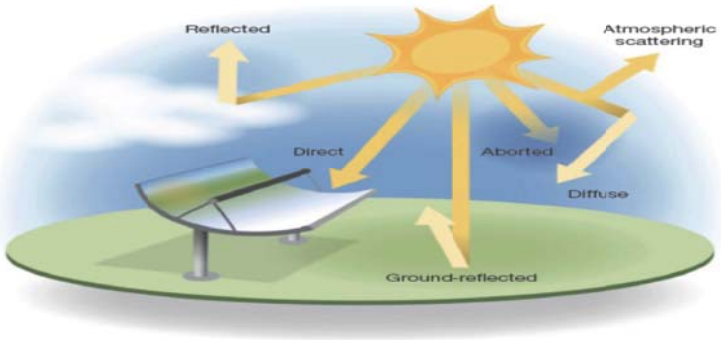
Concentrated Solar Thermal Power Technology

A. Concentrated Solar Thermal Power

1. Concentrated solar thermal power (CSP) is a state-of-the-art electricity generation technology that converts solar energy into usable heat and electricity. CSP and solar photovoltaic are two main branches of solar technology that are currently growing rapidly in the global renewable energy market. While solar photovoltaic directly converts both direct and diffuse irradiation into electricity through the photovoltaic effect, CSP produces high-temperature heat by capturing and concentrating direct sunlight and using this heat to generate electricity (Figure 1).

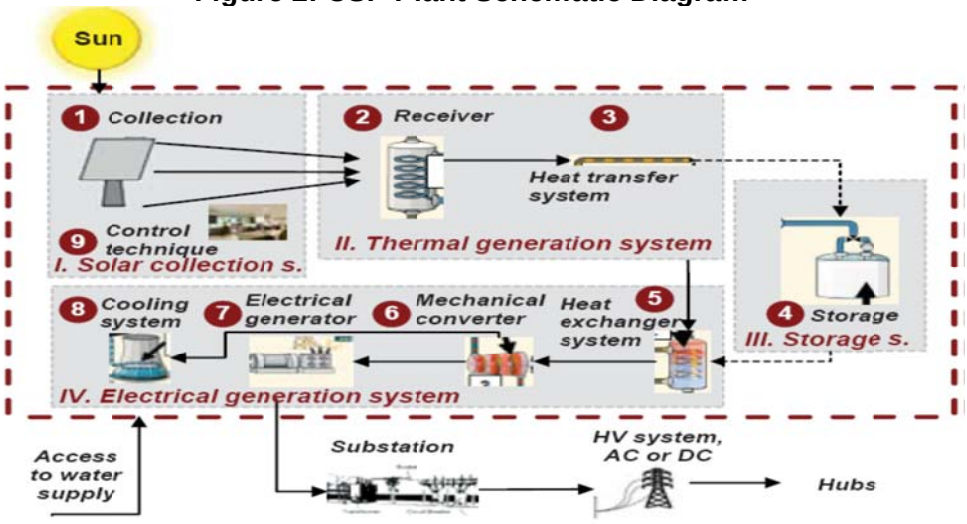
Figure 1: Components of Solar Radiation on the Earth's Surface



Source: National Renewable Energy Laboratory, Washington, DC.

2. Many conventional power plants today use fossil fuels as the source of heat to generate high-temperature steam, and consequently electricity, by running a large turbine. A CSP plant, on the other hand, uses the sun as heat source. It uses hundreds of mirrors to reflect and concentrate sunlight, generally referred to as direct normal irradiation, onto receivers, which capture the solar energy and convert it into high-temperature heat, used to generate steam. This steam can then be directly used to produce electricity through conventional steam (Figure 2).

Figure 2: CSP Plant Schematic Diagram



Source: A.T. Kearney Global Management Consultants (2010).

B. CSP technologies

3. There are four main CSP technologies, categorized according to the way they focus the sun's rays and convert them into usable heat (Figure 3).

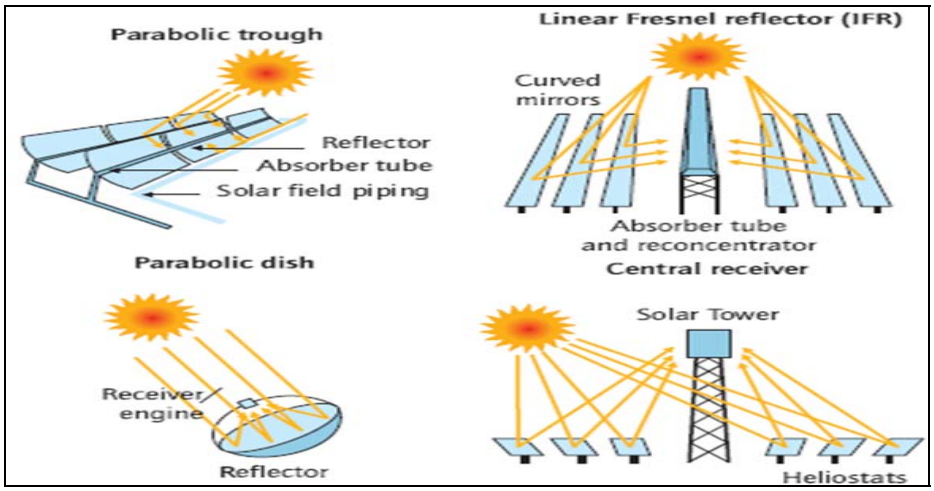
- **Parabolic trough.** Parabolic trough–shaped mirrors concentrate sunlight onto a receiver tube filled with heat transfer fluid. The heated fluid is then circulated through a series of heat exchangers to produce superheated steam. This steam drives a conventional steam generator to produce electricity. Parabolic-trough technology is the most mature and has the largest market share among all CSP technologies, with over 2,000 megawatts (MW) of installed capacity.

