United States Environmental Protection Agency

Auxiliary and Supplemental Power Fact Sheet: Solar Power

DESCRIPTION

Solar power is one of the most promising renewable energy sources today. Solar cells, also known as photovoltaic (PV) cells, can be used as Auxiliary and Supplemental Power Sources (ASPSs) for wastewater treatment plants (WWTPs). When photons in sunlight randomly impact the surface of solar cells, free electrons are generated, which flow to produce electricity.

Figure 1. Solar panels (or arrays) on the roofs of buildings.

Solar cells are often assembled into flat plate systems that can be mounted on rooftops (Figure 1) or placed at other sunny locations (Figure 2). A solar cell is composed of several layers of different materials. The top layer is a glass cover or other encapsulating material designed to protect the cell from weather conditions.

Figure 2. Solar "tree" placed out in the open where sunshine is abundant, Styria, Austria.

Beneath the glass layer is an anti-reflective layer that prevents the cell from reflecting sunlight away. Below this layer are two semiconductor layers that are typically made from *n*- and *p*- silicon (Figure 3).

A set of metallic grids or electrical contacts is placed around the semiconductor material, one above the material and the other below. The energy of the absorbed light is transferred to the semiconductor. The energy knocks electrons loose from the semiconductor, allowing them to flow freely. An electric field within the solar cell forces the freed electrons to move in a certain direction. The top grid, or contact, collects the flowing electrons from the semiconductor.

The bottom contact layer is connected to the top contact layer to complete the electrical circuit.

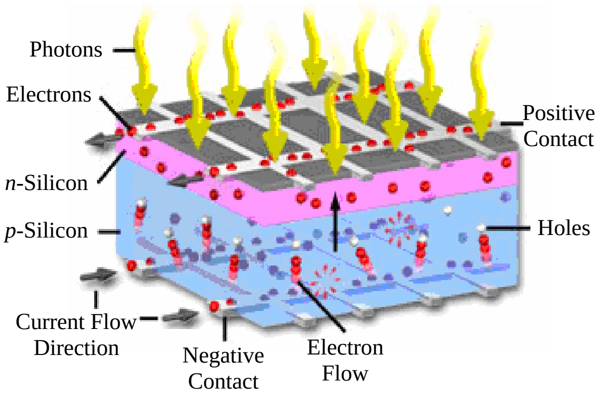


Figure 3. Electron and current flow in solar cell.

This flow of electrons is the current, and by placing metal contacts on the top and bottom of the solar cell, that current can be drawn off to be used externally. This current, together with the cell's voltage (which is a result of the strength of its built-in electric field), defines the power (or wattage) that the solar cell can produce.

Solar cell efficiency varies and is determined by the material from which it is made and by the production technology used to make it. Commercially available solar modules are between 5 to 17 percent efficient at converting sunlight into electrical energy,[1] and in some cases can be as high as 40 percent.[2] Research is always underway to produce cost-effective solar panels with improved efficiency and higher wattage. In 2006, SunPower Corporation announced the company's newly developed SPR-315 solar panel which is 19.3 percent efficient and carries a rated power output of 193 kilowatts. The new SPR-315 solar panel is designed to generate more power with fewer panels, thus maximizing energy production while reducing installation cost. SunPower also claims that the new SPR-315 solar panel performs better than most other solar panels during cloudy or hot weather. The SPR-315 solar panel is now commercial availability.[3,4]

Solar modules generally can produce electric energy in the range from 1 to 160 kilowatts (kW). An individual solar cell will typically produce between one and two watts. To increase the power output, several cells can be interconnected to form a module (Figure 4). Similarly, modules can be connected to form an array (Figures 1 and 2). A solar array with a surface area roughly the size of two football fields could produce 1000 kW of peak power. Ideally, a backup storage system should be included with the solar system to store power so that it can be used during low light conditions or at night.

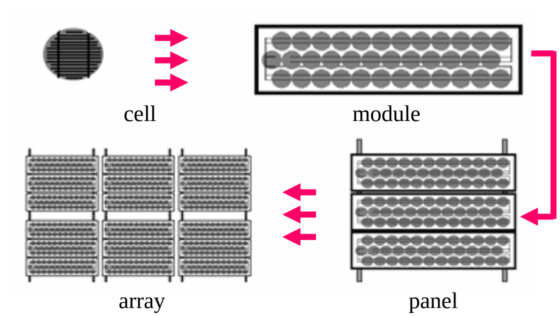
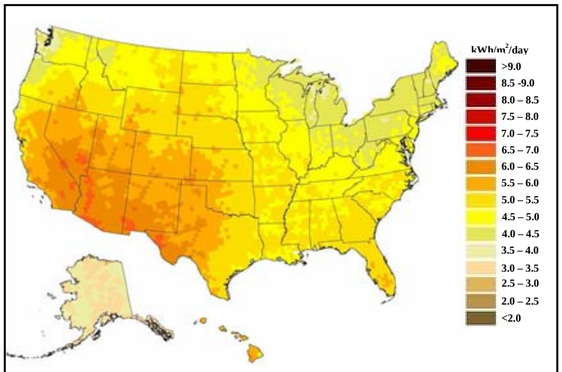


Figure 4. Solar module composed of individual solar cells.

ADVANTAGES & DISADVANTAGES

There are several advantages to using solar cells. Solar cells can generate electricity with no moving parts, they can be operated quietly with no emissions, they require little maintenance, and are therefore ideal for remote locations.

