SOLAR TECHNOLOGY AND DEVELOPMENT OVERVIEW

Ref. No.: PR-020749

03 September 2021

CLASSIFICATION

CLIENT'S DISCRETION

ISSUE

A

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Ref. No.: PR-020749 Issue: A Status: Final

KEY TO DOCUMENT CLASSIFICATION

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DOCUMENT HISTORY

ISSUE	DATE	SUMMARY
A	03 September 2021	Final Report

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1. INTRODUCTION

UL Services Group LLC ("UL") has been engaged to provide a report that summarizes solar PV equipment, environmental impacts, operations and maintenance, decommissioning, and safety topics in regard to the development of solar PV plants.

2. WHO IS UL?

As a leader in global services for renewable energy, UL is a trusted independent advisory, testing, inspection, and certification body for a broad range of industries. In the renewable energy space, UL works to help manufacturers, developers, owners, investors, lenders, utilities, and policy makers navigate the risk and complexity associated with renewable resources. UL has become a trusted advisor by providing access to proven science and expert engineering and by offering innovative solutions to meet the unique challenges of the renewable energy industry. UL prides itself on being accessible, flexible, and keenly responsive to the needs of its clients. UL has offices in over 140 countries, a team of over 500 experts, and 35 years of experience. UL advises on wind and solar projects as well as battery and energy storage technologies, helping its clients to make these technologies safer. UL's guidance also helps clients to make these technologies compliant with relevant codes and standards and able to perform to the highest standards. UL's goal is to empower trust in renewable energy throughout the project lifecycle and across the supply chain.

2.1 What Does UL Do for a Solar Project?

For a solar project to receive financing, an independent engineer (IE) is hired by the project lenders to provide technical and commercial expertise that addresses project risks and proposes mitigation to ensure that the solar project is successful.

In its role as an independent engineer, UL reviews and evaluates all aspects of a solar project to ensure that the project has the required permits in place; has appropriate warranties; and has equipment supply, construction, and service contracts in place. UL also verifies that the proposed financial model is sufficient for the project to be built and operated under the proposed budget; that the project has been designed according to applicable state and national codes and standards, including electrical, building, fire, and environmental codes and regulations; that the project has a decommissioning plan; and that the project can effectively and safely deliver power to the grid and sell power to the end users. UL also reviews the energy production estimates and may generate an independent energy production estimate for the solar project to ensure that the original energy estimates are reasonable based on the project location, configuration, equipment/technology, and executed service contracts.

During the review process, UL highlights any risks to the project, community, or electrical grid that are uncovered, and UL then works with the project developers and designers to implement design changes or mitigation measures to minimize or remove those risks.

At the end of the project evaluation, UL produces an independent engineering report that is provided to and reviewed by the project's lenders to give confidence to the investors that the project will work as designed for the expected project life. This report also creates confidence that the project will not have a detrimental impact on the environment or the local electrical grid.

3. UL'S RESPONSES TO COMMON QUESTIONS

3.1 What Is Typical Solar Project Equipment?

A typical utility-scale solar project will have the following equipment:

- Solar modules that convert sunlight to DC electricity
- Mechanical trackers to orient the solar modules towards the sun
- Inverters to convert the DC energy from the solar modules to AC energy that is compatible with the electrical grid
    - Inverters also provide safety features, such as instantaneous shutdown when there is a power outage, as well as features to help ensure that the electrical grid operates in a safe and efficient manner
- Meteorological monitoring stations that collect and provide data to evaluate the solar plant's performance
- A substation to increase the AC voltage from the inverters to the appropriate voltage to allow the solar project to connect to the electrical transmission network
    - The substation also provides safety features to protect the solar plant and the transmission network; all large power generating plants have dedicated substations to provide an interface between the generator and the electrical transmission network
- Internal gravel roads to provide access to the inverters and other major system equipment
    - The remainder of the ground within the plant will be covered with low-growing vegetative species that could be determined in coordination with landowners and agencies to minimize dust and topsoil erosion

3.2 How Is a Solar Module Constructed?

The construction of solar PV modules is similar across the various technologies. A typical crystalline silicon PV module is approximately 6-1/2 ft (2 meters) tall and 3-1/4 ft (1 meter) wide and weighs about 60 pounds (27.5 kg).

A PV module is made up of small, very thin photovoltaic (solar) cells that are strung together with internal wires to collect the electricity. This collection of cells is laminated between sheets of ethyl vinyl acetate (EVA) encapsulant, covered with a layer of front glass and a back sheet (Tedlar), and sealed with a silicon-based edge sealant that secures the solar cells in an aluminum frame.

EVA is also used in different forms in helmets, flip-flops, foam rubber, soccer cleats, and running shoes while Tedlar is a product produced by Dupont that is used to provide a weather barrier for the back of the PV module. Tedlar is used in airplane interiors and whiteboard surface material and is used in the Phoenix Mars Lander as a bio-barrier.

