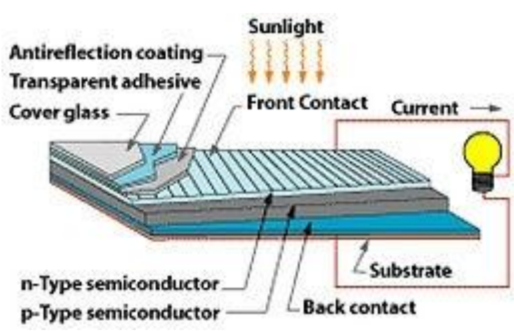
Solar power

Residential rooftop installation of solar panels. US EPA

Stirling dish system at Plataforma Solar de Almeria, Spain. Source: Sandia National Laboratory

Solar power is any process that generates electricity from the sun's radiation. There are two chief technologies for such electrical production: (a) photovoltaics (PV), where solar panels convert sunlight directly to electrical current; and (b) concentrating solar rays to boil water, which is used to provide power. In spite of the enthusiasm for solar plants in a few western countries, the technology requires significant subsidies to compete with fossil fuels, hydroelectric and nuclear power alternatives; in point of fact solar power supplied a mere .0002 of the world power supply as recently as 2008. Although solar is classified as a renewable energy source, there are some significant environmental impacts, including the generation of toxic cadmium residues and the significant destruction and fragmentation of natural habitats. Strides are being made in terms of improvement in solar panel efficiency and manufacturing capacity, such that solar power could make a measurable worldwide contribution to the world's power supply by the 2020 to 2030 time frame. An even greater potential exists in the integrated building systems field, where individual solar units are installed directly within a given structure; in this case, there is much less impact to habitat loss and the transmission costs of electricity are greatly reduced.

Process technology



Photovoltaic technology utilizes impingement of solar photons upon intricately constructed semiconductor layers to produce electrical current. Individual silicon wafers are doped with impurities, typically boron and phosphorus, to produce a p-n semiconductor junction,[1] topped with glazing and bottomed with a conductor (usually aluminum) to collect the electrical current. The resulting collection of wafers is termed a *solar panel*. The collection efficiency of present panels is only about 15 to 30 percent of the incident solar radiation, which daytime insolation is typically about 240 watts per meter in geographically favorable world regions. Alternatively, systems of lenses and mirrors can be used to focus the sun's rays into an intense beam capable of boiling water; such concentrating solar power systems employ the boiling water to run a conventional steam power plant. The most common geometries applied are the parabolic trough, the linear fresnel reflector, the Stirling dish and the solar power tower.

Critical resources

Solar power is the chief type of electrical power production that consumes large quantities of scarce minerals, other than grid and transmission needs common to all sources. The silicon wafer manufacturing process requires a number of specialized metals that are consumed in non-trivial quantities, some of which are difficult or expensive to reclaim in a recycling process. The chief materials that are presently deemed scarce in the Earth's crust are Tellurium, Indium, Ruthenium and Germanium. Gallium and Cadmium are also considered relatively small in reserves, but not as critical as the first four.[2] Silver is also consumed in large quantites by photovoltaic cell production, but its reserves are also more abundant than the most critical metals. Cumulatively, the availability of these metals poses an obstacle to dynamic growth of solar power, even if some advances in material substitution and recycling are made. Alternatively, the increasing scarcity of these materials produced by the solar industry itself will drive up prices for these substances and hence increase the pricing of solar power.

Environmental Impacts


Large solar array.

