HEALTH AND SAFETY ASSESSMENT REPORT

Morven Solar

80 MW_{AC} Photovoltaic Facility

Brooks County, GA

ABSTRACT

This is an assessment of the potential health and safety impacts of the proposed 80 MW_{AC} Morven Solar photovoltaic facility in Brooks County, GA and considers the project design, equipment specifications, and operations, the assessment evaluates potential positive and negative impacts on public health and safety. The conclusion of the assessment is that the Morven Solar project will not create negative health and safety impacts. The clean electricity the project will produce will help to reduce the burning of fossil fuels, which will reduce pollution from those sources and provide millions of dollars' worth of local public health benefits as a result.

Tommy Cleveland

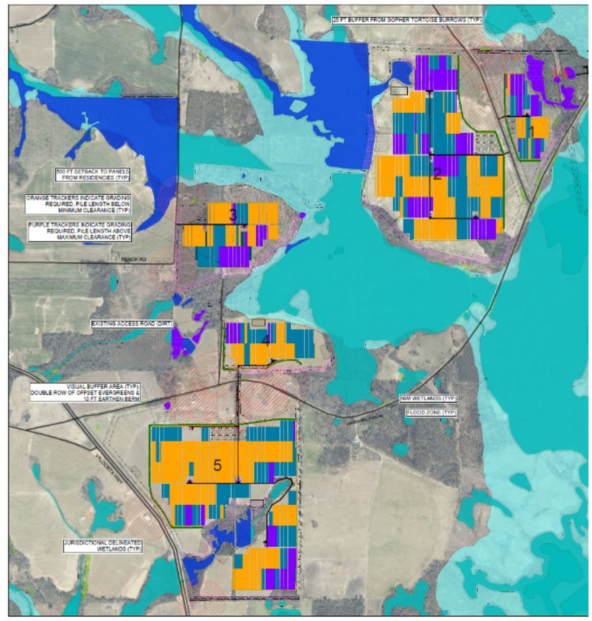
Solar Health and Safety Expert

February 6, 2023

Health & Safety Assessment Report

Morven Solar
Brooks County, GA

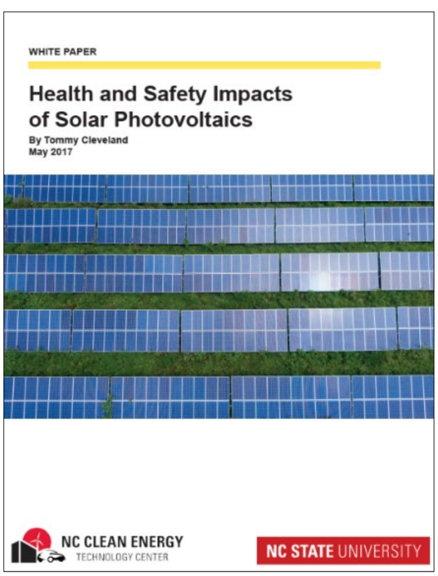
Project Overview:



- **Project Name:** Morven Solar
- **Developer**: Pine Gate Renewables
- **Capacity**: 80 MW_{AC} (~112 MW_{DC})
- **Project Area**: ~940 acres (property lease area), ~603 acres (proposed disturbed area)
- **Solar Panels**: crystalline silicon modules: Canadian Solar BiHiKu5 Mono modules, or equivalent
- **Structure**: single-axis trackers (~North-South rows, slowly rotate East to West each day)
- **Inverters**: central station type (~2 to 4 MW each): Sungrow SG3600UD_MV, or equivalent
- **Point of Interconnection**: Georgia Power 230 kV transmission line passing through the northwest corner of the project area
- **Interconnection Equipment**: 230 kV/34.5 kV project substation and interconnection facilities located near Georgia Power transmission lines in northwest center of the project

Report Author

The author of this report is **Tommy Cleveland** (the "Author"), an expert in solar energy and its community impacts, based in Raleigh, North Carolina. Mr. Cleveland graduated from North Carolina State University ("NC State") with undergraduate and master's degrees in mechanical engineering, where he focused on energy. His solar career started with his master's thesis, which led to working over 12 years at the North Carolina Clean Energy Technology Center at NC State University. While at the university, Tommy worked on nearly every aspect of solar energy; from teaching, to testing equipment, to research & development, to leading a statewide stakeholder group in the development of a template solar ordinance. During his time at NC State, North Carolina became the state to install more photovoltaic ("PV") capacity than any state other than California, mostly in the form of 2-5 MW_{AC} utility-scale solar facilities covering around 40 acres each. Utility-scale solar was unfamiliar to the hundreds of communities around the state where the systems were proposed, and many of those communities had questions about the technology and its potential to harm public health or the environment in their community. Many of those questions found their way to Mr. Cleveland and he expanded his already broad knowledge of PV to research and find answers to the questions being asked. Over time he became an expert on the potential health and safety impacts of PV and was the lead author of the 2017 NC State white paper on the topic (pictured to the left). Since mid-2017 Mr. Cleveland has worked as a solar engineer at an energy engineering firm conducting interconnection commissioning of utility-scale solar and battery facilities for utilities in North and South Carolina. In this role Mr. Cleveland was the engineer responsible for (interconnection) commissioning over 60 PV sites and 4 battery sites. Mr. Cleveland has been licensed as a professional engineer in NC since 2007, and is also licensed in SC, VA, FL, and OH.



Executive Summary

This report assesses the potential health and safety impacts of the proposed Morven Solar 80 MW_{AC} PV project. The Morven Solar facility, located in Brooks County, Georgia, plans to install silicon-based solar panels on single-axis tracking racks that slowly follow the sun across the sky. Large central inverters will convert the DC solar electricity generated by the solar panels into grid-synced AC electricity. Transformers will boost the voltage for connection to an onsite substation that connects to a Georgia Power transmission line. All solar equipment is setback at least 500 feet from nearby homes, and view and sound are blocked with either mature trees or a 10-ft earthen berm topped with 2 dense rows of vegetation.

PV panels are not new. They have been used and studied for over 40 years and are well understood by the scientific community. Utility-scale solar facilities are newer, but they too have been installed and studied for over a decade, and scientists also have a clear understanding of their function and impacts.

PV systems produce emission-free electricity. This directly replaces electricity production from fossil fuel power plants that produce large quantities of harmful emissions. The health benefits of clean solar electricity are hard to put a dollar figure on, but the EPA's best attempt at doing just that puts the value in the "Southeast" between 0.81 and 1.83 cents per kWh produced by utility-scale solar. Even at the bottom end of this range, **this equates to Morven Solar providing $1.7 million of public health benefit per year, and $50 million of public health benefit over 30 years.**

The limited risks to health and safety of the Morven Solar project are not unique to solar but exist for any source or use of grid electricity. These are electric shock, arc flash, and fire. Due to world-class safety regulations in the U.S. and an experienced solar industry, these risks are extremely low, and the secure and isolated nature of ground-mounted PV facilities, including Morven Solar, results in negligible risk to the public.