- **Solar tower.** A solar tower system uses a circular array of sun-tracking mirrors (heliostats) to concentrate sunlight onto a central receiver on the upper part of the tower (50–100 meters in height) for electricity generation. Solar-tower technology is currently considered to be at a medium-commercial stage among CSP technologies, and is best suited to utility-scale power plants.

- **Stirling dish.** A stand-alone parabolic dish–shaped mirror concentrates sunlight onto a receiver mounted at the focal point of the dish. This system shows the highest solar-to-electricity conversion efficiency (23%–30%) among CSP technologies. Since each unit produces electricity independently through a Stirling engine, parabolic-dish systems are not yet reliable for use in large (utility-scale) projects and component costs are still quite high. However, this can be a suitable technology option for supplying electricity in remote isolated areas.

- **Linear Fresnel reflector.** This system is conceptually very similar to a parabolic trough. But instead of using parabolic-shaped mirrors, it concentrates sunlight onto a linear and fixed receiver through an array of nearly flat reflectors. The most significant advantage of the linear Fresnel reflector system is that it requires lower investment costs and shows a higher land-to-electricity ratio than a parabolic trough. However, linear Fresnel reflector systems are less efficient than parabolic-trough systems.

Figure 3: CSP Technologies

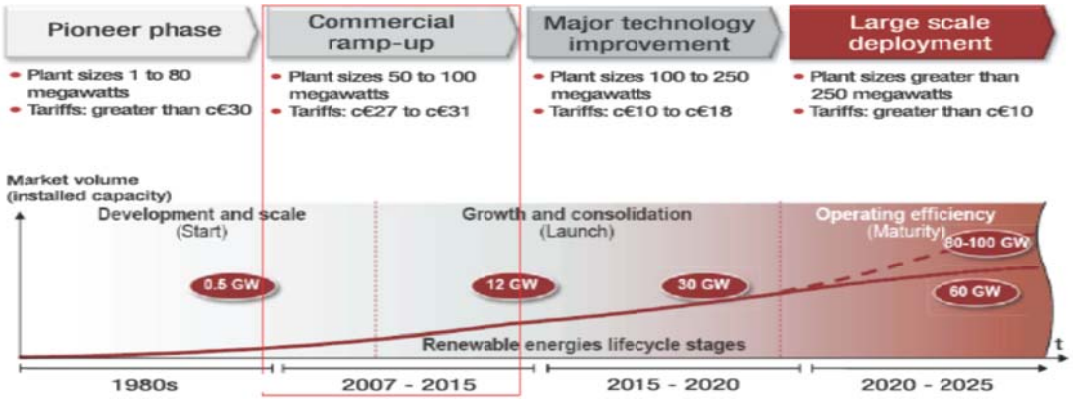


(Source) IEA 2010

C. Current CSP market

4. CSP moved into the commercial ramp-up phase in 2007. By 2012, global installed capacity exceeded 2 gigawatts (GW), and this rapid expansion is expected to continue providing much-needed learning factor benefits, lowering cost through economies of scale. Figure 4 illustrates the current status of CSP development globally. While CSP is growing rapidly, however, its growth is still confined to Spain and United States, which together account for about 90% of global installed capacity. The Middle East and North Africa region has appeared as a new incubator of CSP mainly because of its rich solar resources and the solar energy trade agreement between Middle East and North Africa and the European Union. Other countries, such as Australia, India, and the People's Republic of China are also showing increasing interest and have several utility scale demonstration CSP plants under preparation.

Figure 4: CSP Road Map



Source: A.T. Kearney Global Management Consultants (2010).

5. The IEA estimates that CSP could contribute up to 11% of annual global electricity production by 2050. A study done by SolarPACES in 2009 concluded that, with faster development, CSP could provide one-fourth of the global electricity demand by 2050 (Richter, Teske, and Short 2009). In the long run, CSP technologies are expected to substitute for combined-cycle gas turbine as peak-and mid-load providers.