Concentrated Solar Power as Renewable Energy and Perception of Risks

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Abstract ***Beginning with the surge in coal use which accompanied the industrial revolution, energy consumption has steadily transitioned from wood and biomass to fossil fuels .The early development of solar technologies starting in the 1860s was driven by an expectation that coal would soon become scarce. However, development of solar technologies stagnated in the early 20th century in the face of the increasing availability, economy, and utility of coal and petroleum. Solar concentrating technologies such as parabolic dish, trough and Scheffler reflectors can provide process heat for commercial and industrial applications. The main concern about both types of solar power generation – photo voltaic and concentrated solar power – is that they can potentially cause the displacement or exclusion from important habitats of nationally and/or globally threatened, rare, endemic or range-restricted bird species. Other potential risks include collision with the reflective surfaces. All these factors have been duly emphasized in the paper with suggested remedies of the probable environmental hazards.***

Keywords ***Photo voltaic, Concentrated Solar Power, energy consumption, solar technologies, Scheffler Reflectors***

1 Introduction

The problem of bird deaths at solar power farms is a complex one. Some solar developers have been powering down bright lights that had attracted insects at night, or switching to LEDs, and using nets to keep birds at bay. But that apparently is not enough. "The diversity of birds dying at these solar facilities, and the differences among sites, suggest that there is no simple 'fix' to reduce avian mortality," the federal report states. [1] The report recommends improving bird- and bat-death monitoring through the use of sniffer dogs, video cameras, and daily surveys. It also lists recommendations for directly reducing avian mortality. Those recommendations include clearing vegetation around solar towers to make the area less attractive to birds, retrofitting panels and mirrors with designs that help birds realize the solar arrays are not water, suspending operations at key migration times, and preventing birds and bats from roosting and perching at the facilities. The recommendations are being considered by regulators. The Center for Biological Diversity supports those proposed measures. It also suggests restoring bird habitat elsewhere to draw birds away from the solar facilities, which could help the rails and other species recover. And it wants the government to undertake new scientific research -- research that could offer clues for better protecting birds from solar power farms. The first commercial system was the Solar Total Energy Project (STEP) in Shenandoah, Georgia, USA where a field of 114 parabolic dishes provided 50% of the process heating, air conditioning and electrical requirements for a clothing factory. This grid-connected cogeneration system provided 400 kW of electricity plus thermal energy in the form of 401 kW steam and 468 kW chilled water, and had a one-hour peak load thermal storage. Evaporation ponds are shallow pools that concentrate dissolved solids through evaporation. The use of evaporation ponds to obtain salt from seawater is one of the oldest applications of solar energy. Modern uses include concentrating brine solutions used in leach mining and removing dissolved solids from waste streams. In some states of the United States legislation protects the "right to dry" clothes. Unglazed transpired collectors (UTC) are perforated sun-facing walls used for preheating ventilation air. UTCs can raise the incoming air temperature up to 22 °C and deliver outlet temperatures of 45–60 °C. The short payback period of transpired collectors (3 to 12 years) makes them a more cost-effective alternative than glazed collection systems. [2] As of 2003, over 80 systems with a combined collector area of 35,000 square meters had been installed worldwide, including an 860 m^2 collector in Costa Rica used for drying coffee beans and a 1,300 m^2 collector in Coimbatore, India, used for drying marigolds.