Common concerns about toxicity, and electric and magnetic fields ("EMF") from solar facilities are understandable, but the operating characteristics and materials present in the equipment means that neither toxicity nor EMF pose a material risk to public health or safety. The potential for toxicity impacts from PV technology has been studied by academic and regulatory entities for decades, resulting in an understanding that while solar panels may contain small amounts of toxic materials, they pose no risk to public health. EMF is generated by all electricity, including solar PV systems, but does not extend far beyond the physical wires and equipment, so any EMF generated by the project will not impact anyone outside of the facility.

Other common concerns, such as heat island effect, glare, noise, and disposal, are also investigated as potential impacts of Morven Solar. Research and experience regarding heat island effect shows that, like other utility-scale PV projects, the Morven Solar project will not change the temperature of the surrounding area. The closest airport is about 12 miles away and the closest air traffic control tower is about 15 miles away, which is too far for the project to cause a solar glare hazard at either airport. The 500-ft setback from homes, and the berm and vegetative buffer, results in no sound impact to neighbors.

When the solar panels reach the end of their useful life they will be removed from the site and disposed of in conformance with federal, state, and local requirements, which could mean recycling or disposal in a landfill. Today the main constituents of the solar panels, and the other equipment such as racking and transformers, can be recycled within the existing recycling infrastructure. Technology to recycle nearly all the constituents in solar panels exists today and is expected to be much cheaper and widely available when the solar panels at this project reach the end of their useful life. The project has a decommissioning plan and will post a decommissioning bond to cover the cost of decommissioning in a worst-case scenario.

Based on my knowledge of science and engineering, personal experience with PV technology, review of academic research, analysis of the proposed project, and review of materials provided by the project developers about the proposed Morven Solar project in Brooks County, Georgia, my conclusions are summarized as follows:

- The Morven Solar project will not result in any negative impacts to public health or safety.
- The Morven Solar project will not increase the temperature of the area surrounding the site.
- The Morven Solar project will not create a glare hazard for aviation or other negative glare impacts.
- The Morven Solar project will not create bothersome noise for any neighbors.

Introduction

Purpose:

This report assesses the potential health and safety impacts of the proposed Morven Solar project. It also seeks to educate readers on the health and safety impacts of PV systems using accurate scientific sources of information.

Overview of Potential Impacts:

The proposed solar PV system is likely to remain in operation at least 30 years, and this report considers its potential impacts in Brooks County from the start of construction onward, including decommissioning of the project and restoration of the land. This assessment considers all aspects of the project but focuses on those unique to solar projects.

Potential Positive Health and Safety Impacts:

Every utility-scale PV project creates a significant reduction in pollution because it produces emission-free electricity that replaces electricity that otherwise would have been largely produced by burning coal and natural gas. Burning these fossil fuels for electricity production is a significant source of air, water, and soil pollution, so reducing their use is a clear public health benefit.

The US Environmental Protection Agency ("EPA") conducted a study across 14 US regions to estimate how much pollution PV systems avoid and how much public health value the resulting cleaner air provides to each region. These experts calculated that based on the sunshine available, the way electricity is currently produced, and the public health impacts of fossil fuel-fired electricity, every kilowatt-hour ("kWh") of electricity produced by utility-scale solar in the "Southeast" region provides o.81 to 1.83 cents of public health benefit.[1] At this rate of benefit, **the Morven Solar project will produce $1.7 to 3.7 million of public health benefits every year**, which could add up to $50 to $113 million over the life of the project. **The public health benefits of generating pollution-free electricity with PV are very significant.**

The positive benefits of PV are widely understood and well documented, so this report will not address them further. Furthermore, the positive public health impacts of the Morven Solar project dramatically overwhelm any negative health and safety risks.

Potential Negative Health and Safety Impacts:

While PV facilities, like any electricity generating facility, provide some potential for negative health and safety impacts, the Morven Solar project does not present any negative health and safety risks specific to its location or technology choice. The only aspect of PV systems that presents risk of physical harm is the potential for electrical shock, arc flash, or fire, which are hazards present with any electrical system and not unique to solar. There are several other aspects of PV systems that often raise public health and safety concerns, but no other aspect of PV systems poses more than an insignficant risk of negative public health or safety impacts.

The Morven Solar project site is located on several parcels that are currently used for a mixture of for crops, timber, pasture, and a small number of rural residences. Where the Morven Solar project is near residential properties, the project provides a 500-ft setback from the center of each house to any solar equipment, which creates significant separation of neighbors from the solar equipment. In addition, views of the project are minimized or blocked entirely with either existing mature trees or a 10-ft tall constructed earthen berm topped with an offset 5-ft tall planted vegetation buffer. This combination of large setback, significant berm, and thick vegetative buffer is extremely uncommon around existing solar facilities and many other land uses. Due to the relatively flat topography of the area, these buffering features will not only physically separate the public from this project but they will also make the facility nearly invisible to passersby and neighbors, which will greatly minimize the dominant potential impact on the community, the visual impact.

[1] US Environmental Protection Agency, Public Health Benefits-per-kWh of Energy Efficiency and Renewable Energy in the United States: A Technical Report. 2nd Ed, May 2021, www.epa.gov/statelocalenergy/public-health-benefits-kwh-energy-efficiency-and-renewable-energy-united-states

This report will address all the potential health and/or safety risks of the Morven Solar project, including common concerns that have no potential for public health impact. Specifically, this report addresses the following possible negative impacts/concerns:

- Electrical Shock and Arc Flash
- Fire and Emergency Response
- Toxicity
- Electromagnetic Fields (EMF)
- Heat Island Effect
- Glare and Noise

This report does not address environmental impacts, such as wildlife impacts or erosion, that do not directly impact human health and safety, however the state of Georgia has robust permitting processes in place to protect any construction project, including utility-scale solar facilities, from violating environmental protection laws, such as the Clean Water Act. In addition to stormwater-related permitting required by the Georgia Department of Natural Resources, Environmental Protection Division, the Georgia Department of Natural Resources, Wildlife Resources Division is responsible for ecological environmental review activities such as impacts to engendered species.

Before addressing each of the above impact categories, this report provides an overview of utility-scale PV equipment, facility construction, and operations.

Utility-Scale PV Equipment, Construction, and Operations[2]

To understand the potential impacts of a utility-scale PV system it is helpful to understand the components of a typical PV facility, as well as how a facility is constructed and maintained. The components and practices in this overview are typical of the industry and representative of the proposed Morven Solar project. The initial site work occurs first, but the order of the other construction steps is flexible and may occur concurrently.

