OHIO DEPARTMENT OF HEALTH
SOLAR FARM AND PHOTOVOLTAICS
SUMMARY AND ASSESSMENTS

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Introduction

The Ohio Department of Health's (ODH) role in the Ohio Power Siting Board has historically been to assess cases to determine whether the construction, alteration, operation, or decommissioning of any power-generating structure or facility will have an impact on the health and wellness of the public. ODH works in partnership with fellow state agencies, including the Ohio Department of Natural Resources (ODNR), which assesses ecological impacts, and the Ohio Environmental Protection Agency (OEPA), who is responsible for environmental licensing and regulation, to provide a robust, holistic assessment.

The purpose of this ODH document is to assess, based upon existing research, whether solar farms and photovoltaic technologies have the potential to cause harm to human health. ODH has developed this document at the request of the Ohio Power Siting Board in response to an increase in the construction of new solar power facilities in Ohio.

The determinations within this document were made based upon a review of literature available at the time of its original publication. As scientific information changes over time, and as photovoltaic technologies and the landscape of solar energy within Ohio changes, ODH will reevaluate these conclusions as needed. ODH did not conduct independent, peer-reviewed research to produce this document.

Crystalline Silicon

Photovoltaic (PV) technologies convert sunlight into energy using conductive materials. PV panels are also called solar panels.

A form of the element silicon known as crystalline silicon (c-Si) is the most common semi-conductor used in the construction of PV panels accounting for 95% of PV panels sold worldwide and is the second-most ubiquitous element on Earth after oxygen. The c-Si used in PV panels is harvested through the processing of silica (SiO2, also known as silicon dioxide or sand) to remove the attached oxygen molecule. The refined c-Si is converted to a PV cell by processing further with small amounts of boron and phosphorus, which are not generally toxic to humans (NC Clean Energy Technology Center, 2017).

While c-Si itself is benign and non-toxic, there may be some toxic trace elements in c-Si-based PV panels. Particularly in older models, a tin-based solder containing a small amount of lead (Pb) may be used in the panels' construction. Lead has long been known to be toxic to humans, and long-term exposures have been known to cause adverse neurological, renal, cardiovascular, hematological, immunological, reproductive, and developmental effects, especially in children (ATSDR, 2020). However, the amount of lead in a PV panel is generally very small (13 grams per panel, or roughly one-half of the lead contained in a typical 12-gauge shotgun shell or 1/750th of the lead contained in a single car battery), and many manufacturers have moved to using lead-free solder (NC Clean Energy Technology Center, 2017).

Additionally, because of the construction of c-Si-based PV panels, the general public is not likely to come into direct contact with the c-Si compound nor any of the solder from a solar farm. A typical c-Si-based PV panel consists of a nonreactive backing (typically aluminum), a lower layer of an encapsulant (typically a plastic acetate), the c-Si cells, an upper layer of encapsulant, and a thick sheet of glass, all completely surrounded by an aluminum frame. This design ensures that the cells and solder are completely encapsulated and protected from rain and other elements that might corrode or damage them, and also means that the general public would not come into contact with any potential toxic elements contained in the panel unless the construction was purposefully ground into a fine dust (National Renewable Energy Laboratory [NREL], 2020).

No emissions of any kind can be generated when using PV panels under normal conditions (NREL, 2003). As an added layer of protection, most ground-mounted, large-scale arrays are enclosed by fencing to prevent the general public and trespassers from coming into contact with the installations, thus preventing unsafe situations (Massachusetts Department of Energy Resources [MassDEP] et al., 2015).

See below for discussion on **PV End of Life Disposal and Storage**.

Summary and ODH Assessment: Information to date does not indicate a public health burden from the use of crystalline silicone (c-Si) in solar farms which are operating under normal conditions. Crystalline silicone itself is nontoxic to humans. While there may be some hazardous chemicals used in the construction of a PV panel, there is not likely to be a completed exposure pathway to the general public given the fact that these substances would be fully encapsulated by non-toxic, nonporous substances like glass and, therefore, are not likely to enter the environment. Fencing around large ground-mounted installations will help prevent contact from trespassers.

