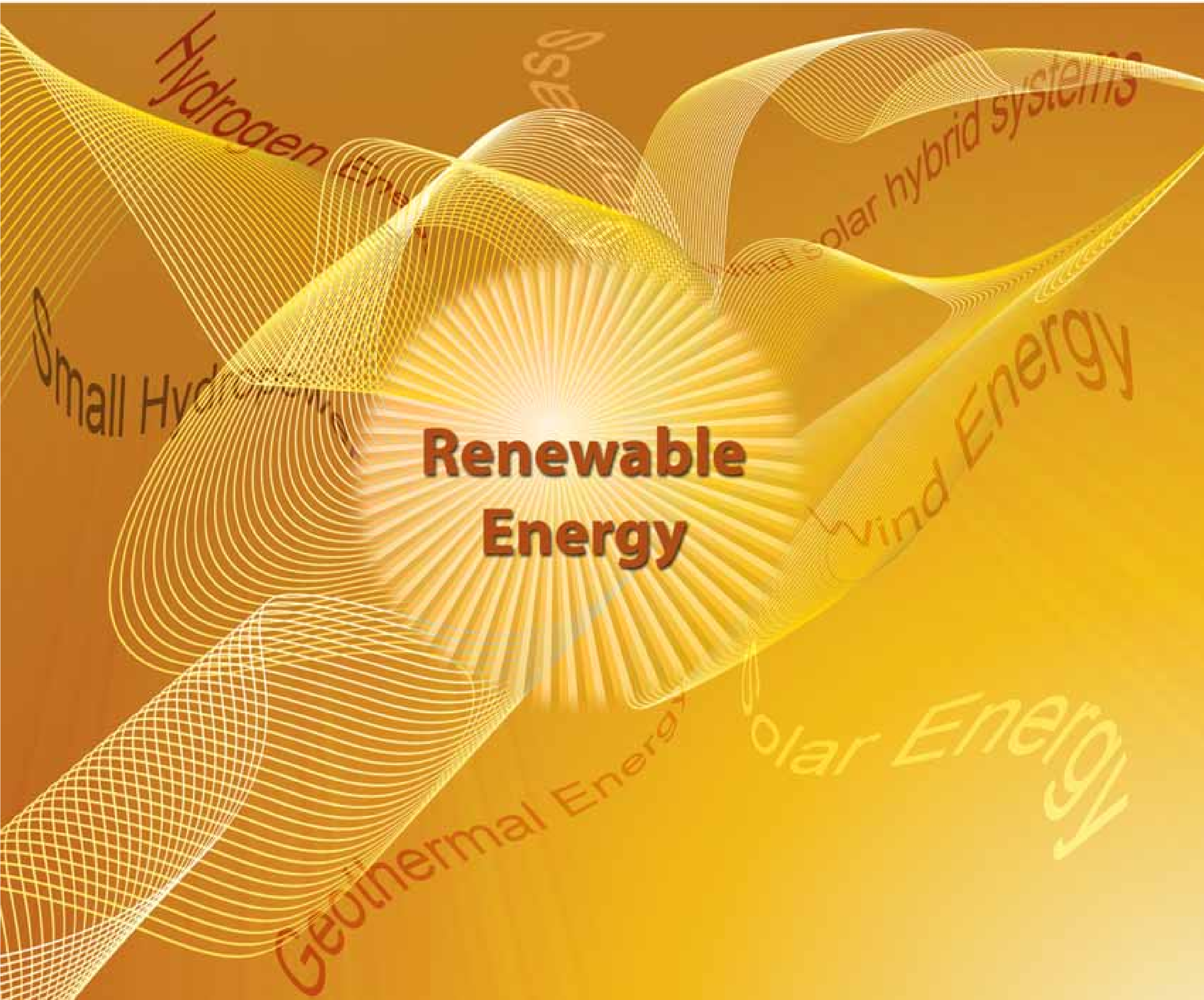

अक्षय ऊर्जा से देश विकास

गांव गांव बिजली, घर घर प्रकाश

सत्यमेव जयते

Ministry of New and Renewable Energy
Government of India
www.mnre.gov.in

POWER *from* solar tower

Mayadhar Swain
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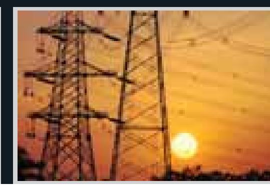


Sun is the principal source of almost all kinds of energy, both conventional and non-conventional. Although solar radiation is being utilized from time immemorial for drying, heating, and so on, direct production of electrical energy from it is a more recent development. The solar energy received on earth everyday can produce 2500 times more power than we currently consume. But we should have the proper means and technology to harness the energy economically. Electricity can be generated from solar radiation through the following methods.