Initial Site Work (construction entrance/driveway, sedimentation and erosion control installation, clearing and grubbing, potentially some grading, perimeter fence, and internal road installation)



[2] Photo sources: author, ncre-usa.com, NC DEQ, blueoakenergy.com, solarbuildermag.com, hbc-inc.com, solarprofessional.com, ccrenew.com, and landiscontracting.com

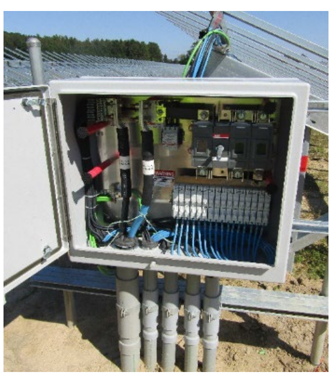
Underground Work (trenching for wires from PV combiner boxes to inverters, inverter pad installation, trenching for medium voltage cables to interconnection equipment)



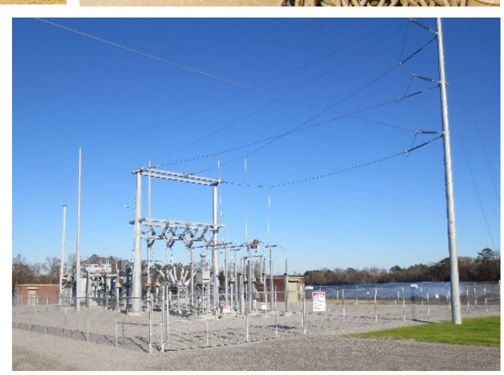
PV Panel Structure/Racking (driving of steel piles, installation of racking "tables", installation of PV panels)



Electrical Work (connection of PV module wiring, combiner boxes, inverters, transformers, interconnection facilities)





Establishment of Ground Cover (required to close out sedimentation and erosion control permitting)


Operations and Maintenance (24/7 monitoring, vegetation maintenance, preventative maintenance)



Electrical Shock and Arc Flash

Figure 1. Perimeter Fence with Warning Signs

Any electricity over 50 volts presents an electrical shock hazard, including the electricity in PV facilities. However, like electrical systems in buildings, the solar facility must adhere to the National Electrical Code ("NEC") and the equipment must be certified to the appropriate UL safety standards. Unlike buildings, members of the public are restricted from entering a utility-scale solar facility (via a perimeter fence). To help ensure that only qualified people have access to the equipment, the NEC requires a perimeter security fence with electrical warning signs. The lack of public access coupled with the high U.S. electrical safety standards results in effectively no risk of electric shock for the public.

In circuits with significant available fault current there is another electrical hazard, called arc flash, which is an explosion of energy that can occur due to a short circuit. This explosive release of energy causes a flash of light and heat, and creates a shockwave that can knock someone off their feet. The risk of arc flash in a solar facility is no different than the risk at commercial or industrial buildings, except that solar facilities are much less accessible. Equipment with an arc flash risk requires arc flash warning labels, and only trained personnel wearing the proper personal protective equipment are allowed to work on it. Due to the secure perimeter and the high U.S. electrical safety standards, there is effectively no arc flash risk to the public.

Fire and Emergency Response

Every electrical system has some risk of starting a fire, including electrical systems in residential, commercial, and industrial buildings. It is this hazard that motivated the creation of the NEC over 100 years ago. Due to the high standard required by the NEC, modern electrical systems rarely start fires. Like electrical systems in buildings, PV systems must also adhere to the NEC. In the rare case that a PV system has a fault that starts a fire, there is very little combustible material present for it to ignite. The only flammable portions of PV panels are the few thin plastic layers, the plastic junction box, and the insulation on its wires. The inverters are also capable of igniting, however, like PV modules, they consist primarily of non-flammable materials. The inverters and transformers are located on concrete pads or raised steel platforms that are isolated from other equipment and vegetation, so a fire in this equipment poses little treat of spreading.

Heat from a small flame is not adequate to ignite a PV panel, but an intense fire or an electrical fault can ignite a PV panel. One real-world example illustrating the low flammability of PV panels occurred during July 2015 in an arid area of California. Three acres of grass under a utility-scale PV facility burned without igniting the panels mounted just above the grass.[3] Another example occurred recently in Florida, where there was a 5-acre grass fire under a portion of a 400-acre PV facility that did not ignite any modules.[4]

The most significant fire hazard at a utility-scale solar facility may be the oil in the transformers. There are medium voltage transformers dispersed throughout the site located by each inverter, called inverter step-up ("ISU") transformers, and there is a large transformer in the interconnection substation, known as the generator step-up ("GSU") transformer. Traditionally these types of transformers are filled with a non-PCB mineral oil, which is derived from petroleum, and is electrically insulating but flammable. A popular alternative to mineral oil is a transformer fluid made of biodegradable vegetable oil, such as FR3 by Cargill or VG-100 by GE. This type of oil not only has several performance benefits over mineral oil, but it is also dramatically reduces the fire hazard of transformers. These vegetable oils' flash point of 330°C is dramatically hotter than mineral oil transformer fluid (160°C). Unlike mineral oil, FR3 and VG-100 are classified as a K-class, "high-fire-point", "fire-resistant", and "less-flammable" fluid. Also classified as "nonpropagating", it is self-extinguishing, and will not continuously burn if ignited. Mineral oil, however, will keep burning for hours when ignited, with no feasible way to stop it until all the oil is consumed. Neither mineral oil- or vegetable oil-filled transformers would create a fire hazard for the community or property surrounding the solar facility.

No special equipment is required to respond to a fire incident at a utility-scale PV facility. The most important thing for first responders to know is that as long as the sun is shining on the PV panels they will produce dangerous voltage. However, there is no danger in touching undamaged equipment. There are multiple electrical disconnect switches in PV systems which allows problem areas to be electrically isolated quickly. The International Association of Fire Fighters ("IAFF") provides online training on responding to fires at PV facilities at www.iaff.org/solar-pv-safety.

Risks of fire associated with ground cover and perimeter vegetation are reduced by landscaping plans that are developed with this specific goal. First responders can safely extinguish grass fires inside of the facility, or monitor and protect the areas surrounding the facility, to ensure the fire does not spread to surrounding areas. The solar facility owner remotely monitors the system around the clock and has personnel available 24/7 for emergencies.

Sources for Further Reading on Fire and Emergency Response:

- Duke Energy: Fire Safety Guidelines for Rooftop- and Ground-Mounted Solar Photovoltaic (PV) Systems, September 2015
- North American Electric Reliability Corporation (NERC): Lessons Learned, Substation Fires: Working with First Responders, February 2019

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[3] Matt Fountain. The Tribune. Fire breaks out at Topaz Solar Farm. July 2015. www.sanluisobispo.com/news/local/article39055539.html
[4] WBMM News 13, Fire breaks out at Jackson Co. solar farm. August 2022, www.youtube.com/watch?v=byE_BpUX2mc

Toxicity (Equipment and Operations)

Toxicity is probably the most common health and safety concern with PV systems that members of the public have, although as detailed below, the systems do not pose a material toxicity risk to the public or the environment. This report examines all possible sources of toxicity, from site construction to decommissioning at the end of the project life. The potential sources of toxicity are organized into two categories: (1) equipment and (2) operations and maintenance ("O&M").

Toxicity: Equipment

The main equipment at a solar facility is PV modules (a.k.a. solar panels or PV panels), metal structures for mounting the solar panels, and wiring to collect the electricity they produce. The other major components are inverters and transformers. Inverters are enclosed power electronic equipment that do not contain liquids and are treated like other electronic waste at the end of their life. Transformers contain non-toxic mineral oil or vegetable oil and are no different than the typical transformers outside of most residences, schools, and shopping centers. Solar panels have raised the most public concerns related to toxicity, so they are covered in depth below, but since transformers contain liquid they are also addressed.