A PVC junction box brings the power generated by the module to the outside, and two copper wires allow the module to be connected to the PV array.

An aluminum frame is typically installed around the edges of the PV module to provide protection from damage, to support the PV module, and to provide a method to mount the PV module to the tracker or fixed-tilt mounting structure. A junction box on the back of the module and external electrical wires allows the module to be electrically connected to other modules and to the inverter so that the absorbed solar energy can be converted to usable power.

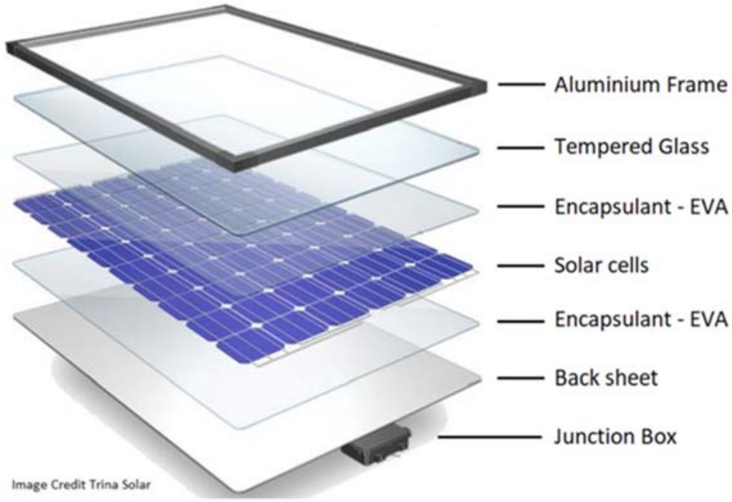

Figure 3.1: Parts of a Solar Module (Image Credit: Trina Solar)

A crystalline silicon PV module is approximately 76% glass, 10% plastic (polymer), 8% aluminum, 5% silicon, 1% copper, and small amounts of other metals, including silver, tin, and lead. The Reduction of Hazardous Substances (RoHS) Directive limits the use of hazardous materials in products and equipment. Many module manufacturers comply with this directive and have minimized the use of hazardous materials in their products.

3.3 What Is the Composition of Solar Modules?

There are two main types of solar modules currently used in PV plants: crystalline silicon modules and thin-film modules. Crystalline silicon PV modules make up 92.5% of the PV modules produced annually, and thin-film modules (cadmium telluride, copper indium gallium selenide, amorphous silicon, etc.) make up the remaining 7.5% [1]. Other types of solar modules are currently in development, such as organic PV cells that use carbon-rich compounds to convert sunlight to electricity and perovskite PV cells that are a type of thin-film module with a special crystal structure. As of mid-2021, organic and perovskite PV modules are currently only available in limited quantities for small demonstration and research projects.

3.3.1 What Are Crystalline Silicon Solar Cells?

Crystalline silicon solar cells are made from high purity silicon that is produced from quartz sand. The first step in producing these solar cells is to create silicon ingots drawn from molten silicon that are either a single large silicon crystal or an ingot that contains many large crystals. After the ingots cool, they are sliced into thin wafers that are then polished and infused with a thin layer of phosphorous to make the silicon into a light sensitive semiconductor. These cells then have metal contacts and wires added to collect the electrons freed by sunlight. The cells are then assembled into modules that have no moving parts and are sealed from the environment to prevent moisture from entering the module.

3.3.2 What Are Cadmium Tellurium (CdTe) Solar Cells?

The most common thin-film module currently in the market is the cadmium tellurium (CdTe) module. Thin-film modules are constructed by depositing the active solar material (CdTe) in thin layers on the front glass of a PV module. This material is typically just a few microns thick or about 1/10th the diameter of a human hair. Several different layers are deposited along with the CdTe to create the solar cell. Materials used in these types of cells include tin oxide and copper pastes to create the electrical connections between the cells. For comparison, the amount of cadmium used in a 1-square-meter solar module is less than the amount of cadmium in a typical C-cell NiCad battery.

3.4 How Do Solar Modules Work?

Solar panels work by collecting sunlight and converting it to electricity via the photovoltaic effect, which was discovered in 1839 by Edmond Becquerel. Certain semiconductor materials, most notably silicon, exhibit the photovoltaic effect, which allows them to generate electricity when exposed to sunlight. When a PV module is exposed to sunlight, photons of light interact with the semiconductor material, giving additional energy to electrons in the silicon. When connected to a circuit, these electrons flow from the solar modules through the electric circuit to where the solar energy is used. In most cases, this circuit would be the inverter that converts the DC electricity from the solar panels to AC electricity for distribution on the electrical grid. Alternatively, the DC electricity can be used directly to charge batteries or be used in an RV or off-grid cabin. After passing through the inverter or other loads, the electrons flow back to the solar cells to complete the electrical circuit.