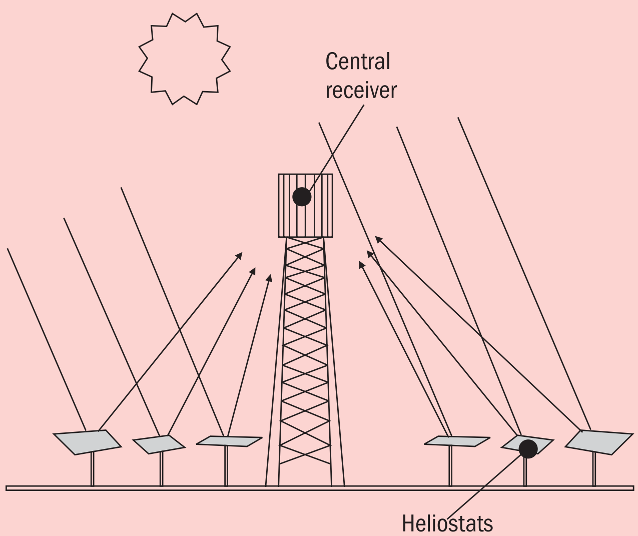
- Photovoltaic cells
- Solar thermal power

Photovoltaic cells

Solar radiation is directly converted to electricity by solar photovoltaic cells. The cell consists of two or more appropriately sandwiched thin layers of semiconducting material, usually silicon. When the solar cells are exposed to sunlight, the incoming photons of radiation separate positive and negative charge carriers of the semiconducting material. This generates voltage and hence electricity. The greater the intensity of light, the greater is the flow of electrons. The electric output from a single cell is small. So a number of cells are connected in series or parallel to get the desired power output. The module containing multiple cells is called solar panel.

Solar thermal power

Solar thermal power station is like a conventional thermal power station having steam boiler, turbine, and generator. In a conventional thermal power station, water is heated by coal, gas, or petroleum oil to produce steam, which



Schematic representation of a central receiver system

SOLAR TOWER

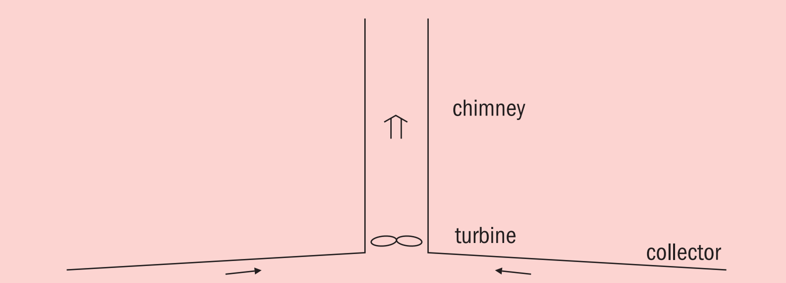
rotates the turbine and generator to produce electricity. But in the case of solar thermal power station, steam is produced by heat derived from solar radiation. To achieve this, sunrays are reflected from large mirror surfaces to concentrate on to a point on the solar receiver.

Schematics of a central receiver system used for generating power using solar thermal energy is shown in Figure 1. The surface of the solar receiver may reach to a temperature as high as 1000 ºC. In the receiver, an HTF (heat transfer fluid) is heated. The hot HTF is used to produce steam which turns a turbine to produce power. Presently, the major solar thermal power stations include 354 MW plant in California desert, 64 MW plant in Nevada of USA, and 11 MW plant in Spain. Two 50 MW and one 15 MW plant are under construction in Spain.