Contents of PV Panels

The Morven Solar project will install silicon-based PV panels sourced from reputable manufacturer meeting established criteria including third-party rankings for performance, reliability, and bankability. Specifically, the project plans to use a bi-facial monocrystalline silicon module manufactured by Canadian Solar. The PV panels are the most expensive and most important component in a solar facility, so the owner performs due diligence to ensure that the panels selected and delivered to the project are properly manufactured, certified, and tested.

The diagram below shows the components of a typical silicon PV panel, including a closeup of the solar cells and the electrical connections. Over 80% of the weight of a PV panel is the tempered front glass cover (or, front and back heat-strengthened glass) and the structural aluminum frame, which work together to create a strong, durable panel that outlasts its typical 30 to 35-year performance warranty. The encapsulation films are clear plastic lamination layers that protect the cells and electrical contacts from moisture for the life of the panel. These layers also maintain the panel as a single unit in the event of breakage of the glass cover(s), similar to the film in auto windshields that keeps them from fragmenting if the windshield shatters.

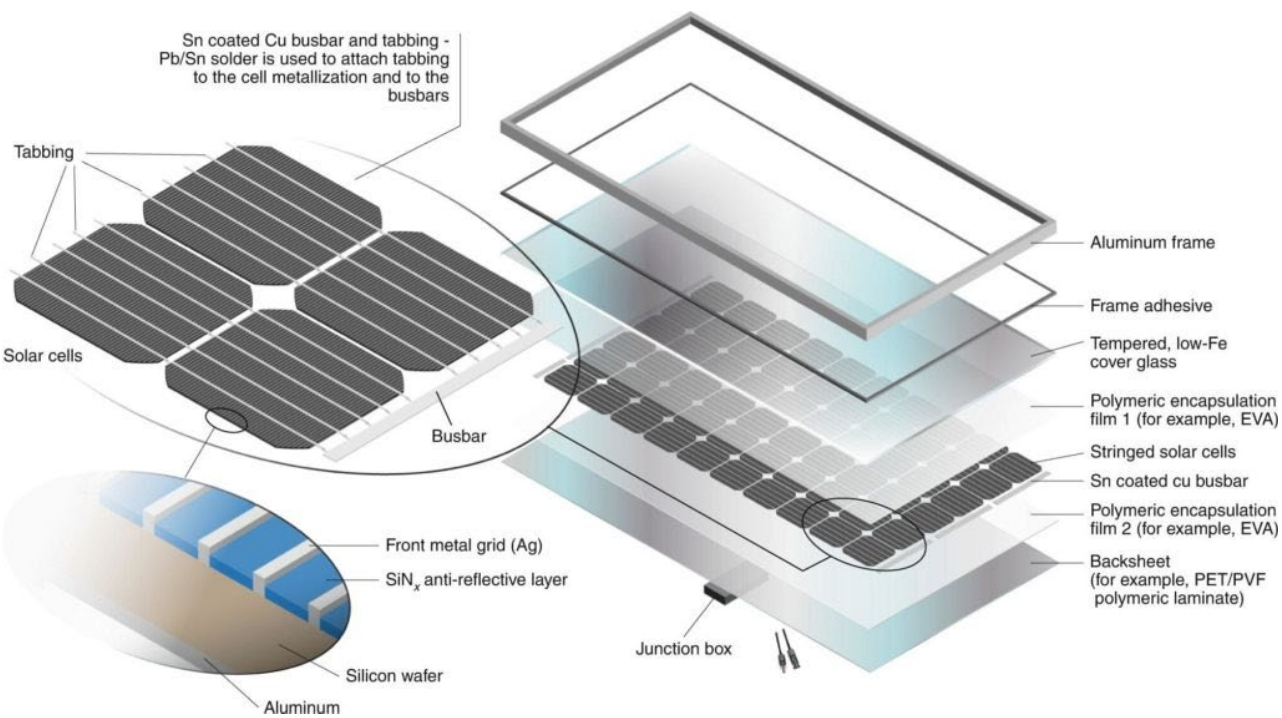

Figure 2. Contents of Framed Crystalline Silicon Panels (Source: NREL)

As can be seen in Figure 2, there are no liquids to leak from a broken panel. The glass and plastic layers are inert. The silicon PV cells are nearly 100% silicon, which is harmless and is the second most common element in the earth's crust. The only component of a PV panel that has any potential of toxic impact is the lead in the solder, which is the same tin-lead solder (~36% lead) that is standard in the electronic industry. This solder is used to connect the solar cells together, by connecting the thin strips of silver that collect electricity from each cell to the next solar cell and to the busbars at the end of the circuit.[5] The tiny amount of silver in a panel does not create a toxicity hazard, but it does add potential recycling value.

Even though there is only a tiny amount of lead in each panel, the total amount of lead in all the PV modules in a utility-scale project adds up to a considerable amount of lead. However, these PV panels are spread out over a large area and when the amount of lead in the PV panels is compared to the amount of lead naturally occurring in the soil under the PV array, it is obvious that even if all the lead somehow leached out of every module (which as explained below is impossible), the increase in total lead in the soil would be less than the naturally occurring difference between different soils. Across the US soils naturally have between about 10 and 50 mg of lead per kg of soil, with the average being somewhere in the 20s. Across 93 USGA survey locations across Georgia, the values ranged from 2 to 115 with an average of 15 and a median of 11.[6] For a location that naturally has 15 mg of lead per kg of soil, all the lead in all the PV modules in the facility would have the same amount of lead as just the top 4 inches of soil at the site.[7]

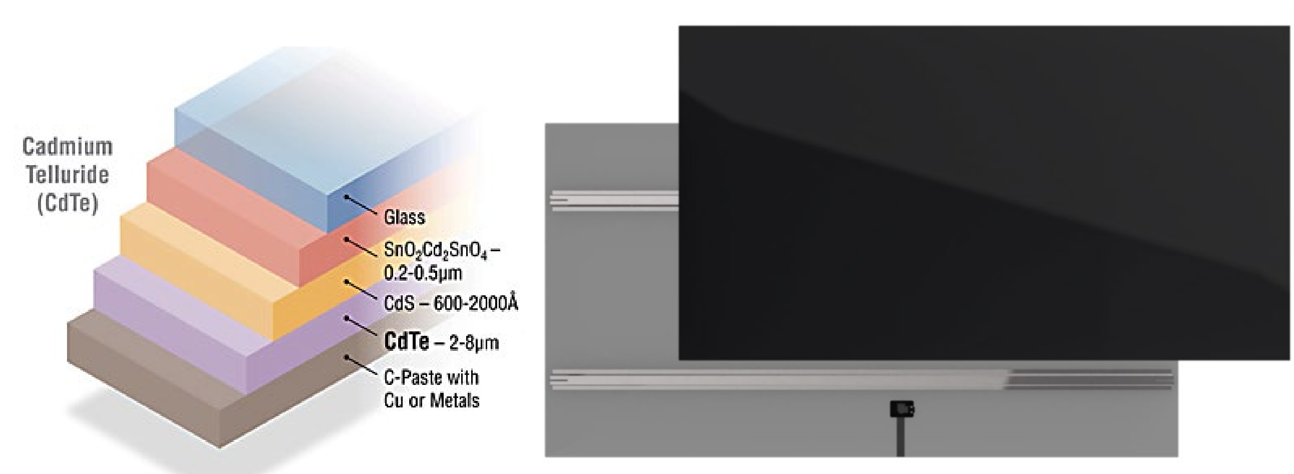

Figure 3. Contents of Cadmium Telluride Panels (Source: NREL); Front and Rear Photo of First Solar Series 7 CdTe Panels (Source: First Solar)