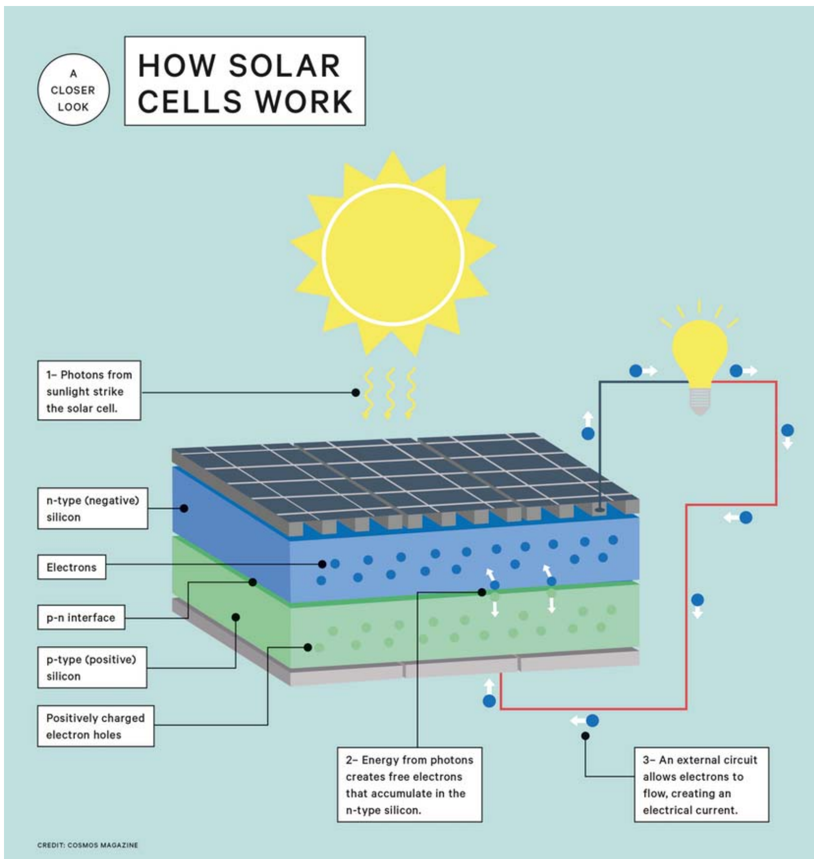

Figure 3.2: How a Typical Silicon Solar Cell Works

3.4.1 Are Solar Panels Toxic, and/or Do They Leech Toxic Materials into the Soil?

The composition of a crystalline silicon PV module is approximately 76% glass, 10% plastic, 8% aluminum, 5% silicon, and 1% other metals, including copper, silver, and tin. The European Union's Waste Electrical and Electronics Equipment (WEEE) directive of 2012 sets a target of 85% recovery target for electronic materials. Several recycling companies have claimed the ability to recover up to 95% of the materials used in PV modules [2] [3]. There are small quantities of lead used in the solder paste that connects the cells together. Toxicity Characteristic Leaching Procedure (TCLP) testing has shown that the lead used in the PV modules is encapsulated in the modules in such a way that there is no leaching of the lead into the surrounding environment under normal operating conditions [4]. Currently, crystalline silicon PV modules are approved for disposal in landfills. However, reuse and recycling efforts are underway to minimize the number of PV modules that end up in the waste stream. Recycling requires dismantling the panel in various ways through chemical, thermal, or mechanical methods to extract the various metals. Another method of dealing with end-of-life panels is incineration, which is the least environmentally friendly method next to exporting the panels to a landfill. Neither incineration nor landfilling recaptures any valuable material, and these methods are not considered to be viable final options for module disposal.

The National Renewable Energy Laboratory conducted a study that investigated the risks associated with the use of CdTe modules [5]. The study highlights the potential environmental health and safety (EHS) risks associated with CdTe modules in all phases of module construction and use. The study determined that the highest sources of risk were in the construction phase of the modules when the cadmium is present as feedstock in large quantities. The risk from the use of CdTe modules was determined to be nonexistent as the thin layers of CdTe are stable and encapsulated between two layers of glass, which are sealed from the environment to prevent water ingress. The study states, “Unless the modules are purposely ground to a fine dust, dust particles cannot be generated” [6]. The CdTe modules currently on the market and broken pieces of CdTe modules pass Federal (TCLP-RCRA) leaching criteria for non-hazardous waste, and such modules could be disposed of in landfills. However, the potential for hazardous material issues may increase as the number of modules nearing end of life increases significantly in coming years and as new module technologies are introduced to the market [7] [8]; thus, additional research should be conducted to address these issues. First Solar, the largest manufacturer of CdTe modules, has implemented a recycling plan to deal with their PV modules that are no longer useable [9] [10].