2 CSP Projects and the Technology involved

Working with member countries, Solar Power and Chemical Energy Systems (Solar PACES) has compiled data on concentrating solar power (CSP) projects around the world that have plants that are either operational, under construction, or under development. CSP technologies include parabolic trough, linear Fresnel reflector, power tower, and dish/engine systems. The National Renewable Energy Laboratory's CSP Program assists Solar PACES in maintaining the projects database behind this Web site. Project operators or developers supply information for the key data fields for their projects. Solar PACES experts then review the information to ensure accuracy and completeness. Solar PACES, an international program of the International Energy Agency, furthers collaborative development, testing and marketing of concentrating solar power plants. Activities include testing large-scale systems and developing advanced technologies, components, instrumentation, and analysis techniques. Concentrating solar power (CSP) technology may be categorized as: (a) Parabolic Trough Systems—line- focus systems that use curved mirrors to focus sunlight on a receiver, (b) Linear Fresnel Reflector Systems—line-focus systems that use relaxed and flat mirrors arranged to focus sunlight on a receiver, (c) Power Tower Systems—point-focus systems that use heliostats to focus sunlight on a tower-mounted receiver, (d) Dish/Engine Systems—point-focus systems that use curved mirrors to focus sunlight on a receiver. Solar Photovoltaic (PV) electricity generation converts solar radiation directly into electricity through a solar panel. PV Solar Farm consists of an area covered by photovoltaic panels. PV uses semi-conductor materials to convert sunlight directly into electricity. PV panels can be fixed or track the sun in one or two axes. Concentrated Solar Power (CSP) farms (plants), on the other hand, consists of a series of mirrors/heliostats/trough panels that reflect sunlight. CSP farms consist of a series of heliostats/trough panels with mirrors which concentrate sunlight on a receiver tower (although some CSP farms are developed without receiver towers). CSP farms potentially have greater impacts on birds than PV farms because of the associated central receiver tower, standby focal points and heliostats. It operates by concentrating the suns energy to produce heat which either drives a steam turbine or an external heat engine to produce electricity. A liquid [known as heat transfer fluid (HTF) which usually consists of a mix of oils] or a gas medium is heated and this is used to convert water to steam, which is used to generate electricity through a steam turbine generator. The reflected heat is mostly concentrated onto a central receiver tower and standby focal points (although other technology within CSP exists). The heat is used to raise steam to drive turbines and generators. Linear concentrators are curved panels that reflect and focus the sun's rays onto a tube that runs the length of the panel. The tube contains a fluid that heats up creating steam which is used to drive a turbine. The two main configurations are the parabolic trough type, where the tube runs along the focal line, and the linear Fresnel type, which uses Fresnel lenses to collimate the reflected beam such that one receiver tube can be positioned over several mirrors. This type provides greater mobility in tracking the sun and is also less expensive. A typical arrangement of photovoltaic panels is shown in Figure 1. Figure 2 (a), on the other hand reveals Concentrated Solar Power (CSP) facility. The Parabolic troughs are used to concentrate sunlight on the central receiver tower. Figure 2(b) shows a schematic presentation of CSP technology and the layout of a CSP facility. CSP operates by concentrating the Sun's energy to produce heat which either drives a steam turbine or an external heat engine to produce electricity. The heat transfer fluid (HTF) medium is then cooled, condensed and reused.[3]

Fig.1. Photo-voltaic (PV) solar farm showing typical arrangement of photovoltaic panels .
Credit Alamy stock photo

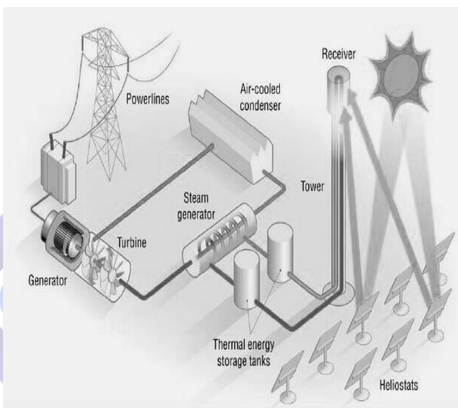

Fig. 2 Concentrated Solar Power (CSP) Facility - Parabolic troughs concentrating sunlight on the central receiver tower with schematic presentation of CSP technology and the layout of a CSP Facility. CSP operates by concentrating the sun's energy to produce heat which either drives a steam turbine or an external heat engine to produce electricity. The heated liquid (HTF) or gas medium is then cooled, condensed and reused .
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SCHFFLER REFLECTORS