The leading alternative PV technology to silicon-based PV is Cadmium telluride (CdTe), which is by far the most common thin film PV technology. While Morven Solar will you silicon modules and will not use any CdTe modules, this assessment report is still providing a basic introduction to CdTe modules because it is not uncommon for stakeholders to have confusion about the differences in the two technologies. CdTe is referred to as thin film because the active layers are less than 1/10th the thickness of a human hair. Figure 3 above contains two images, on the left is a not-to-scale diagram of the layers for a CdTe PV module (thickness dimension provided in image), and the right image is a photo of two First Solar CdTe modules showing the back of one module and the front of another. The PV cells consist of an incredibly thin layer of cadmium telluride with an even thinner coating of cadmium sulfide (roughly 1/60th the thickness of the CdTe film). Above these active layers is a transparent conducting metal oxide, commonly tin oxide (SnO_2), and below the active layers is a layer of metal to conduct away the electricity. This thin stack is sandwiched between two sheets of heat-strengthened glass that provides electrical

[5] A detailed bill of materials for crystalline silicon PV modules is provided in Table 2 of the International Energy Agency (IEA) PVPS's report entitled: Life Cycle Inventories and Life Cycle Assessments of Photovoltaic Systems, December 2020 https://iea-pvps.org/wp-content/uploads/2020/12/IEA-PVPS-LCI-report-2020.pdf

[6] Smith, D.B., Cannon, W.F., Woodruff, L.G., Solano, Federico, Kilburn, J.E., and Fey, D.L., 2013, Geochemical and Mineralogical Data for Soils of the Conterminous United States: U.S. Geological Survey Data Series 801, 19 p., http://pubs.usgs.gov/ds/801/

[7] PV: 12 g of lead (per panel) per 65 ft^2 (panel footprint of 21.5 ft^2 / ground coverage ratio of 0.40) = 0.223 g of lead/ft^2
Soil: 15 mg of lead per kg of soil * 45 kg of soil per ft^3 * 4 inches (0.333 ft) soil depth * 65 ft^2 = 14.61 g of lead / 65 ft^2 = 0.225 g of lead/ft^2

insulation and physical protection. Like silicon modules there is no liquid to leak. The only aspect of CdTe modules that raises toxicity concern is the cadmium in the cadmium telluride and cadmium sulfide. Cadmium is a toxic heavy metal, but when cadmium is chemically bonded to tellurium in the crystalline structure of the cadmium telluride compound, it has only 1/100th toxicity to humans of cadmium on its own (i.e. not bonded to another element in a compound, also known as free cadmium).[8] The compound cadmium telluride is very stable, so it does not easily break down into cadmium and tellurium.

Cadmium telluride PV panels have been in use for decades, and their potential for creating a health hazard has been studied as long. As shown in the sections below and the some of the reading resources linked at the end of this section, CdTe panels are extremely safe and do not pose any risk to public health and safety, even if installed in large numbers.

Broken PV Panels

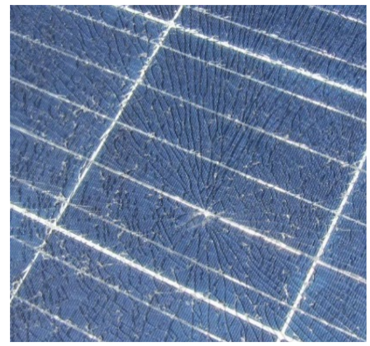

Figure 4. Close-up photo of impact point that broke the glass front of this PV panel

There is zero risk of toxicity escaping from undamaged PV panels because any lead or cadmium is sealed from air and water exposure. Individual panels damaged during the life of the solar facility are identified in days to months through either remote monitoring of system performance or from visual inspections during maintenance by onsite staff. In 2019, an international team of experts conducted an International Energy Agency ("IEA") - Photovoltaic Power Systems Programme ("PVPS") study to assess if there is a public health hazard caused by lead leaching from the broken silicon PV panels or cadmium leaching from cadmium telluride PV panels during the life of a utility-scale solar facility utilizing conservative assumptions to evaluate extreme scenarios.[9] The study examined worst-case exposure routes of soil, air, and ground water for a typical 100 MW_{AC} PV facility for both module types (crystalline and cadmium telluride). For example, the worst-case residential groundwater exposure assumed that all broken panels from the entire array were within 25 feet of the groundwater well, and the chemicals released from every broken panel transported to the same groundwater well. The study found that worst-case lead or cadmium exposure via air, soil, and water were each orders of magnitude less than the maximum levels defined by the EPA to have no adverse health effects. In the case of water, the health-screening level is the same as the maximum concentration level ("MCL") set by the EPA for water quality in public water systems. This study demonstrates that there is no risk to public health from lead or cadmium leached from broken PV panels.

GenX and PFAS

Some solar opponents have raised questions about the possibility of GenX or other per- and polyfluoroalkyl substances ("PFAS") chemicals being emitted by solar panels. PFAS chemicals are a group of chemicals informally known as "forever chemicals" due to their durability in the environment. These chemicals are found in many products, including food packaging materials, firefighting foam, waterproof clothing, and stain resistant carpet treatments, and may have negative health risk. Nearly all the components of a PV panel are PFAS-free, however there is one component that often does contain PFAS, which is the module backsheet, which is the thin plastic layer on the rear of a panel providing electrical insulation and physical protection. An extremely common type of backsheet is based on a plastic known as polyvinyl fluoride (PVF), which is a PFAS material, but not all backsheets contain PVF or other PFAS. Bi-facial modules like those planned for Morven Solar, and other PV panels that have a sheet of glass covering the back of the module, do not require a backsheet because the glass serves the same purpose and thus these modules do not contain any PFAS. Unlike many PFAS products, a PVF backsheet creates very little direct PFAS human exposure. Also, unlike firefighting foams that are a significant source of PFAS in the environment, a PV backsheet is not directly exposed to sun or rain, and does not wash away. Studies of 30-year-old modules with PVF backsheets find that the backsheets are generally still complete and in good functional condition. A fact sheet from the University of Michigan entitled "Facts about solar panels: PFAS contamination" explains more about PFAS and PV panels.[10]

[8] C. Miller, I.M. Peters, and S. Zaveri, Thin Film CdTe Photovoltaics and the U.S. Energy Transition in 2020, https://qesst.org/resources/thin-film-pv-report-2020/, June 2020

[9] P. Sinha, G. Heath, A. Wade, K. Komoto, 2019, Human health risk assessment methods for PV, Part 2: Breakage risks, International Energy Agency (IEA) PVPS Task 12, Report T12-15:2019. ISBN 978-3-906042-87-9, September 2019

[10] "Clean Energy in Michigan" Series, Number 12, Facts about solar panels: PFAS contamination, By Dr. Annick Anctil, https://graham.umich.edu/media/pubs/Facts-about-solar-panels--PFAS-contamination-47485.pdf

PV Panel End-of-Life

PV panels last a very long time, but they do not last forever. Their output declines slightly each year, but panels rarely fail in less than 40 years. The expected economic life of utility-scale PV panels is 30-40 years, at which point they may be replaced by new panels, or the entire project may be decommissioned, returning the land back to how it was before the solar facility was installed. In both instances, the original PV panels are removed from the site. At a typical solar facility, there are three possible fates for solar panels at the end of their economic life at a project, described below. At a minimum in all cases, waste management laws require that the facility owners handle and dispose of the equipment and other facility components in conformance with federal, state, and local requirements. As required by the Brooks County Zoning Ordinance, the project will provide the county with a decommissioning bond in an amount to reasonably cover the cost of the decommissioning.