Regulations in the style of EU Directive 2012/12/EC on Waste Electrical and Electronic Equipment may be imposed in the USA as an effort to increase recycling and reduce waste from electrical and electronic equipment, and these regulations would include PV modules and inverters. These regulations include requirements for depollution and material extraction as well as fee requirements to fund these efforts. The State of California has just begun to consider these issues. Currently, Washington state is the only state in the USA that has regulations on recycling PV modules [11] [12].

In summary, up to 95% of the solar panel is recyclable, and the panel is composed of less than 1% of hazardous materials by mass in their manufacture. In normal operation, solar panels do not represent a significant hazardous materials risk. At the end of module life and/or when dealing with damaged panels, the lead and cadmium may represent a small level of hazard and should be treated accordingly. Currently, little regulatory guidance for the disposal of PV modules exists; however, this lack of regulation is expected to change as more PV modules reach their end of life.

3.5 Do Solar Modules Produce Reflection, Glint, and/or Glare?

Any glass surface with a light source directed towards it will reflect some light off the material’s surface. Reflections from light hitting the glass on PV modules can occur at any time of the day; however, reflections become more apparent when the sun is not directly over the modules, such as in the morning and evening. The intensity of the reflections depends on the positions of the sun and the observer relative to the solar modules. Reflections from light hitting any reflective surface can be also described in terms of duration as “glint” or “glare.” Glint describes a momentary flash of light from any reflective surface, and glare is considered to be a continuous source of excessive brightness. When left unchecked, glint and glare can cause ocular distractions and safety hazards under some circumstances [13].

Since solar modules must use the sunlight cast on them to generate electricity, solar manufacturers intentionally design the solar modules to minimize reflections and maximize absorption of sunlight. The glass on the front of a PV module has an anti-reflective coating applied to the surface that helps absorb light and direct it to the photovoltaic cell for conversion to electricity. For reference, PV modules are no more reflective than the water surface of a lake or pond or windows on a building. In addition, since the earth is continuously rotating, the sun appears to move across the sky at a constant rate, and sun reflection from a PV module will only affect a specific area for a relatively brief period of time.

Ground-mount solar generation plants often use tracking systems that tilt solar arrays to follow the sun and maximize solar energy capture. The trackers resultingly reduce reflections at angles that are not directed toward the sun since the trackers help maintain the solar panels at a position perpendicular to the sun's rays. For a single-axis tracking system, any glare that impacts terrestrial observers would occur in the early mornings with the panels facing east or in the late afternoons when the panels face west. However, single-axis trackers employ a backtracking algorithm that prevents the trackers from shading the row next to them in the early mornings and late afternoons. During backtracking, the modules will point more towards the sky than towards the horizon to help maximize energy gain, so their positioning reduces reflections.

PV modules mounted on fixed-tilt racking structures are designed to be oriented in a single direction and do not follow the sun through the day. These modules are generally mounted facing due south and have tilt angles between 10° and 30° above horizontal. Glare impacts from PV modules mounted in a fixed tilt racking system will move in consistent patterns over the year and depend on the orientation of the array, the location of the observers, and terrain in and around the solar plant. Effects of glare can be easily mitigated on a fixed tilt plant by including hedge rows and/or opaque fencing between the array and any affected observers.

3.6 How Is a Solar Plant Constructed?

The construction of a solar plant is similar to any large construction project. Due to the scale of a utility-sized solar project, the construction can employ up to 400 people and use standard construction equipment. Unlike many large construction projects, for a solar plant, much of the installation work, including installing tracker components, mounting PV modules, and wiring equipment, is done by hand. Some work, such as trenching for cables, driving foundation posts, and installing large equipment, such as inverters and transformers, requires larger equipment, including excavators, forklifts, and small cranes.

Construction permits obtained for a solar project typically detail dust mitigation measures, road use limitations, and required stormwater pollution prevention protocols. Construction of a large PV project takes approximately 12 to 18 months. Upon completion of the project's construction phase, the disturbed areas are typically graded and reseeded with grasses and other vegetative species, which can be determined in coordination with landowners and agencies.

A solar plant receives its fuel from the sun and is very low maintenance, so the sound and dust levels from conventional thermal power plants are not present. Once the solar plant begins operation, very little traffic occurs to and from the solar project.

3.7 What Does Solar Plant Operation Entail?

A typical solar plant operates autonomously, starting up when the sun rises and automatically shutting down when the sun sets. Little input from human operators is required for the day-to-day operation of a solar plant. If the plant detects a problem, it will shut down in a safe manner and send an alert to the operations center. In addition, large solar plants are monitored remotely 24 hours per day, 7 days per week to detect any operational issues or problems with the plant.

All medium and large solar plants have teams of technicians to maintain the plant and keep it operating at peak efficiency. Many of the tasks are described below.

