A PRIMER ON

CPV TECHNOLOGY

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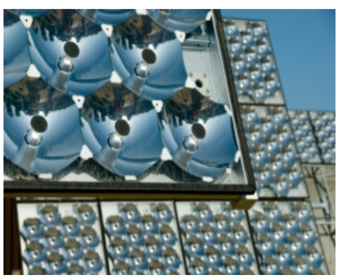
Solar Energy Overview

Current installed power generation capacity throughout the world is 2TW. Between the growth in energy consumption and replacement of aging power plants it is estimated that as much as 6 TW of capacity will be required by 2030. Relying primarily upon fossil fuels to meet this increased demand will have severe impacts upon the environment and natural resource reserves. Alternative sources must be implemented in large scale, and solar is the most abundant renewable in the world with one hour of solar energy hitting the earth capable of meeting the current world demand for one year. In essence, we have at our disposal free fuel for life…it just has to be harvested. Of the various solar technologies available, it is Concentrated Photovoltaics (CPV) which is increasingly recognized as the technology which holds the greatest promise in meeting the energy challenges facing the world.

Concentrator Photovoltaic Technology



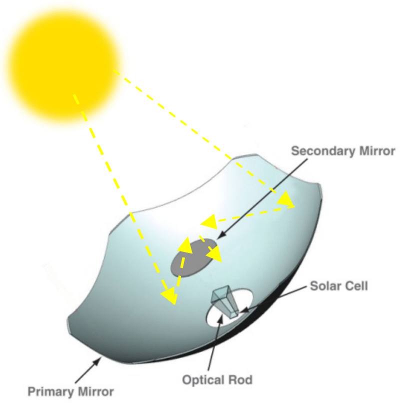
Example of one CPV technology implementation. This system, designed by SolFocus, utilizes reflective, non-imaging optics to concentrate light from the sun.

A concentrating photovoltaic (CPV) system converts light energy into electrical energy in the same way that conventional photovoltaic technology does. The difference in the technologies lies in the addition of an optical system that focuses a large area of sunlight onto each cell. Concentrating photovoltaics has been an established science since the 1970s, but is only now reaching commercial viability. It is the newest technology to enter the solar sector, and presents exciting possibilities when deployed in large volume, including the promise of competing head-to-head with conventional power generation from oil, gas and coal.

CPV systems can be thought of as "telescopes," trained on the sun's position and feeding the concentrated light to the cell. The magnification ratio used in different CPV system designs varies so widely that three classes of systems have developed:

- low concentration, where the magnification ratio is less than 10X;
- medium concentration, between 10X and 100X;
- high concentration, where the ratio lies above 100X, but is usually less than 1000X.

There are two main types of concentrating optical systems in use today: refractive types that use Fresnel lenses, and reflective systems that use one or more mirrors. Regardless of the chosen optical system, the result is concentrated sunlight being aimed at the sensitive face of the cell, to produce more energy from less photovoltaic material.



In the diagram above, a reflective, mirror-based optical system is used for concentration. The sun's light is collected by the primary mirror, which focuses the light onto the secondary mirror, which concentrates light onto the photovoltaic cell located at the base of the optical rod.

The Benefits of Concentrating

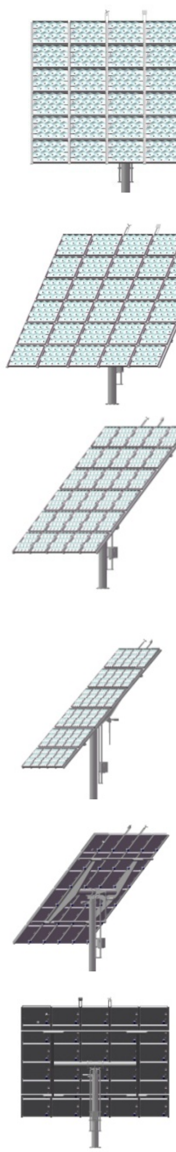
There are two fundamental reasons to concentrate. The first reason is cost. Area for area, optics in a concentrator system are less expensive than the photovoltaic cell. The basic concept is that if the amount of cell area per unit can be reduced, then the overall cost of the system will drop. In the case of high concentration, it is common to find a cell of 1 square centimeter being fed from an optical system that captures more than 500 square centimeters of sunlight. To a first approximation, most solar cells are linear in operation; they will put out proportionally more energy with increasing sunlight, so in the above example, the photovoltaic cell will transform 500 times more energy in the concentrator than it would if simply exposed to the direct sun. This means that the cell, per unit of energy, costs 1/500 as much.