There are a number of significant adverse environmental impacts from the manufacture and disposal of solar power systems, particularly in the case of photovoltaic systems. With regard to air quality there are a number of pollutants entering the atmosphere as a result to the mining and manufacturing processes leading to the production of solar panels.[3] Substantial carbon monoxide is released into the atmosphere from the Siemens process in producing metallurgical grade silicon. The toxic heavy metal cadmium is also emitted in considerable quanities in the manufacturing of photovoltaic wafers; in fact, emissions of cadmium are similar to those produced by coal fired power plants when compared on a energy production output basis of the two technologies. There are additional cadmium emissions in the disposal phase in both air emissions and soil contamination pathways. Certain quantities of hydrochloric acid air emissions arise during the silicon production process, but these are expected to be reduced in the future with an increased mix of solar grade silicon. With regard to greenhouse gas production, there is considerable impact based upon carbon dioxide emissions from the manufacturing process of the silicon wafers, aluminum backing and other frame components. Production of metallurgical grade silicon relies on carbothermal reduction of quartz that fires a coal bed to 1200 degrees Celsius; this process necessarily releases considerable carbon dioxide. Overall, greenhouse gas emissions are more favorable overall for solar compared to fossil fuel plants, but more adverse than nuclear, wind or tidal energy generation.

For large array systems the impacts of habitat destruction and habitat fragmentation is considerable, especially since these systems are often constructed on sensitive desert soils such as the Mojave Desertinstallations. The impacts of building integrated technologies are much less severe, since they can rely upon existing or planned structures for their installation, rather than the taking of pristine areas. Thus, in regard to habitat destruction, the impacts of large array solar systems are more severe than either fossil fuel plants or nuclear plants.

Systems analysis


Photovoltaic solar array at Nellis Air Force Base, California. Source: U.S. Air Force

Several broad elements of solar power applications should be addressed to provide an adequate overview of this topic: operational power versus capacity; useful life; and energy payback. In terms of capacity available, solar installations typically yield approximately twenty percent of capacity, chiefly due to the diurnal solar cycle, but aggravated by cloud cover and seasonal inefficiency. The more sophisticated systems have solar panel tracking capability which allows optimization of the panel angle by time of day, but this feature does not dramatically improve performance. This realm of generation relative to installed capacity places solar power considerably below the 80 to 95 percent range common in fossil fuel and nuclear plants, and even below the approximate 40 percent ratio found in wind generation.

The useful life of most advanced solar power generation systems is approximately 23 years, which is an optimistic level considering that the fundamental technology is improving rapidly, so that present plants will be effectively outdated in another decade. Useful lives of fossil fuel and nuclear plants are typically 40 to 60 years in comparison. The energy payback time for a solar plant is approximately three years, but this measure is properly measured as a mix of current energy products, implying that the first three years of operation are essentially a break even period for fossil and nuclear fuel saved. The economic payback time for solar installations also considers labor and other investment costs of constructing a new solar plant, so that the total economic payback time for new solar installations is approximately eight to twelve years; moreover, this payback can be enhanced by a number of governmental incentive programs designed to stimulate building integrated solar installations at the property owner level.

Geography

The geography of installations of major solar power plants has been driven by latitude, national wealth and intensity of societal commitment. Latitudes as close to the equator as 35 degrees are generally the most favorable. Spain is an example where all of the precursors form a confluence and that country has been a leader in solar development; however, recent trends, moderated by the inherent need to continue subsidies, have marked a rapid decline in that country. Other historically important players include Portugal and the southwestern USA. Noteworthy among more northern latitudes are Canada and Germany, whose societal commitments have overcome an inherent latitude inefficiency.

A great untapped potential lies in China, the nation that is the world leader in greenhouse gas production. The inherent geography, size and sunlight days in China give it the possibility of generating large amounts of solar power; in fact, China ranked ninth among world nations in production of solar cells, almost all of which are exported. However, the installed solar capacity that China does have is revealing, since it is a nation strongly attuned to economic payback: The main installation of solar power in China is individual building rooftop thermal units.[4] China's future use of large scale solar not only would reduce its production of black carbon and other greenhouse gases, but would capitalize on the enormous percentage of its land area that receives more than 2200 hours per annum of sunlight and its unusually large land area (such as the North China Plain) which has been ecologically destroyed by overgrazing, overdrafting of groundwater or other intensive agricultural practices.

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