3.7.1 What Maintenance Is Required?

Technicians will visit the site on a regular basis to clean air filters on the inverters, monitor the operation of the trackers, verify that the electrical components are functioning correctly, and perform minor repairs to the plant. In the event that an issue arises or an inverter or tracker stops working, a team of technicians will be dispatched to the plant to diagnose the cause of the problem and repair the equipment. The maintenance team works to minimize the time that the plant is not fully operational.

All equipment used at a project is either mechanical or electrical, and no chemicals need to be used or stored on-site. The tracker drive gears typically do not require any lubrication during their operational life due to the limited number of cycles that the drive system incurs. Mounting structures are inspected for rust and corrosion, and then touchup paint is applied where needed.

Visual inspections of the project are conducted on a regular basis to ensure that all the equipment at a PV project is functional, is in good condition, and is correctly and securely mounted. Any damaged equipment identified during these inspections is promptly repaired or replaced, and any loose equipment is securely fastened in place.

Annual thermal inspections of the electrical equipment are conducted to ensure that the equipment is functional and does not present a fire or safety hazard to the project.

3.7.2 Do Solar Plants Require Vegetation Management?

One of the main maintenance tasks at a solar plant is keeping the vegetation from interfering with equipment operation and shading over the PV modules. The construction of a PV project will disturb some of the areas within the plant, and these areas will require reseeding to prevent erosion. Most projects will reseed the site with local or pollinator-friendly plants as required in the environmental permits. In addition, many permits require the project operators to monitor the site and remove any invasive species that were introduced during the construction period.

There are several methods for managing vegetation, including planting low-growing species, facilitating mechanical removal using conventional lawn mowers and string trimmers, and using grazing animals. The use of herbicides is typically minimized and limited to the removal of noxious weeds. The use of herbicides at solar plants was found to be similar to herbicide use in agriculture [14].

Vegetation management is also important to minimize fire danger at a PV project. PV modules generate heat when they absorb sunlight, and dry vegetation in contact with the PV modules could become a fire hazard under the right conditions. The International Fire Code, Section 1205.5.1 requires a brush-free area around the PV array and a maintained vegetative surface below the PV array to minimize fire danger from dry brush.

3.7.3 Do Solar Plants Require Stormwater Management?

Stormwater collection systems are sometimes required at solar plants where ground water is prevalent. A hydrological study is done as part of the initial design phase of the plant to identify flood zones, water flow paths, and typical rainfall amounts. From the hydrological study, the location, size, and quantity of stormwater retention ponds are determined along with the location and size of any required drainage ditches. The retention ponds are designed in accordance with local, state, and federal regulations. The installation of solar modules affects the distribution of rainwater at a PV plant by collecting water along the edges of the solar modules. Local vegetation and proper vegetation management are used to minimize erosion at the site as erosion can adversely affect the project's mounting structures.

Toxicity Characteristic Leaching Procedure (TCLP) testing on PV modules has shown that there is no leaching of the materials used in the production of the PV modules into the surrounding environment. Runoff from solar modules typically contains dust, pollen, and residue from bird excrement but no toxic materials from the PV modules.

Maintenance for the stormwater management system typically consists of maintaining the vegetation around the retention ponds, cleaning the drainage ditches, and ensuring that erosion is not occurring within the plant or array field.

3.7.4 Are Solar Plants Safe?

The safety of a PV plant is achieved through proper system design that minimizes the exposure of plant workers to hazardous conditions through adherence to the National Electrical Code, the National Electrical Safety Code, and NFPA 70E, the Standard for Electrical Safety in the Workplace. All workers at a PV plant are trained on appropriate safety procedures and required to wear personnel protective equipment (PPE).

A solar project is surrounded by a fence to limit access to the plant and access to electrical equipment. Lighting of a PV plant is limited to the project's substation and the operations and maintenance building for the projects. After sunset, there is little sound or activity at the solar facility. There are typically no lights around the facility; the only lights that would be used at the site provide safety illumination at the facility's substation and at the entrance to the operations and maintenance building. The lighting can be installed to minimize glare outside of the intended areas.

3.7.5 What Is the Downside of Solar?

UL believes solar is one of the cleanest and most cost-effective sources of electricity. However, every source of energy has tradeoffs, and solar is no different. Compared with other sources of energy, solar requires a relatively large area to produce electricity at the scale needed to power society. Nevertheless, the land is not permanently altered like it is in mining or gas extraction, and the land can be returned to farming or other beneficial use after the solar facility is removed. Furthermore, the solar resource will never run out and leave behind an economic void in communities.

3.7.6 Do PV Modules Require Cleaning?

A PV plant relies on converting sunlight to electricity through glass-encased solar cells. The glass on the front of the modules must be kept clean and free of debris to allow the PV modules to operate at maximum efficiency. In the eastern portion of the United States (east of the Mississippi River), many projects rely on rainwater and snow to keep the modules clean.