The second reason lies with manufacturability and reliability. Concentrating systems are mechanical assemblies, and can make use of inexpensive, field-proven materials and manufacturing techniques, such as are used in the automotive and disk drive industries. By using common materials such as glass and aluminum for the bulk of a system, and much less solar cell material, concentrator systems are less susceptible to supply constraints of specialized materials such as PV cells, making the technology highly scalable to large volumes of production. While the technology is new in terms of commercial deployment, the reliability of seals, coatings, and many other concentrator components have been established for years in these other industries, and tests and qualification criteria are well established. Use of these established techniques and knowledge is helping to rapidly penetrate the solar marketplace with reliable systems which can move into volume-manufacturing in a short time period.

About the Solar Cells

With most CPV, especially in high concentration designs, the photovoltaic cells used differ from those used in traditional photovoltaic systems which are usually crystalline silicon cells. CPV cells, referred to as “multi-junction” or “III-V” cells, were originally created for space applications. Now they are being used in terrestrial solar applications, and it is the availability of such cells that has been a key enabler of CPV technology. These cells provide energy conversion efficiencies much higher than traditional silicon cells – approximately 35% today with planned efficiencies over the next few years moving into the 45% range. These high efficiencies contrast with typically 13-18% efficiency for silicon cells. With CPV designs utilizing these types of cells, efficiency levels today are significantly higher than traditional photovoltaic systems, and the headroom for future efficiency improvements is much greater as CPV lends itself to rapidly adopting new cell efficiency improvements, as well as new cell technologies.

With CPV technology panels are mounted on tracking systems which track the sun throughout the day. This is required so that the high efficiency cells remain in direct alignment with the sun as it moves across the sky. Accurate tracking technology is critical to CPV technology.



Tracking is Required

The main disadvantage to concentrators lies in the “acceptance angle”, or field of view. Because concentrator optics are in essence telescopes, they only see a small proportion of the sky. The higher the concentration level, the narrower this angle. As a result, concentrators above 3X need to track the sun on either one or two axis. Above approximately 20X all concentrators have to track on two axes, the required accuracy increasing at the larger concentrations. Also worth noting is that the narrower the acceptance angle, the less diffuse light (light refracted through clouds or scattered from dust particles) seen, and so the lower the power output. For optimum results medium and high concentration systems have to be sited in clear, sunny conditions climates where the amount of direct sunlight is high.

CPV versus Other Solar Technologies

CPV is one of several solar technologies, all of which provide value in utilizing the sun as a clean, renewable source of power. However, each is suited to different applications and operating environments. The key is in selecting the right solar technology for the right applications.

Traditional photovoltaics is a mature technology. While lower efficiency than CPV, traditional PV does not require direct sunlight and so in areas where there are clouds or hazy conditions, it is often a good choice. Also, since tracking isn't required it is well-suited to roof-top applications. However, traditional PV suffers from temperature degradation in hot climates resulting in up to 20%+ lower energy output than the rated level. The technology is also faced with limited future efficiency improvements and is dependent on large amounts of photovoltaic material, making it susceptible to supply constraints as have been faced in the recent years. The cost-reduction path for the technology is also limited by the cost of the silicon which composes the bulk of the system.

Thin film solar technology uses materials such as cadmium telluride and amorphous silicon which are strong light absorbers and only need to be about 1 micron thick. Offering a high potential for cost reduction, these materials also lend themselves to incorporation into building materials for the creation of energy-generating buildings. However, thin films are much less efficient in their energy conversion with typical efficiency levels of 8-10%, which means that the land or surface area required to produce a given amount of electrical power is significantly larger than is required with other PV technologies. Also, the materials used in thin films such as cadmium are less environmentally friendly, requiring aggressive plans for the recycling/disposal of components at the end of their useful life.

Another technology worth noting is Concentrating Solar Power (CSP). With CSP high temperature collectors concentrate sunlight using mirrors or lenses to create steam used for electric power production. CSP is not a photovoltaic technology. CSP plants utilize the same approach as traditional electrical generation plants, but replace fossil fuels with sunlight in driving the steam turbines. While CSP has maturity in the market and has shown reasonably low-cost solar electricity generation in large-installations, there are drawbacks. Installations need to be large in scale – around 100MW or more in size – and deployment time is lengthy. Land use is extensive and disruption of the land significant. As a concentrating technology, CSP needs to be located in high sun areas with large land areas, such as deserts. Yet CSP consumes significant amounts of water - 850 gallons or more per MWh

– which is a rapidly growing concern worldwide, particularly in the high-sun regions.

The Solar Solution

Solar energy has just begun to be tapped as a solution to the world's energy crisis. Significant research continues to go into the technology, continually seeking to improve the harvesting techniques of photons and the ability to convert them to electricity at very high efficiency levels. The focus should not be on which solar technology will win out over the other, but rather on how to maximize the potential of all solar technologies in the areas where they excel, in order to have solar move from being a niche technology to a mainstream energy source with tremendous global potential. Solar is a bright spot on the horizon, and holds the promise in the near-term of providing a very low cost source of renewable, clean energy.