Solar tower / chimney

A recent development in solar energy is a solar tower/chimney. It is a method used for large-scale generation of electricity from solar radiation. The principle is very simple. It is based on the well-known principle of greenhouse effect, chimney updraft effect, and wind turbine. Ambient air is drawn into a very large circular greenhouse-like collector. The air is warmed by solar energy due to the greenhouse effect. With the help of the greenhouse effect, sunrays are captured and these in turn heat the air beneath the collector. The collector roof is covered with glass or plastic foil. This allows short-wave solar light from the sun to pass through, but block out reflected long-wave heat radiation. The resulting convection causes the air to rise and escape through a tall tower.

The difference in density between the warm air in the tower and the cold air outside causes an upward airflow. As with a convector heater, cold air is simultaneously sucked in at the outer open edge of the collector roof. Turbines with generators are installed inside the tower and while the air moves up inside the tower, it rotates the turbines, which produce electricity. Constant round-the-clock operation is also possible. For this, closed water tubes are positioned under the collector roof. During the daytime, heat energy is stored in water tube and at night, they release the heat to warm the air. The water tubes need to be filled only once and there is no need for any further water inputs during the operation.



Working of a solar tower

Turbine

Essentially, the turbines are more closely related to pressure-staged Kaplan-type turbines than to velocity staged wind power plants subject to natural wind. These turbines are manufactured by makers of hydro-electric plant turbines. It basically operates like a hydroelectric power plant but with hot air. Turbines can be installed in a ring around the base of the tower with a horizontal axis. Also, a single large vertical axis turbine can be installed in the chimney for smaller plants.

Glass collector

The collector roof is covered with glass or plastic sheets or foils. The longitudinal girders are designed in such a way that vacuum cleaners can run along them to clean the roof. For large plants, the glass roof has to be several kilometres in diameter.

Tower

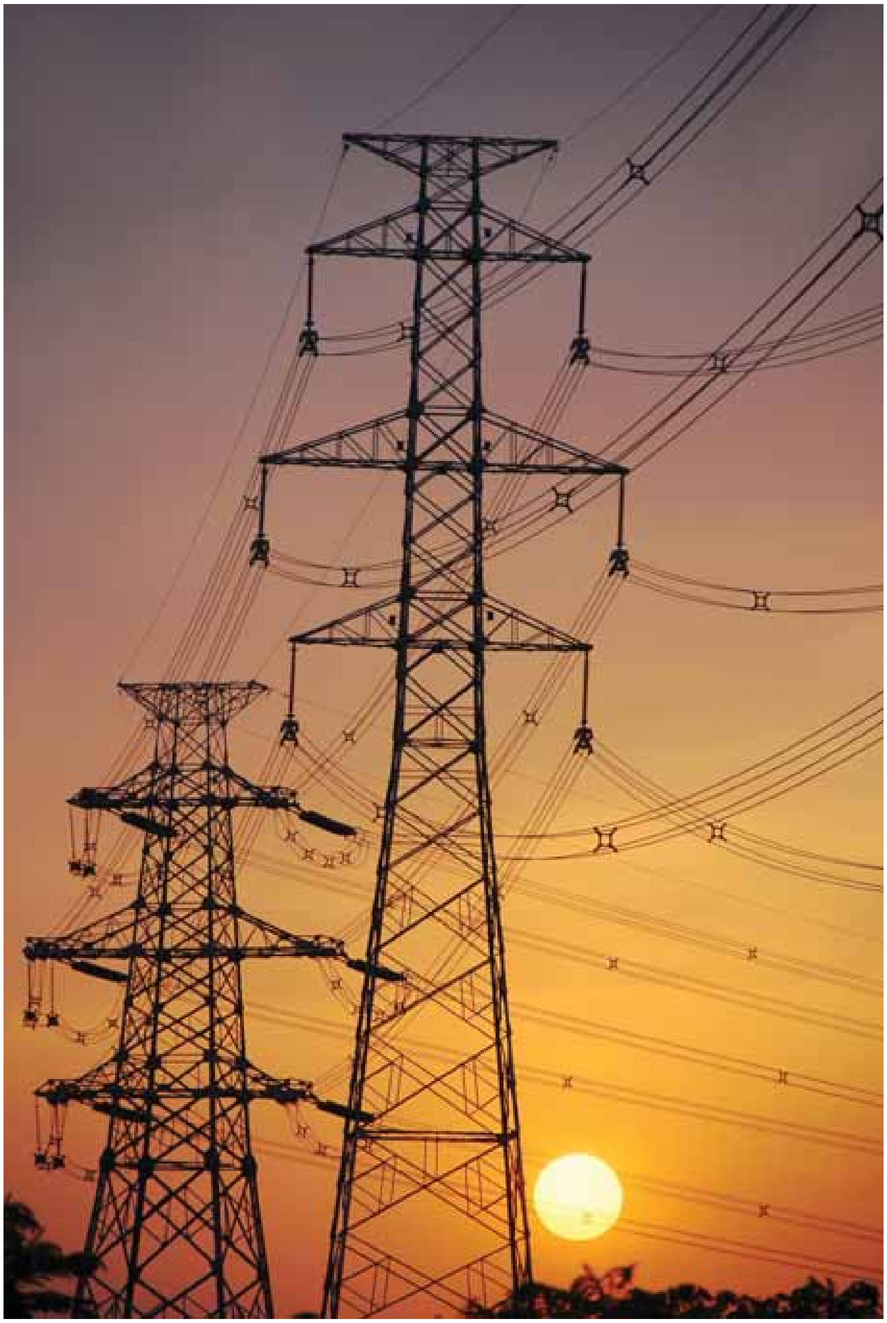
The solar chimney, is erected at the centre of the collector field. As the normal chimneys or flues, the taller the chimney the greater the draught obtained. The greater the wind speed, the more energy does the wind contain that can be harvested. Therefore, the height of a commercial solar chimney has to be more to achieve a large annual output. For the tower/chimney, various types of construction materials have been compared. Among the types of structures that can be used (such as steel truss, cable nets, or textile membranes), it is reinforced concrete tubes that promise to deliver the longest service life and also it will be most economical for desert areas. A chimney in a desert country made from reinforced concrete tubes promises the longest life span at least costs.