In the western USA where dust is an issue as well as in areas with excessive pollen accumulation, projects find that module washing is sometimes necessary. There are many methods for cleaning the modules, including water hoses, compressed air, robotic cleaners, and tractor-mounted cleaners with brushes and water sprays. Typically, compressed air is used to blow the dust from the modules, or the modules are cleaned with distilled or deionized water. In some cases, a special cleaner is used on sections of the PV array to remove pollen, soot, or other sticky substances. The material safety data sheet (MSDS) for a popular PV module cleaner indicates that the solutions are non-flammable, are nontoxic, and do not have any usage restrictions [15]. Many of the solutions contain less than 3% alcohol by weight and are considered to be biodegradable [15].

3.8 What Is the Energy Recovery Period for a PV System?

Studies performed by NREL in Colorado and the Fraunhofer Institute in Germany in mid-2000s show that the energy recovery period for complete PV systems is between 1 and 4 years depending on project location, project type, and selected equipment. In other words, a large PV project takes between 1 and

4 years to generate the equivalent amount of energy that was required to fabricate the components and construct the project. Since many PV projects are projected to operate for 25–35 years, the energy consumption is offset fairly early on in the project's lifetime, leading to a generation advantage compared to many other technologies.

3.9 How Loud Is a Solar Project?

Solar projects do make sound; however, the sound levels produced from solar projects are lower than many typical daytime activities and are significantly reduced at night. A well-designed layout for a solar project can minimize any sound heard at the edges of the plant.

The sound that is generated by a solar project is mainly from the switching devices in the inverters and the cooling fans both in the inverters and on the main power transformer. Other system components, such as tracker drive mechanisms, can make sound; however, the sound level from other system equipment is typically much lower than the sound levels generated by the inverters.

Inverter manufacturers report that the sound levels around inverters are typically less than 67 dB(A) when measured 33 feet from the inverter. This sound level is comparable to the sound level of an office and less than the sound level inside a typical automobile [16].The perceived sound levels from the inverters drops by a factor of 4 (6 dB(A)) for each doubling of distance from the specific inverter.

The sound levels from the main power in the substation coincide with the sound levels from the PV inverters. During the mid-afternoon period, the sound levels will be at their maximum and will taper off as the sun sets. The sound levels generated by the main power transformer and the substation equipment are similar to those generated by the inverters, are in the 65 dB(A) to 70 dB(A) range within the substation, and are typically less than 57 dB(A) at the edge of the substation [17]. A sound level of 57 dB(A) is comparable to the sound level of a normal conversation [16].

The PV system and substation can be designed to minimize sound levels at the solar plant's perimeter fence and to meet local and state sound ordinances.

3.10 Do Solar Projects Work in the Cold?

Successful solar projects are installed around the world in various climate zones, including the far north. For example, Germany has the fourth largest solar energy fleet size relative to other countries even though it is further north than most of the United States and has a sunshine level similar to Alaska's [18] [19]. In terms of temperature, solar modules and electrical equipment, such as conductors, perform more efficiently in cold temperatures than in hot temperatures. This phenomenon occurs because the panels and other equipment experience less heat loss at cold temperatures than at warm ones. The cooler temperatures result in minimal temperature impacts compared to sites in hot desert climates, where temperatures could result in a 5–10% loss in energy.

While PV panels perform more efficiently in cooler climates, impacts from snow can occur in the winter months. When the panels are partially covered with snow, they do not produce much energy. Snow does occur in many locations where solar PV projects are developed as solar development is occurring in some of the United States' snowiest states, including New York, Massachusetts, and New Jersey [19]. In practice, at solar generation sites, snow tends to melt or slide off PV panels fairly quickly and can clear some sediment off the solar panels when it slides off [20]. This effect is especially true for tracking PV arrays that can turn to avoid snow buildup and to assist with sliding, allowing the arrays to shed the snow more readily—usually within a day or so of a snow event. Smaller snow events with little accumulation are unlikely to result in any substantial loss. A fraction of the sunlight hitting snow on solar panels can also shine through the snow in some cases and allow the panel to generate electricity [19]. As a result, snow-related losses can be kept to a minimum at most locations with snow. In addition, snow on the ground surrounding exposed solar panels can increase energy output due to increased irradiance levels via sunlight reflecting off the snow [21].

3.11 What Happens if a Tornado or Other Natural Disaster Spreads Shattered Solar Panels onto Neighboring Properties?

Modern solar panels are made to meet strict environmental policies; therefore, the broken pieces of the solar panel do not pose a health risk to those in the area or an environmental risk to the land as discussed in Section 3.4.1.