Solar panel end-of-life options:

- **Reuse**: It is most likely that when the PV panels at the Morven Solar project are decommissioned, they will still produce up to approximately 80% of their original output and have another decade of productive life, making them viable to be reused as solar panels on rooftops or ground-mounted applications. Markets for used solar panels exist today and are likely to be much more mature in 30-40 years when the project's PV panels near the end of their life.
- **Recycling**: Any panels that are not reused as working panels could be recycled. Currently in the US it is possible to recycle the largest constituents of silicon PV panels using the existing glass and metal recycling infrastructure. Today this recycling comes at a cost premium to disposing the panels in a landfill. However, as PV recycling technology improves and the number of panels reaching end-of-life increases dramatically, it is possible that in the future recycling PV panels will more than pay for itself. Recycling plants built specifically to recycle PV panels can recycle nearly 100% of the panel, including the valuable silver and refined silicon they contain, and can be optimized for the task, significantly reducing the cost to recycle each panel. Only recently was the first industrial-scale PV-specific recycling plant built, in France, but in the coming decades it is expected that PV-specific recycling plants will become commonplace. PV recycling technology is clearly still in its infancy. However, it is expected that when the Morven Solar PV panels reach the end of their useful life in 35+ years, the US PV recycling infrastructure will be robust, such that reuse or recycling of the PV panels will be the preferred options or required by new U.S. regulations, as it has been for years in Europe.

  

  Figure 5. PV Panels Waiting to be Recycled (Source: LuxChemtech GmbH)

  First Solar, the only significant manufacturer of cadmium telluride modules, has been developing and successfully using a recycling process for their thin film modules for decades. This focus on recyclability and recycling, allows First Solar to offer recycling services for First Solar modules reaching the end of their useful life.

  The Solar Energy Industries Association ("SEIA") started the SEIA National PV Recycling Program several years ago to accelerate PV recycling in the US. Currently the program aggregates the services offered by recycling vendors and PV manufacturers, making it easier for the industry to select a cost-effective and environmentally responsible end-of-life management solution. **The program identifies Preferred Recycling Partners through an evaluation process. These partners are capable of recycling PV modules, inverters, and other related equipment today**. The current SEIA PV Recycling Partners are listed on the program's website, and full access to the program and the Preferred Recycling Partners is available to SEIA members.
- **Disposal**: For most solar facilities, if panels are not reused or recycled, federal waste management laws (Resource Recovery and Conservation Act, "RCRA") require that PV panels, like any other commercial/industrial waste, be disposed of properly, which is typically in a landfill. In order to determine the proper disposal method, RCRA requires that all commercial/industrial waste be identified as either hazardous or non-hazardous waste, which for PV panels is determined using the Toxic Characteristic Leaching Procedure ("TCLP") test developed by the EPA. This test seeks to simulate landfill conditions and check for leaching of 8 toxic metals and 32 organic compounds from a wide variety of commercial/industrial waste. Little data has been published about the TCLP test results of solar panels, but it is known that some early silicon panels that contain more lead than modern panels exceed the TCLP test limits for lead.

Researchers at Arizona State University's Photovoltaic Reliability Laboratory have done the most robust investigation of methods for conducting accurate TCLP tests on PV panels, and their latest research found that all three of the PV panels tested (all 3 were crystalline silicon) passed the TCLP test, classifying them as non-hazardous waste.[11] First Solar CdTe modules are also reported to pass the TCLP test.

A worst-case scenario would be tons of PV panels being disposed of in a non-sanitary landfill, which is essentially a huge pile of garbage with little to no effort to minimize leaching from the waste that is illegal in many world regions, including in Georgia. A recent IEA-PVS research study on silicon and cadmium telluride PV panels disposal risks used this worst-case situation to evaluate the potential for cancer and non-cancer hazards through comparison of predicted exposure-point concentrations in soil, air, groundwater, and surface water with risk-based screening levels created by the EPA and the World Health Organization ("WHO").[12] One of the report's authors, Gavin Heath with the US Department of Energy's National Renewable Energy Laboratory ("NREL"), summarized their findings about lead in silicon PV panels and cadmium in cadmium telluride PV panels this way: "under the worst-case conditions, none of them exceeded health-screening thresholds, meaning they're not deemed to potentially have significant enough risk that you'd want to do a more detailed health risk assessment."[13] The worst-case scenario defined in the research has many conservative assumptions, and thus likely overestimates the risk of disposal in a *non-sanitary* landfill. **It is important to stress that Georgia only allows solid waste disposal in sanitary landfills, which are engineered facilities with plastic liners, leachate collection systems, and covers, all of which dramatically reduce the potential for human exposure compared to non-sanitary landfills**. This and other research show that if the Morven Solar PV panels are disposed of in a landfill, they will not create a negative public health impact.

In 2019 the North Carolina legislature passed HB 329 (S.L. 2019-132), requiring the NC Department of Environmental Quality (DEQ) to prepare a report to guide rulemaking regarding decommissioning of solar PV and other renewable energy facilities and proper disposal of their equipment. While the policy recommendations in the report do not apply to Georgia, the information is likely to be useful in Georgia. The report, issued January 1, 2021 and titled *Final Report on the Activities Conducted to Establish a Regulatory Program for the Management and Decommissioning of Renewable Energy Equipment*[14], provides a thorough discussion addressing many questions landowners and communities have about solar decommissioning in a state that at that time had more solar panels installed than any state other than California. NC DEQ compiled the input and commentary of numerous stakeholders, including the renewable energy industry, environmental organizations, and academia, including the author and NC State University's Clean Energy Technology Center. The report is well researched and very informative. NC DEQ provides several key findings and recommendations, but no recommendations for changes in NC regulations of solar facilities. One of the report's key findings is that "According to Division of Waste Management experts, if every end-of-life PV module is disposed of in landfills, landfill capacities will not be negatively impacted."

Transformer Oil

While PV modules and inverters do not have any liquids that could leak into the environment, the GSU transformer in the substation and the ISU transformers located with each inverter do contain an oil. Several types of oil can be used in transformers to provide the needed electrical insulation and cooling, but the most common type of transformer oil is mineral oil, which has been used in transformers since transformers were first manufactured in the 1890s. Due to the large volume of oil contained in a GSU transformer, they are installed with a secondary containment structure under them to contain any oil leaked or spilled. The smaller ISU transformers are approximately the same size as the transformers located throughout every community; behind schools, shopping centers, apartments, etc., and they typically do not provide secondary containment.