Scheffler reflector is a solar device for the concentration of solar light that allows, amongst other applications, to cook with solar energy. The aim that led to the development of the Scheffler reflector was to make solar cooking more comfortable. With this idea, the German physician Wolfgang Scheffler designed a solar cooker that allowed the cooking focus to be still while the sun kept its apparent path in the sky, and that had a structure that would allow cooking from inside of the building. After passing the opening the light is redirected by a small reflector (secondary reflector) to the black bottom of the cooking pot. There it is absorbed and transformed into heat. The efficiency for cooking, i.e. heating water from 25°C to 100°C, can reach up to 57% and depends on the cleanliness of the reflector-surface and the state of insulation of the cooking-pot. At the focal-point itself we have measured optical efficiency of up to 75% (with 2mm ordinary glass mirrors). Depending on the season an elliptical reflector of 2,8m x 3.8m (standard size of 8m² Scheffler-Reflector) collects the sunlight of a 4,3m² to 6,4m² area, measured perpendicular to the direction of the incident light (aperture). That way the cooking power varies with the season. As an average a 8m² Reflector can bring 22 liters of cold water to boiling temperature within one hour (with 700W/m² of direct solar radiation).[4]

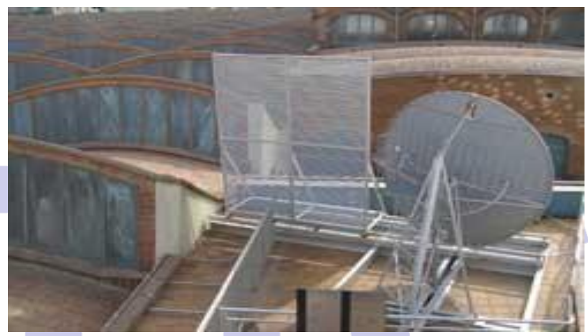

Fig.3 A Scheffler reflector being used as a solar cooker to cook food by concentrating the sunlight. *Credit Alamy stock Photo*

The output of a reflector with a surface of 10 square meters varies depending on the season of the year between 2.2 kW during summer and 3.3 kW during winter, assuming solar radiation of 700 watts per square meter. At our latitudes, the power (energy per unit time) of the Scheffler mirror is higher in winter than in summer as the area of the mirror is used more effectively when the sun is lower in the sky. The total energy received during a day is however still greater during summer as there are more hours of sunshine.[5]

3 Green Job Hazards: Solar Energy

Solar is a growing sector for green energy and green jobs. Various worker health and safety hazards exist in the manufacture, installation, and maintenance of solar energy. Employers working in the solar energy business need to protect their workers from workplace hazards and workers need to understand how to protect themselves from hazards.
Two commercially viable solar energy sectors are

solar electric and solar thermal or solar water heating.[6]

3.1 Solar Electric

Solar energy can be converted into electricity using photovoltaics (PV), or concentrating solar power (CSP). PV systems are the most common and use semi-conductors and sunlight to make electricity. The more solar modules a PV system or array has, the more electricity will be generated. Materials presently used for photovoltaics include monocrystalline silicon, polycrystalline silicon, microcrystalline silicon, cadmium telluride, and copper indium selenide/sulfide and many more. [7]

3.2 Solar Thermal or Solar Water Heaters

Types of solar water heating systems include direct and indirect (Glycol) systems and are chosen largely by climate; freezing temperatures can damage some types. [8]

4 Hazards and Controls

Workers in the solar energy industry are potentially exposed to a variety of serious hazards, such as arc flashes (which include arc flash burn and blast hazards), electric shock, falls, and thermal burn hazards that can cause injury and death. Solar energy employers (connecting to grid) are covered by the *Electric power generation, transmission, and distribution* standards and therefore may be required to implement the safe work practices and worker training requirements of OSHA's Electric Power Generation, Transmission and Distribution Standard, 29 CFR 1910.269. While solar energy is a growing industry, the hazards are not unique and OSHA has many standards that cover them. This page provides information about some hazards that workers in the solar industry may face. Workers, who install and/or maintain solar panels often work on roofs, use ladders and scaffolding, are in proximity of ledges and sunroofs, and are exposed to fall hazards. As more solar panels are installed on the surface of a roof, the walking area which may once have been available may no longer be available to workers. This may force workers to squeeze by or walk very close to skylights and/or roof hatches. To protect workers from these potential fall hazards through skylights, roof edges and roof hatches, employers must make sure that skylights are guarded or that workers near skylights use personal fall protection. Solar energy equipment can generate electrical energy and may be connected to electrical circuits. Workers may be exposed to electrical hazards from solar panels and from electrical circuits. While installing or servicing solar panels, employers should assure that workers cover the solar panels, in addition to protecting workers from electrical circuits. Workers performing servicing or maintenance of solar panels may be exposed to injuries from the unexpected energization or release of stored energy in the equipment. [9]