Cadmium Telluride

Cadmium telluride (CdTe) is used in thin-film solar cells which form PV panels. Thin-film solar cells are made by depositing a semiconductor material on a supporting material, such as glass or plastic. Although crystalline silicon is used in approximately 95% of PV panels sold today, CdTe is the second-most common material, representing approximately 5% of the world market (Office of Energy Efficiency & Renewable Energy [EERE], n.d. b).

Cadmium, in pure elemental form, is a toxic heavy metal. Acute inhalation exposure to high levels of cadmium can damage the lungs. Eating food or drinking water contaminated with high levels of cadmium can lead to stomach irritation, vomiting, and diarrhea. Long-term exposure to lower levels of cadmium in air, food, or water leads to a buildup of cadmium in the kidneys and possible kidney damage or disease. Cadmium is classified as a carcinogen by the U.S. Department of Health and Human Services (DHHS) and by the International Agency for Research on Cancer (IARC), and as a probable carcinogen by the US EPA (Agency for Toxic Substances and Disease Registry [ATSDR], 2012a).

Cadmium telluride is an inorganic compound formed of cadmium and tellurium. Limited data exists on CdTe toxicology, but it is known to be more stable and less soluble than pure cadmium and is likely less toxic than pure cadmium. Additionally, due to CdTe's high melting point, typical residential fires which burn in the range of 800°C – 900°C are not hot enough to vaporize CdTe which has a melting point of 1041°C with evaporation starting at 1050°C (NREL, 2003). This renders CdTe much more heat resistant than cadmium which has a melting point of approximately 321°C and a boiling point of approximately 675°C (ATSDR, 2012b).

As with c-Si-based panels, because of the construction of CdTe-based PV panels, the general public is not likely to come into direct contact with the CdTe compound from a solar farm. Most CdTe layers in PV panels are about 1 – 3 microns thick; approximately 3 to 9 g/m^2 cadmium is contained in a typical CdTe-based PV panel with an average of 7 g/m2 per panel, which is less cadmium than is found in a C-sized NiCd rechargeable battery (NREL, 2003). In addition to the amount of CdTe actually used in PV panels being relatively small, the surface containing CdTe is fully encapsulated or "sandwiched" between a non-toxic aluminum backing and thick glass (or plastic) panes (Office of EERE, n.d. a), meaning that direct contact with the cadmium compound is not possible unless a panel is purposely ground into a fine dust. No emissions of any kind can be generated when using PV panels under normal conditions (NREL, 2003). As an added layer of protection, most ground-mounted, large-scale arrays are enclosed by fencing to prevent the general public and trespassers from coming into contact with the installations, thus preventing unsafe situations (MassDEP et al., 2015).

See below for discussion on **PV End of Life Disposal and Storage**.

Workers in PV panel production facilities and other industrial processes using CdTe are more likely to be exposed to cadmium and its compounds through contaminated air and by accidental ingestion from hand-to-mouth contact than the general public. The National Institutes of Health, in its Laboratory Chemical Safety Summary for CdTe, classifies CdTe as an irritant and issues the Warnings "Acute toxicity, oral", "Acute toxicity, dermal", and "Acute toxicity, inhalation" (NCBI, n.d.). Note: "Warning" and "Danger" are signal words used to indicate the relative level of severity of a hazard for a given chemical. "Warning" is considered to be less severe than "Danger" (Occupational Safety and Health Administration [OSHA], 2013).

Summary and ODH Assessment: Information to date does not indicate a public health burden from the use of cadmium telluride (CdTe) in solar farms operating under normal conditions. While more information is needed to understand the toxicity of CdTe, there is not likely to be a completed exposure pathway to the general public given the fact that the small amount of CdTe used in the PV panels is fully encapsulated by non-toxic, nonporous substances like glass and, therefore, is not likely to enter the environment. Security measures such as fencing around large ground-mounted installations will help prevent contact from trespassers.

There is a higher health risk for workers in facilities that use CdTe for manufacturing or processing. Employers should follow OSHA and National Institute for Occupational Safety & Health (NIOSH) regulations for providing personal protective equipment to workers and for maintaining a healthy workplace.