The Rocky Mountain Institute (RMI) commissioned a study of PV systems installed in the Caribbean after the 2017 hurricane season and concluded that well-designed solar projects can and have survived impacts from category 5 hurricanes. The RMI released a report [22] that provides guidance to system engineers on best practices for designing PV systems that will be subjected to high winds. UL worked on several recovery projects in the Caribbean after the 2017 hurricane season and notes that there were many systems that survived direct hits from two category 5 hurricanes within a two-week time span. Several modules were torn from their mounting; however, due to their weight and the size of the PV plant, the modules did not leave the boundaries of the project. Modules did sustain broken glass; however, due to the methods of module construction, that broken glass was bonded to the solar cells as discussed in section 3.2 and to the module backing and was not disbursed around the plant.

Solar facility owners have many layers of insurance policies covering their projects. For incidents like tornados or other acts of God, during construction, the general contractor has a comprehensive builder's all-risk policy in place that covers the full cost of repair to the project. During operations, the owner will replace the builder's all-risk insurance with all-risk property insurance that covers casualty events. In addition, the owner will have business interruption insurance that covers the cost to the owner for loss of revenue during the downtime of the facility. Owners will also have commercial general liability insurance that covers property damage or bodily injury to third parties, workers compensation and employer's liability policies, pollution liability, auto liability, and an additional umbrella/excess policy for additional coverage for claims in excess of the primary CGL policy. These insurance policies (and others) are required by lenders, tax equity investors, and off-takers (power purchasers). Tax equity investor agreements often include clauses requiring the project to be rebuilt after a casualty event to avoid the recapture of the Investment Tax Credit that would occur if a project is not rebuilt during the period when the Investment Tax Credit is earned after the project is placed in service.

3.12 Are There Environmental Concerns for Solar PV Plants?

Solar projects are typically sited to reduce potential impacts to existing environmental resources, such as forested areas and wetlands/waters. Preconstruction studies are typically conducted to identify resources that are present; potential impacts; and avoidance, minimization, and/or mitigation measures that should be implemented to address impacts. Environmental studies conducted for solar projects may include wetland delineation, floodplain review, cultural resource studies, visual and noise impact studies, and Phase I environmental impact assessments.

Solar projects are required to obtain state/federal permits or operate under an existing programmatic permit for construction-related impacts to wetlands/waters, floodplains, and stormwater, which will require related avoidance, minimization, and/or mitigation measures. Solar panels are typically sited outside of wetlands, water, and floodplain areas, and projects are able to avoid significant impacts to these resources. Depending on impacts, projects may be required to minimize or mitigate impacts, or projects may do so voluntarily as a best practice. A typical solar project plans to avoid or minimize impacts to water resources and may include a Vegetation Restoration Plan; Stormwater Pollution Prevention Plan; and Spill Prevention, Control, and Countermeasure Plan in addition to other specific permitting requirements.

PV plants can be operated to limit or eliminate the use of toxic chemicals. Typically, vegetation management (Section 3.7.2) is conducted by mechanical means (string trimmers and conventional lawn equipment), is limited by planting low-growing vegetation, or employs grazing animals to maintain the vegetation at a low height. If used, herbicide use is typically minimized and limited to the removal of noxious weeds. Vegetative species and herbicide use can be coordinated with the landowners and agencies. Electrical transformers used within the PV plant are either “dry-type” transformers that use forced air to cool the transformer or oil-filled transformers that are available filled with mineral oil or “FR-3” oil, both of which are considered to be environmentally friendly and nontoxic.

3.13 Are There Wildlife Impacts from Solar Projects?

Solar projects are typically sited in agricultural areas with lower-quality wildlife habitat, and these projects are sited to reduce potential impacts to higher-quality habitats located at the project site, such as forested or riparian areas. Preconstruction studies are conducted to identify resources that are present; potential impacts; and avoidance, minimization, and/or mitigation measures that should be implemented to address impacts. Wildlife studies conducted for solar projects may include species presence/absence surveys and habitat assessments.

Solar projects are often able to avoid significant impacts related to protected species and associated habitats via siting and project design, which allow the projects to avoid identified sensitive or higher-quality habitat areas. Depending on the extent of impacts, projects may be required to minimize or mitigate impacts or may do so voluntarily as a best practice. Typical solar project plans that avoid or minimize impacts may include a Wildlife/Habitat Management Plan, Vegetation Restoration Plan, and Landscaping/Screening Plan.

Once operational, solar projects do not cause significant wildlife impacts. During construction, solar projects are usually able to implement measures to avoid impacts to protected species and avoid a federal or state incidental take permit.[1] Additionally, solar projects are often located in agricultural areas, which generally provide limited suitable protected species habitat, or industrial areas, which provide no habitat. However, habitat impacts may occur, and projects may be required or may volunteer to avoid/minimize or mitigate construction impacts. Species/habitat impact avoidance may include preconstruction clearance surveys, construction timing restrictions, biological monitoring during construction, and/or construction activity avoidance buffers. Informal discussions with the US Fish and Wildlife Service and the state wildlife agency are conducted to help identify species concerns, recommended studies, and recommended avoidance and minimization measures.