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[11] Tamizhmani, G., et al. (2019). Assessing Variability in Toxicity Testing of PV Modules. In 2019 IEEE 46th Photovoltaic Specialists Conference (pp. 2475-2481). Institute of Electrical and Electronics Engineers Inc.. https://doi.org/10.1109/PVSC40753.2019.8980781 Publicly-accessible version: https://dev-pvreliability.ws.asu.edu/sites/default/files/93_assessing_variability_in_toxicity_testing_of_pv_modules.pdf

[12] P. Sinha, G. Heath, A. Wade, K. Komoto, Human health risk assessment methods for PV, Part 3: Module disposal risks, International Energy Agency (IEA) PVPS Task 12, Report T12-16:2020. ISBN 978-3-906042-96-1, May 2020

[13] Green Tech Media, Landfilling Old Solar Panels Likely Safe for Humans, New Research Suggests, April 2020, www.greentechmedia.com/articles/read/solar-panel-landfill-deemed-safe-as-recycling-options-grow

[14] https://deq.nc.gov/h329-final-report

Ongoing monitoring of transformer temperature and pressure, and regular preventative maintenance, is likely to find the rare leak when it is still small before it has a chance to leak much oil.

There was a time when most transformer oil was toxic. From 1929 to 1977 polychlorinated biphenyls ("PCBs"), a man-made alternative to mineral oil, was commonly used as transformer oil instead of mineral oil. However, the toxicity of PCBs was eventually understood, leading to PCBs being banned in the US in 1979. Today, transformers either use mineral oil or vegetable oil, both of which are free of PCBs. Mineral oil is non-toxic to humans, in fact "baby oil" that is commonly used to soothe an infant's skin is a scented mineral oil. Although non-toxic to humans, mineral oil is an environmental contaminate and harmful to aquatic ecosystems, so any release to the environment should be avoided. The potential for negative environmental impact from spilled vegetable oil is much less because these oils are biodegradable, so the time they impact the environment is short-lived. Federal regulations dating back to the Clean Water Act of 1973 require that facilities with significant quantities of oil prevent pollution of water.[15] The current EPA regulations require that facilities with over 1,320 gallons oil, and with the potential for spilled oil to impact surface water, develop and implement an oil spill prevention, control and countermeasure ("SPCC") plan. While the risk of negative environmental impact from a transformer oil spill/leak cannot be eliminated entirely, these regulations along with standard industry practices, result in a low probability for a substantial spill and a high probability for a quick clean-up response to minimize impact if a spill were to ever occur.

Figure 6. GSU Transformer with Secondary Containment to Capture any Leaked Oil

Toxicity: Operations & Maintenance

Unlike most other electricity generation facilities, PV systems do not produce any air emissions. The only way they could produce emissions is in the case of a fire. The potential human health impacts from contact with smoke from burning PV panels was studied by the IEA-PVPS in their first report on human health risk assessment. In that study they did not study ground-mounted PV, presumably because of the extremely low risk of significant fire, but they did investigate the potential health impacts of lead in silicon modules and cadmium in cadmium telluride modules dispersing in smoke from a fire in a building that is covered in rooftop PV modules. The study considered several worst-case scenarios for different size buildings and different environments and found no risk of harmful health impacts from the smoke from PV panels.[16]

The only other two aspects of O&M that have raised concerns about toxicity are the fluids used to wash panels and herbicides used to maintain vegetation.

- **Panel Washing** – Across GA there is ample rain to keep the panels clean. If the panels do need to be washed, it would occur infrequently and typically with use of deionized water and cleaning brushes.
- **Herbicides** – The industry standard practice for maintaining the vegetation at solar facilities is similar to how most cities maintain their parks, which is they primarily rely on mowing and string trimmers for vegetation and use herbicides along fences, on roads, and under some equipment. Parks and solar facilities also use herbicides to strategically remove problem weeds, especially woody weeds, to maintain a healthy cover of the desired species of grasses and other low-growing vegetation. This mode of herbicide use applies significantly less herbicide volume than is commonly applied in GA agriculture. For example, Round-Up-Ready crops are common row crops that have been engineered for the entire field to be sprayed with Round-Up (glyphosate) several times each season. Additionally, farmers applying most types of herbicides to their fields are not required to be certified or licensed, but a GA commercial pesticide applicators license is required to apply any herbicide to a solar facility.

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[15] Environmental Protection Agency, webpage: Overview of the Spill Prevention, Control, and Countermeasure (SPCC) Regulation, www.epa.gov/oil-spills-prevention-and-preparedness-regulations/overview-spill-prevention-control-and

[16] P. Sinha, G. Heath, A. Wade, K. Komoto, 2018, Human Health Risk Assessment Methods for PV, Part 1: Fire risks, International Energy Agency (IEA) PVPS Task 12, Report T12-14:2018, https://iea-pvps.org/wp-content/uploads/2020/01/HHRA_Methods_for_PV_Part1_by_Task_12.pdf

Sources for Further Reading on Toxicity:

- QESST (Engineering Research Center at Arizona State University): Thin Film CdTe Photovoltaics and the U.S. Energy Transition in 2020, June 2020
- International Renewable Energy Agency (IRENA): End-of-life management: Solar Photovoltaic Panels, June 2016
- Electric Power Research Institute (EPRI): Solar PV Module End of Life: Options and Knowledge Gaps for Utility-Scale Plants, December 2018
- EPRI: Feasibility Study on Photovoltaic Module Recycling in the United States, April 2018
- EPRI: Solar Photovoltaics: End-of-Life Management Infographic, March 2021
- National Renewable Energy Laboratory (NREL): A Circular Economy for Solar Photovoltaic System Materials, April 2021
- Solar Energy Industries Association (SEIA): SEIA National PV Recycling Program, with factsheet, checklist, and peer-reviewed article, (accessed December 2021)
- North Carolina Department of Environmental Quality: Final Report on the Activities Conducted to Establish a Regulatory Program for the Management and Decommissioning of Renewable Energy Equipment, January 2021

Electromagnetic Fields (EMF)

Exposure to EMF, or electric and magnetic fields, is a fact of everyday modern life. Electromagnetic fields come in many different frequencies, ranging from grid electricity with a frequency of 60 hertz to x-rays and gamma rays that are billions of billions of times faster. The faster the frequency, the stronger the EMF. The EMF coming from grid electricity, including from the inverters, transformers, and AC wires to be used at the Morven Solar project, has a much lower frequency and therefore much lower energy than the EMF from cell phones, wireless internet, and even radio and TV towers. The solar panels and the wire connecting them to the inverters carry direct current electricity, which has a frequency of zero hertz, and thus produces static electric and magnetic fields. The voltage and current of these circuits are both relatively low, so the electric and magnetic fields they produce are both rather weak. The static magnetic fields the panels generate are much weaker than the earth's natural static magnetic field, which can be demonstrated by a compass still pointing north when placed near the panels.