Technically cylindrical, natural draft tower is preferred. More the height of the tower, the more will be the power generation. For a 200 MW plant, a suitable height would be 1000 metre with a tower diameter of 170 metre. Wall thickness of the chimney can be decreased by putting stiffening spoked wheels inside.

Output

The solar tower/chimney works on the principle of updraft. Hence, the generating capacity of this plant depends primarily on three factors namely intensity of solar radiation, the collector area, and the chimney height. With a large collector area, more volume of air is warmed up to flow up the chimney. Collector areas as large as 7 km in diameter have been considered. With a larger chimney height, the pressure difference between the warm air in the collector and the air at the top of the chimney increases the stack effect thus increasing the velocity of air.

This is because as the height of the chimney increases, the atmosphere pressure at the top of the chimney decreases. For a 200 MW solar power plant, chimney of 1000 metre height has been designed. A combined increase of the collector area and the chimney will have a greater effect on the size of the power plant and hence, the energy production. Further, its location in a desert area can have the added advantage of higher intensity of solar radiation.



Advantages

- It is a renewable source of energy. The sun as an energy source is unlimited.
- It has no ecological harm, as it does not emit any harmful gases into the atmosphere.
- It does not require any fuel for generation. Hence, dependence on imported coal, oil, or gas can be reduced for some countries.
- Its operating cost is very less which somehow balances its higher capital cost.

Courtesy: http://reich-chemistry.wikispaces.com

- There is no resettlement and rehabilitation problem as it can be installed in a deserted area as well.

Limitations

- High capital cost
- High energy cost compared to conventional sources of power
- Large land requirement
- The visual impact of very high towers and tens of squares of kilometres of collector.
- Limited number of industry partners

Cost and economic feasibility

Assuming an overall interest rate of 8% and depreciation over 40 years, electricity from a solar tower will cost slightly more than electricity generated by a newly built coal-fired thermal power plant. If we reduce the assumed interest rate to 4%, electricity from the solar tower will be competitive with that from thermal power station. As government of some countries are giving subsidies, concessions, and tax benefits to renewable energy, soft loans are available for this type of project. Further, the entrepreneur of the project can avail benefit on carbon trading as per the Kyoto Protocol. A great amount of investment cost is made up of labour cost. This creates jobs meaning added value to the country.