5 Commercial Deployment of CSP around the World

The commercial deployment of CSP plants started by 1984 in the US with the SEGS plants. The last SEGS plant was completed in 1990. From 1991 to 2005 no CSP plants were built anywhere in the world. Global installed CSP-capacity has increased nearly tenfold since 2004 and grew at an average of 50 percent per year during the last five years. In 2013, worldwide installed capacity increased by 36% or nearly 0.9 gigawatt (GW) to more than 3.4 GW. Spain and the United States remained the global leaders, while the number of countries with installed CSP was growing. There is a notable trend towards developing countries and regions with high solar radiation.CSP is also increasingly competing with the cheaper photovoltaic solar power and with concentrator photovoltaics (CPV), a fast-growing technology that just like CSP is suited best for regions of high solar insolation. In addition, a novel solar CPV/CSP hybrid system has been proposed recently.[10]

Year	2010	2011	2012	2013	2014	2015	2016
Installed	307	629	803	872	925	420	110
Cumulative	969	1598	2553	3425	4335	4750	4815

Table 1: Worldwide Concentrated Solar Power since 2010

Data Sources REN21・CSP-world.com IRENA

6 Effect on wildlife

Insects can be attracted to the bright light caused by concentrated solar technology, and as a result birds that hunt them can be killed (burned) if the birds fly near the point where light is being focused. This can also affect raptors who hunt the birds. Federal wildlife officials have begun calling these power towers "mega traps" for wildlife. According to rigorous reporting, in over six months, actually only 133 singed birds were counted. By focusing no more than four mirrors on any one place in the air during standby, at Crescent Dunes Solar Energy Project, in three months, the death rate dropped to zero. [11]

Fig 4. Dead warbler burned in mid-air by solar thermal power plant Credit

7 Solar Farms Threaten Birds

Certain avian species seem to crash into large solar power arrays or get burned by the concentrated rays. Fewer than 1,000 are thought to still be sloshing about in cattail-thick marshes from Mexico up to Utah and across to California. But if you were lucky enough to spot one, you might chuckle at its oversized toes. When officials with the National Fish and Wildlife Forensics Laboratory saw one of these endangered birds last year, it was no laughing matter. It was dead. It was one of 233 birds recovered from the sites of three Californian desert solar power plants as part of a federal investigation. The laboratory's wildlife equivalents of CSI stars concluded that many of the birds had been fatally singed, broken, or otherwise fatally crippled by the facilities.[12]

Fig 5 . Yuma clapper rail. *Credit: Fish & Wildlife Services*

Conservationists say they're also worried about yellow-billed cuckoos, which might be added to the federal government's list of threatened species, and endangered southwestern willow flycatchers, though none of those birds have been found dead at any of the solar sites. The effects of wind turbines on birds, which research suggests kill far fewer birds per megawatt hour than do fossil fuel plants; have long been a source of consternation for many environmentalists. Their bird-killing effects have been serious enough to kill and hamper some planned projects. Now, as concentrated solar farms start to sweep the globe, solar energy developers are facing similar outcries and opposition for the harm that their clean energy facilities can cause to wildlife.