Photovoltaics (PV) End of Life Disposal and Storage

An average PV panel will last for 20 to 30 years after initial installation, after which it will be decommissioned for reuse, recycling, or landfill disposal (MassDEP et al., 2015). For those indicated for landfill disposal, there is ongoing discussion about whether PV panels should be classified as hazardous or non-hazardous waste.

Internationally, to determine whether a PV panel should be classified as hazardous or non-hazardous waste, the results of leaching tests are heavily relied upon (International Renewable Energy Agency [IRENA], 2016). These tests are designed to observe how crushed or broken pieces of PV panels behave when submerged in a liquid for a defined period of type, after which the liquid can be tested to determine whether any toxic chemicals are "leaching" from the fragments into the liquid. According to the Federal Resource Conservation and Recovery Act (RCRA), most modern PV panels pass a test known as the Toxic Characteristic Leaching Procedure (TCLP), a test designed to simulate landfill disposal and determine the risk of leaching of hazardous materials (e-CFR, 2021; NC Clean Energy Technology Center, 2017). Additional research from Japan has also indicated that, even following catastrophic events including earthquakes, fires, and tsunamis causing damage to PV panels, it is unlikely that cadmium leached from CdTe-based panels will cause increases in air and seawater levels high enough to exceed environmental regulation values (Matsuno, 2013).

However, it is possible that some types or brands of PV panels will be considered hazardous wastes while others will not. Some older silicon-based panels may have been produced using lead or hexavalent chromium. Simply knowing that the PV panel is crystalline silicone- or CdTe-based is not an indicator of whether or not the panel should be considered a hazardous waste without conducting testing (DEPARTMENT OF TOXIC SUBSTANCES CONTROL [DTSC], 2021).

As an alternative to disposing of PV panels in landfills, decommissioned panels may be either recycled or repaired/refurbished and reused. According to the National Renewable Energy Laboratory, reusing modules is conceivable, but practically and economically challenging, and recycling processes for thin-film PV and crystalline silicon-based PV panels remains underdeveloped in the US. However, recycling PV panels allows for the recovery of both precious and toxic materials used in PV panels, including glass, metals and semiconductor materials which may lower the environmental burden of extracting and refining new mineral resources (NREL, 2019).

Summary and ODH Assessment: To prevent public health risks, ODH recommends that solar panel end of life disposal and storage plans be considered during the application and review process for new solar farms, and again during the decommissioning of solar farms. The determination of whether a solar panel is to be classified as hazardous or non-hazardous waste should be carried out on a case-by-case basis for each solar farm or array undergoing decommissioning.

Regardless of whether a panel marked for decommissioning is to be considered hazardous or non-hazardous, ODH recommends that retired panels marked for disposal be sent to an engineered landfill with various barriers and methods designed to prevent leaching of materials into soils and groundwater.

Both recycling and reusing panels (with or without repairing/refurbishing) will help to keep panels and potential hazardous materials out of landfills and creates less demand for the extraction and refining of new mineral resources which may have ecological and subsequent public health impacts. More research is needed to fully understand the benefits of recycling solar panels.

Heat

Recent studies have shown that large-scale solar arrays may increase surrounding ambient air temperatures by as much as 4°C* when compared to more distal air temperatures (Barron-Gafford, G. et al., 2016). This phenomenon is known as a photovoltaic heat island effect. These heat islands appear to be relatively localized to the solar arrays with temperatures cooling to ambient temperature around 300 meters from the perimeter of the array. Additionally, complete cooling of the array at night as well as the presence of buffers such as access roads and shade trees around the perimeter show some protective qualities against the heat island phenomenon (PV Environmental Research Center, 2013). Heat islands are less likely to occur with smaller solar arrays and single panel installations.

*(*Note: The study where an increase of 4°C was observed was conducted in an arid desert region of Arizona, which receives significantly more sunlight and achieves higher ambient air temperatures annually than any region of Ohio, which is largely classified as a humid continental climate and receives significantly more rainfall annually, and thus more cloud cover and reduced sunlight. Solar arrays in Ohio would not be likely to generate as much of a temperature increase due to these factors.)*

Detriments from the heat island effect, if any, are more likely to be ecological in nature. ODH defers to the Ohio Department of Natural Resources and Ohio Environmental Protection Agency for ecological issues.