There are also disadvantages associated with the use of solar cells. Good weather and location is essential since solar cells require adequate sunlight to charge. Some geographic locations do not receive adequate levels of sunlight throughout the year (Figure 5) and large areas are needed to generate power in regions that require considerable amounts of power. Although solar cells require very little maintenance, they can be difficult to repair when maintenance is needed. Additionally, the initial cost of solar cells is very high.



Model estimates of monthly average daily total radiation using inputs derived from satellite and/or surface observations of cloud cover, aerosol optical depth, precipitable water vapor, albedo, atmospheric pressure, and ozone resamples to a 40 km resolution.

Produced by the Electric and Hydrogen Technologies and Systems Center, May 2004.[5]

Figure 5. Annual Solar Radiation in the U.S. (Flat Face, Facing South, Latitude Tilt).

COST

Currently, installed solar systems cost from $6,000/kW to $10,000/kW. The cost of a solar system depends on the system's size, equipment options, and installation labor costs.

The average factory price of a solar panel is about $5/watt, excluding balance-of-system (BOS) costs. BOS costs can result in an additional 30 to 100 percent increase to the factory costs. Major BOS cost items include control equipment (maximum power point trackers, inverters, battery charge controllers), solar array support structures, battery storage (if present), installation and associated fees, insurance, and data acquisition system and sensors.

Solar Energy prices have declined on average 4% per annum over the past 15 to 20 years. In the early 1980's, system costs were more than $25/watt. Costs are expected to decrease 40% by 2010. Improvements in conversion efficiencies and manufacturing economies of scale are the underlying drivers.[2]

APPLICATIONS OF SOLAR POWER AT WASTEWATER TREATMENT PLANTS

Several wastewater treatment plants have installed solar cells to generate electricity for process controls. Oroville, a town in Northern California, operates a 6.5 MGD WWTP which services 15,000 households and many industrial users. In 2002, amidst an energy crisis that saw the price of utilities rise 41 percent, the Oroville Sewage Commission (SC-OR) decided to pursue solar power as a solution to reduce costs and increase energy self-reliance. That same year, the utility installed a 520-kW ground-mounted solar array capable of being manually adjusted seasonally to maximize the solar harvest. The solar array consists of 5,184 solar panels covering three acres of land adjacent to the WWTP. The total cost of the solar system, which is the fifth-largest solar energy system in the United States, was

$4.83 million, with a rebate to the utility of $2.34 million from the Self-Generation Incentive Program of Pacific Gas and Electric (PG&E) and managed through the California Public Utilities Commission (CPUC). SC-OR was able to see an 80% reduction in power costs.

The SC-OR solar array is designed to produce more power than the utility needs during peak hours, and because the system is connected to the local energy grid, it can feed all of the excess energy back to the power utility so that SC-OR can receive credit on their power bill. This credit goes toward paying for the off-peak power that the treatment plant uses at night. SC-OR saved $58,000 in the first year and expects the solar array to pay for itself in 9 years.

In addition to using wind power, the 40-MGD Atlantic County Utilities Authority (ACUA) Wastewater Treatment Facility in Atlantic City, New Jersey, installed five solar array totaling 500-kilowatts for the facility.[6] The five solar arrays were place at different locations throughout the facility and include two "ground-mount" arrays, two "roof-mount" arrays, and a "canopy" array. The roof-mount arrays are mounted such that they could withstand hurricane force winds.

The solar array can generate electricity at rates lower than 5 ¢ per kWh for the next 20 years. This is the second largest solar array in the state producing over 660,000 kWh of electricity annually or about 3% of the facility's 20 GWh annual electricity needs. This equivalent amount of energy displaces 388 barrels of oil and over 400,000 pounds of carbon dioxide. Energy rebates of $1.9 M were obtained from the New Jersey Board of Public Utilities and an additional anticipated savings of over $35,000 is expected each year. The total cost of the project was about $3.9 million.

In 2001, SolarBee Inc. developed the SolarBee®, which is a floating solar-powered circulator that is capable of moving up to 10,000 gallons of water per minute for long distances (Figure 6). The SolarBee® possesses battery storage for up to 24-hour operation, which is beneficial during low sunlight conditions. A single SolarBee® unit can effectively aerate a 35-acre lake or treat a 25 million gallon drinking water reservoir or tank.

Figure 6. SolarBee®, manufactured by SolarBee Inc.

Since its creation, over 1,000 units have been installed in many treatment applications including wastewater lagoons. Use of the SolarBee® circulator can effectively improve biochemical oxygen demand and sludge reductions, control odor, and reduce total solids and ammonia concentrations in the effluent.

In 2005, the City of Myrtle Beach in South Carolina installed five SolarBees into the first three cells of the city's 50-acre wastewater lagoon (Figure 7). Improvements in dissolved oxygen and H_2S levels within the lagoon after a few months prompted the city to budget for five additional Solarbees for the following year. Once installed, electrical savings is expected to average $100,000 per year.[7]

Figure 7. SolarBee® installed in City of Myrtle Beach, South Caolina, 50-acre wastewater lagoon.

In southwest Arizona, the City of Somerton replaced a 40-horsepower wastewater lagoon aeration motor with four solar-power aerators. The project cost was about $100,000 with an expected electric energy costs savings of $25,000. Other applications of solar-powered aerators include the Wastewater Treatment Facility in Bennett, Colorado and the Town of Discovery Bay Community Services (TDBCSD) Wastewater Treatment Plant, California.

Benefits of using solar-power aerators not only include energy savings, but also reduces odor, greenhouse gas emissions, and biosolids volume at the bottom of a pond or basin that would otherwise have to be dredged and disposed.

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