8 Threats to the Environent

Reports have emerged about high numbers of birds burned to death at a solar energy facility in the southwestern US. One hundred forty-one bird carcasses were found at Ivanpah from June 2012 to December 2013, one-third of which likely died from the solar flux, with telltale signs including feather curling, charring, melting and breakage. Most were house finches and yellow-color warblers whose diets consist mostly of insects. Finding a way to keep the birds from flying into the concentrated beams, just because the energy is green doesn't mean our responsibilities end there. The main goal should still be to reduce emissions AND reduce the impact to local ecosystems. And that doesn't just apply to energy producers, but to manufacturers, infrastructure, consumers and builders, too. The main concern about both types of solar power generation – photovoltaic and concentrated solar power – is that they can potentially cause the displacement or exclusion from important habitats of nationally and/or globally threatened, rare, endemic or range-restricted bird species. Other potential risks include collision with the reflective surfaces.[13]

8.1 Role of Environmental Regulatory Bodies on death of Birds

The Ivanpah solar thermal power plant in the Southern California desert supplies enough carbon- free electricity to power 140,000 homes. The intense light that surrounds the top of Ivanpah's power towers attracts insects, including Monarch butterflies. It is claimed that these events represent the combustion of loose debris or insects. But from a bird's eye view, a sea of those shiny bluish panels can literally look like a sea, a desert oasis for them to alight. For birds, bats and butterflies, though, the futuristic project is the Death Star, incinerating anything that flies through a "solar flux" field that generates temperatures of 800 degree Fahrenheit when 300,000 mirrors focus the sun on a water-filled boilers that sit on top three 459-foot towers.At times birds flew into the solar flux and ignited."It appears Ivanpah may act as a 'mega-trap,' attracting insects which in turn attract insect-eating birds, which are incapacitated by solar-flux injury, thus attracting predators and creating an entire food chain vulnerable to injury and death," concluded scientists with the National Fish and Wildlife Forensics Laboratory in a report that investigated 233 bird deaths representing 71 species at three Southern California solar power plants.It's important to put that death toll in context. Every year as many as 988 million birds—that's not a typo—or nearly 10 percent of the United States's avian population, die from colliding with windows, according to a study published in March. The feds saw what appeared to be a bird go up in flames every two minutes, according to the report. "Given that Ivanpah has only been operational for a short period of time, it is premature to determine the significance and extent of impacts to insects, birds, or bats.""Climate change is by far the biggest concern for all forms of wildlife on the planet and we have spent millions of dollars on projects like Ivanpah in our quest to find ways to provide clean, sustainable and renewable energy," Holland added.While about 60 percent of the 233 bird deaths occurred at Ivanpah, solar technologies considered more environmentally benign also proved fatal to birds.The Desert Sunlight project developed by First Solar, for instance, deploys hundreds of thousands of solar panels like those found on residential rooftops. The birds killed at Ivanpah include a peregrine falcon, a red-shouldered hawk and an ash-throated flycatcher. The report recommends among other things that NRG shut down the power plant during peak migration times for some bird species and install video cameras to monitor birds as they fly into the solar flux.NRG spokesman Jeff Holland took issue with some of the recommendations."While the report provides some initial data on bird mortality at the Ivanpah project, it also presents premature conclusions regarding the severity of impacts and proposed recommendations which are not supported by scientific literature, nor standard protocols and processes that are necessary prior to drawing scientific conclusions," he told The Atlantic in an email. The construction of Ivanpah, which was built by BrightSource Energy and now is operated by NRG Energy, faced delays when it turned out the site 45 miles south of Las Vegas is a hot spot for the imperiled desert tortoise.The Fish and Wildlife biologists cautioned that their results are preliminary and that much more research needs to be done on avian mortality around solar power plants.But the scientists and members of the Fish and Wildlife Service's Office of Law Enforcement (OLE) saw first-hand those trade-offs when they visited Ivanpah, where mirrors called heliostats heat water to generate steam to drive an electricity-generating turbine.[14]