3.14 Do Solar Projects Have Permanent Impacts on the Landscape?

A solar plant has a minimal impact on the land where it is installed throughout the life of the project. The PV modules are mounted on trackers or racking structures that are elevated above the ground and that allow light to reach the ground below the modules. This light encourages the growth of local vegetation, which enriches the soil and prevents erosion. The current industry trends are to use bifacial PV modules which generate electricity from both the front and backsides of the modules. It is in the developer’s interest to maintain local vegetation under and around the PV modules to maximize the energy capture from the backside of the modules.

Since a solar plant uses sunlight for fuel, there are no fuel storage facilities and no fuel delivery terminals at a solar plant. The operation of a solar project (as described above in Section 3.7) requires minimal input, and typically, the only activities at a solar project are the regularly scheduled maintenance or the

[1] An incidental/eagle take permit is issued typically by USFWS, but some states also have take permits. A take permit allows a specified amount of “incidental take” or killing/injuring of a protected species. Typically, take permits are long, expensive processes that require development of a conservation plan that includes long-term compliance monitoring and compensatory mitigation.

maintenance required to repair equipment. Waste management plans are implemented by the project operator to appropriately recycle and dispose of used equipment.

There are no toxic or otherwise harmful impacts on the land after a solar project has been decommissioned according to industry best practices, including full removal of all solar facility equipment.

Temporary construction-related ground disturbance, vegetation, and water resource impacts can be restored following completion of construction. Longer-term ground disturbance, vegetation, or water resource impacts that were required for operation can be fully restored as part of decommissioning.

3.15 What Does the Decommissioning of PV Systems Entail?

A PV system that has reached the end of its useful life can be dismantled, and the site can be returned to its prior use. Much of the material in a PV system can be recycled or reused. The steel, copper, and aluminum, which are used to support the PV modules and equipment, comprise the major components, and carry the power from the modules to the grid, can be recycled. The PV modules can be sold on the secondary used market or recycled. As mentioned in section 3.4.1, up to 95% of PV module can be recycled. There are currently 16 companies in the USA that recycle solar modules. There is also a thriving market for used modules in rural and off-grid systems.

All equipment can be removed from the PV project site, and the area can be easily returned to its original use. Unlike parking lots and industrial sites, very little earth moving is undertaken prior to installing a PV system beyond grading for access roads and inverter pads and leveling small areas with steep slopes. Topsoil is left in place, and grass is encouraged to grow in the array field to minimize dust and erosion.

A solar project typically has trenches for electrical cables, concrete foundations for inverters and maintenance buildings, and steel piles for PV module mounting systems. The access roads within a PV project are gravel or unimproved dirt tracks for maintenance vehicles. Once a project has reached its end of life, all the PV equipment can be removed, and the equipment can be recycled or reused. The concrete foundations can be broken up and trucked off-site for use as fill elsewhere, and any gravel roads can be removed and reseeded with local vegetation. The ground below the PV modules has typically been maintained to promote the growth of desired local vegetation, which has the benefit of enriching the soil and minimizing erosion.

3.15.1 How Does Solar Panel Recycling and Landfilling Work?

During the decommissioning of the solar plant, the panels are separated from the other materials, such as the support structures, and stockpiled for further disposition. There are several companies within the USA that offer recycling. The stockpiled panels can be sent to these facilities, where the materials in the panels are separated and recycled. There are metals in the frame and the wiring as well as silicon and glass. Up to 95% of the total solar panel can be recycled. The other option for solar panel disposal is to send them to a landfill. Only modules that pass health risk tests can be sent to a general landfill. However, as mentioned before in section 3.4.1, modern modules (those made after 2000) already meet strict health safety policies and are eligible for burial in a landfill.

3.15.2 Can Solar Projects Be Farmed after Project Decommissioning?

Unlike residential developments, shopping malls, or industrial plants, solar farms require very little land preparation and are composed of mostly permeable surfaces. Grading and earth moving are limited to access roads and inverter pads. Low-growing vegetation is encouraged to grow to keep the topsoil in place and to prevent erosion. A small percentage of land at a project site (typically less than 0.25%) is used for access roads and inverter pads, but the large majority of a project is covered by PV panels mounted on steel posts above groundcover vegetation. As part of decommissioning, all project components, including PV panels, posts, electrical lines, roads, and inverter pads, are removed, and farming activities may resume as they were before the solar project.

3.16 Are Solar Panels Made in America?

Although a majority of the panels on the market are foreign made, there are a few American solar companies with manufacturing plants in the USA. Solar module companies, including First Solar, SunPower, Tesla, and LG Solar USA, have facilities in the United States [23]. In addition, some of the foreign companies, including Jinko Solar and Hanwha Q-Cells, have opened manufacturing plants in the USA. Other manufacturers are in the process of siting and constructing module factories in the USA.

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