Appropriate location

The appropriate location for a solar tower power station should have the following characteristics.

- High annual solar radiation on horizontal surface (>1700 kWh/m^2)
- High insolation (>3000 hours/year)
- Low average annual winds (<3 m/s)
- Limited strong winds (<25 m/s)
- No snows, hail, or sand storms

History

In 1903, Spanish Colonel Isidoro Cabanyes first proposed a solar tower power plant in the magazine *La energia electrica*. One of the earliest descriptions of a solar tower power plant was written in 1931 by a German author, Hanns Gunther. Beginning in 1975, Robert E Lucier applied for patents on a solar tower electric power generator. These patents were granted in Australia, Canada, Israel, and the USA between 1978 and 1981.

Prototype in Spain

In 1982, a medium-scale working model of a solar tower power plant of capacity 50 kW was built under the direction of German engineer Jorge Schlaich in Manzanares, Ciudad Real, 150 km south of Madrid, Spain. The project was funded by the German government. During operation, the optimization data was collected on a second-by-second basis. This power plant operated for approximately eight years, consistently generating 50 kW output but encountered severe structural instability close to the tower due to induced vortices and was decommissioned in 1989. The features of the plant are given below.

- Tower height: 200 m
- Collector diameter: 240 m
- Turbine capacity: 50 kW
- Tower diameter: 10 m
- Collector height: 2 m
- Collector area: 45 000 square metre
- Tower weight: 125 tonnes
- Collector weight: 5.5 kg/m^2 (without glass)
- Roof segment size: 9 x 9 m

The pilot plant conclusively proved the concept of works and provided data for design modifications to achieve greater commercial and economic benefits associated with an increased sale of economy. Based on this experience, there is a proposal to construct a solar tower of height 750 metres to produce 40 MW power at Ciudad Real in Spain.

Renewable Energy at a Glance in India

S.No.	*Source/system*	*Estimated potential*	*Achievement as on 31 March 2008*
I	**Power from renewables**		
A	**Grid-interactive renewable power**	(MW)	(MW)
1	Wind power	45 195	8757.00
2	Bio power (agro residues and plantations)	16 881	606.00
3	Bagasse cogeneration	5 000	800.00
4	Small hydro power (up to 25 MW)	15 000	2180.00
5	Energy recovery from waste (MW)	2 700	55.25
6	Solar photovoltaic power	–	2.12
	Sub total (A)	**84 776**	**12 400.37**
B	**Captive/combined heat and power/distributed renewable power**		(MW)
7	Biomass/cogeneration (non-bagasse)	–	95.00
8	Biomass gasifier	–	100.11
9	Energy recovery from waste	–	26.70
	Sub total (B)	**–**	**221.81**
	Total (A+B)	**–**	**12 622.18**
II	**Remote village electrification**	**–**	4 198 villages/hamlets
III	**Decentralized energy systems**		
10	Family-type biogas plants	120 lakh	39.94 lakh
11	Solar photovoltaic systems	50 MW/km^2	120 MW$_p$
	i. Solar street lighting system	–	70 474 nos
	ii. Home lighting system	–	402 938 nos
	iii. Solar lantern	–	670 059 nos
	iv. Solar power plants	–	2.22 MW
	v. Solar photovoltaic pumps		7148 nos
12	Solar thermal systems		
	i. Solar water heating systems	140 million m^2 collector area	2.30 million m^2 collector area
	ii. Solar cookers		6.20 lakh
13	Wind pumps		1284 nos
14	Aero generator/hybrid systems		675.27 kW
IV	**Awareness programmes**		
16	Energy parks	–	504 nos
17	Akshay Urja shops	–	269 nos
21	Renewable energy clubs	–	521 nos
22	District Advisory Committees	–	560 nos

MW – megawatt; kW – kilowatt; MW$_p$ – megawatt peak; m^2 – square metre; km^2 – kilometre square