Summary and ODH Assessment: Information to date does not indicate a public health burden from heat generated by PV panels or from the heat island effect. ODH encourages sufficient setbacks of large-scale solar farms from residential structures to ensure any excess heat generated by PV arrays dissipates. The installation of perimeter access roads and shade trees may also provide some additional protective qualities.

Glare

Because the purpose of PV panels is to trap sunlight, and any sunlight reflected means it cannot be converted into energy, PV modules are purposefully designed to reduce glare using anti-reflective glass (NREL, 2018b). PV panels reflect only about 2 percent of incoming light, so glare from PV modules is rare, and pre-construction modeling can ensure that placement prevents glare. Any light reflected from PV panels will have a significantly lower intensity than glare from direct sunlight reflecting on water or window glass since the vast majority of the incoming light will have been absorbed (MassDEP et al., 2015).

Summary and ODH Assessment: Information to date does not indicate a public health burden from glare caused by solar farms which are operating under normal conditions. Research indicates that glare generated by solar farms is no more than that which is generated by windows and calm bodies of water.

ODH recommends that, when siting for the construction of a solar array, pre-construction modeling should be completed to ensure that the panels are placed such that glare is minimized for surrounding residents and businesses.

Noise

Some components of a solar farm produce noise.

The noisiest component of a solar farm is the inverter which generates a low buzzing sound as it converts the electrical current. PV panels equipped with trackers, which allow the panels to move to "track" the sun across the sky, may also make noise, although fixed panels without these trackers will not include this noise. At utility-scale sites, sound levels along the fenced boundary of solar arrays are generally at background levels with only a faint inverter hum audible. Any sound from the array and equipment is inaudible 50 feet from the boundary (Massachusetts Clean Energy Center [MassCEC], 2012). Studies performed in other cases have found that the cumulative sound produced by transformers and inverters in addition to onsite substations were still well below local restrictive nighttime noise standards (Department of Planning and Land Use [DPLU], 2011).

Some noise will occur during the construction phase of a new solar farm or solar array. This noise is expected to be typical construction noise (i.e., heavy machinery, land grading, etc.) and is temporary and unavoidable. The noise generated during the construction of a solar array is expected to be much louder than the noise generated during its typical operation (DPLU, 2011).

Additionally, there may be some amount of noise generated by the upkeep and maintenance of a solar farm, but these are expected to be standard community levels of sound (i.e., lawnmowers, string trimmers or "weed whackers", etc.) (NREL, 2018a).

Summary and ODH Assessment: Information to date does not indicate a public health burden from noise generated by the typical operation and maintenance of a solar farm. While some noise is anticipated and unavoidable, it is not expected to create off-site health issues.

The inclusion of setbacks from residential areas should help ensure any noise generated by the solar farm has reached ambient levels by the time it nears a residential structure.

ODH recommends that, during construction, operation, and maintenance, state and local construction noise and noise pollution ordinances should be adhered to.

Electromagnetic Fields (EMF)

Non-ionizing, low-frequency electromagnetic radiation, also known as an electromagnetic field (EMF) may be generated by certain components of solar farms, including power lines. However, based on available peer-reviewed literature to date, there are no known health risks that have been conclusively demonstrated to be caused by living near high-voltage power lines.

For more information about EMFs, review the separate document **OHIO DEPARTMENT OF HEALTH ELECTROMAGNETIC FIELDS (EMF) SUMMARY AND ASSESSMENTS**.

Summary and ODH Assessment: Information to date does not indicate a public health burden from EMFs generated by components, including power lines, at solar farms.

Battery Storage

Energy produced by photovoltaic technologies may be stored in batteries for later offsite use. There are a wide number of battery technologies available today, including lithium ion batteries, lead acid batteries, and sodium sulfur batteries. Toxicity of these batteries varies based upon their design and the chemicals used.

For more information about batteries, review the separate document **OHIO DEPARTMENT OF HEALTH BATTERY ENERGY STORAGE SUMMARY AND ASSESSMENTS**.

Summary and ODH Assessment: Information to date does not indicate a public health burden from the use of most types of batteries under normal operating conditions. Additionally, fencing around large, ground-mounted installations will help prevent contact from trespassers. The toxicity of batteries varies based upon their chemical design and should be considered prior to disposal.

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