9 Discussions

The construction of solar panel farms and concentrated solar power are both booming businesses. In California, industrial-scale facilities like these are helping utilities meet a state mandate that 20 percent of electricity sold by 2017 is renewable. But if the problem of wildlife impacts festers, the growth of concentrated solar, which by one recent estimate could grow to a $9 billion worldwide industry in 2020, up from $1 billion in 2013, could be crimped by lawsuits and opposition from conservationists. Much of the problem appears to lie in the "lake effect," in which birds and their insect prey can mistake a reflective solar facility for a water body, or spot water ponds at the site, and then hone in on it. Because of the power of the lake effect, the federal investigators described such solar farms as "mega-traps" in their report. The Associated Press reported last week on "streamers" at Bright Source Energy's concentrated solar plant -- a futuristic-looking facility that gamers pass as they drive through the desert between Las Vegas and Los Angeles. That's the name given to birds as their feathers ignite, mid-air, after flying through a concentrated beam of sunlight. Such hapless birds can be burned to death, killed by brute force when they crash to the ground or eaten a predator swoops in to claim their maimed body. These are just some of the ways that large solar plants can kill birds. It's not known how many birds are being felled by the groundswell of such facilities, but the numbers are high enough to concern bird and conservation groups -- regardless of the environmental benefits of solar power. The other solar farms analyzed by the investigators were of the newfangled trough and solar power tower varieties. They included the Genesis Solar Energy Project, also in Riverside County, which uses a trough system in which parabolic mirrors focus sunrays into a tube where water boils into steam that spins a turbine to produce electricity. The mirrors pose similar threats to birds as solar panels. The third facility studied was the Ivanpah Solar Electric Generating System in Bernardino County, Calif., where birds can be burned as they pass through concentrated sunrays that are reflected off thousands of mirrors toward a solar power tower, where water is boiled to produce electricity- generating steam.[15]

10 Conclusions

Space-based solar power (**SBSP**) is the concept of collecting solar power in outer space and distributing it to Earth. Potential advantages of collecting solar energy in space include a higher collection rate and a longer collection period due to the lack of a diffusing atmosphere, and the possibility of placing a solar collector in an orbiting location where there is no night.[16] A considerable fraction of incoming solar energy (55–60%) is lost on its way through the Earth's atmosphere by the effects of reflection and absorption. Space-based solar power systems convert sunlight to microwaves outside the atmosphere, avoiding these losses, and the downtime due to the Earth's rotation, but at great cost due to the expense of launching material into orbit. SBSP is considered a form of sustainable or green energy, renewable energy, and is occasionally considered among climate engineering proposals. It is attractive to those seeking large-scale solutions to anthropogenic climate change or fossil fuel depletion (such as peak oil).Various SBSP proposals have been researched since the early 1970s, but none are economically viable with present-day space launch infrastructure. A modest Gigawatt-range microwave system, comparable to a large commercial power plant, would require launching some 80,000 tons of material to orbit, making the cost of energy from such a system vastly more expensive than even present day nuclear plants. Some technologists speculate that this may change in the distant future if an off-world industrial base were to be developed that could manufacture solar power satellites out of asteroids or lunar material, or if radical new space launch technologies other than rocketry should become available in the future. Besides the cost of implementing such a system, SBSP also introduces several technological hurdles, including the problem of transmitting energy from orbit to Earth's surface for use. Since wires extending from Earth's surface to an orbiting satellite are neither practical nor feasible with current technology, SBSP designs generally include the use of some manner of wireless power transmission and its concomitant conversion inefficiencies, as well as land use concerns for the necessary antenna stations to receive the energy at Earth's surface. The collecting satellite would convert solar energy into electrical energy on board, powering a microwave transmitter or laser emitter, and transmit this energy to a collector (or microwave rectenna) on Earth's surface. Contrary to appearances of SBSP in popular novels and video games, most designs propose beam energy densities that are not harmful if human beings were to be inadvertently exposed, such as if a transmitting satellite's beam were to wander off-course. But the vast size of the receiving antennas that would be necessary would still require large blocks of land near the end users to be procured and dedicated to this purpose. The service life of space-based collectors in the face of challenges from long-term exposure to the space environment, including degradation from radiation and micrometeoroid damage could also become a concern for SBSP.SBSP is being actively pursued by Japan, China, and Russia. In 2008 Japan passed its Basic Space Law which established Space Solar Power as a national goal and JAXA has a roadmap to commercial SBSP. In 2015 the China Academy for Space Technology (CAST) briefed their roadmap at the International Space Development Conference (ISDC) where they showcased their road map to a 1 GW commercial system in 2050 and unveiled a video and description of their design.[17]

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