Electric fields are created around wires and equipment wherever a voltage exists, however it is easily blocked with common materials such as metal, wood, and soil. The WHO in 2005 concluded that there were no substantive health issues related to electric fields (0 to 100,000 Hz) at levels generally encountered by members of the public.[17] The proposed solar project does not produce any voltages higher than the existing power lines, and therefore does not produce any electric fields not generally encountered by members of the public.

Magnetic fields are the other aspect of EMF, and they are created by electric current. Typical Americans are exposed to about 1 milligauss of magnetic field from grid electricity on average during their day, primarily from sources at homes and work[18]. The primary source of magnetic fields in a solar facility are the inverters and the short section of wires between each central inverter and its step-up transformer. To convert direct current to alternating current, inverters use a series of solid-state switches that turn off and on several thousand times a second, creating EMF in the range of 5 kHz to 100 kHz, which is much faster than the 60 Hz of grid electricity but still much slower than even the lowest frequency radio signals. The highest electrical current of any portion of the solar facility occurs in the inverters, ISU transformers, and the few feet of wire between them, making this the source for the strongest magnetic fields in the facility. Yet, because the strength of a magnetic field decreases dramatically with increasing distance from the source, these magnetic fields only extend about 100-300 feet from the inverter and ISU transformer, which is less than the distance from each inverter/transformer to any neighboring residential property lines, at which point the magnetic fields would be expected to measure less than 0.5

[17] WHO factsheet: Electromagnetic fields and public health, Exposure to extremely low frequency fields, June 2007, www.who.int/teams/environment-climate-change-and-health/radiation-and-health/non-ionizing/exposure-to-extremely-low-frequency-field

[18] World Health Organization (WHO), webpage: Electromagnetic Fields – Typical exposure levels at home and in the environment, www.who.int/peh-emf/about/WhatisEMF/en/index3.html

milligauss.[19] Locations of the inverters and ISU transformers at the Morven Solar project have been preliminarily identified and all are well beyond the 500-ft residential setback requirements for the facility. This setback will ensure that no solar ground-mounted equipment is closer than 500 feet from existing residential uses. With these setbacks, the EMF from the inverters and ISU transformers are not expected to extend onto any residential property. Similarly, the magnetic fields from substations generally do not extend far enough to leave the fence around the substation, so the same can be expected for the Project's substation.[20]

The bottom line is that the EMF from the Morven Solar project will not increase the EMF exposure of any neighbors. Even if some EMF from the PV facility were to extend beyond the PV site, there would still be no public health impact because low levels of extremely low frequency ("ELF") EMF exposure are not harmful to humans. After extensive study of the potential health impacts of EMF from grid electricity the WHO concludes:

> *"Despite extensive research, to date there is no evidence to conclude that exposure to low level electromagnetic fields is harmful to human health."*[21]

Sources for Further Reading on EMF:

- Electric Power Research Institute: EMF and Your Health: 2019 Update, December 2019
- World Health Organization: Electromagnetic Fields (accessed September 2022)

Heat Island Effect

The localized effects of utility-scale PV facilities on temperature and moisture are not yet well understood. However, the localized micro-climate effects of utility-scale PV facilities are understood well enough to determine that they do not create a heat island effect similar to the well-documented urban heat island effect from dark, massive, surfaces in urban environments, such as asphalt paved streets and parking lots, that cause urban areas to be significantly warmer than the surrounding rural area during the day and night. The changes that solar panels may make to the way land absorbs, reflects, and emits the energy from sunlight are minimal compared to the changes created by buildings, vehicles, and many miles of concrete and asphalt. By comparison, solar panels absorb and reflect a similar amount of solar energy as vegetation and soil. Solar panels are lightweight and cannot store large amounts of thermal energy, and the ground remains covered in vegetation with its natural exposure to air and water. Additionally, the solar panels remove about 20% of the solar energy that strikes them as electricity sent to the grid.

Initial research into the potential for PV systems to cause a heat island effect has used a variety of techniques, including conceptual energy flow calculations, advanced fluid dynamic computer simulations, and field measurements of temperature.[22, 23, 24] This research found a range of different effects on temperature, but none indicate that a large PV system could affect the temperature of the surrounding community. Most found that compared to similar undeveloped land the air temperature in a solar facility increases during the day, but the nighttime results were mixed. Some studies found PV sites to be cooler than non-PV sites at night, but others found them to be warmer. Much of this variation is likely explained by the different climates studied but may also be due to the different methods of the studies. Much of the research on solar

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[19] Study of Acoustic and EMF Levels from Solar Photovoltaic Projects. Tech Environmental, Inc., December 2012, www.co.champaign.il.us/CountyBoard/ZBA/2018/180329_Meeting/180329__Massachusetts%20Acoustic%20Study%20for%20PV%20Solar%20Projects.pdf

[20] www.niehs.nih.gov/health/materials/electric_and_magnetic_fields_associated_with_the_use_of_electric_power_questions_and_answers_english_508.pdf

[21] World Health Organization (WHO), webpage: Electromagnetic Fields – Summary of health effects, www.who.int/peh-emf/about/WhatisEMF/en/index1.html

[22] Broadbent, Ashley & Krayenhoff, Eric & Georgescu, Matei & Sailor, David. (2019). The Observed Effects of Utility-Scale Photovoltaics on Near-Surface Air Temperature and Energy Balance. Journal of Applied Meteorology and Climatology. 58. 10.1175/JAMC-D-18-0271.1.

[23] Barron-Gafford, G. A. et al. The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures. Sci. Rep. 6, 35070; doi: 10.1038/srep35070 (2016).

[24] V. Fthenakis and Y. Yu, "Analysis of the potential for a heat island effect in large solar farms," 2013 IEEE 39th Photovoltaic Specialists Conference (PVSC), Tampa, FL, 2013, pp. 3362-3366, doi: 10.1109/PVSC.2013.6745171.

heat island effect occurred in arid regions of the U.S. southwest where the results are unlikely to translate perfectly to wetter climates in the southeast. In a written statement of evidence Greg Barron-Gafford, leading solar heat island effect researcher, says that he expects that when the area under the PV array is vegetated with grass, the localized heat island effect will be greatly reduced relative to what his research found in dry climates.[25]

The available studies agree that the slight increase of air temperature in the PV site dissipates quickly with height and distance from the panels as natural processes remove and spread the heat. As a result, any temperature increase that may occur at the Morven Solar project during the day will be limited to the site and will not increase the temperature of any of the surrounding community.

Sources for Further Reading on Heat Island Effect:

- EPA: Learn About Heat Islands, (accessed September 2022)

Glare

PV panels are designed to absorb, and thus not reflect, the solar energy that they receive. However, when sunlight strikes the glass front of a solar panel at a glancing angle, a significant portion of the solar radiation is reflected, which can potentially lead to solar glint (a brief flash) or glare. Glint or glare can temporarily impact a person's vision, including pilots landing aircraft, or motorists driving vehicles. However, the conditions required for a PV project to create glare rarely occur.

PV facilities, such as Morven Solar, that utilize single axis trackers to slowly rotate the solar panels to follow the sun have even less potential to create glare because the trackers help avoid a situation where sunlight hits the panels at a glancing angle. Most modern trackers implement an advanced control strategy known as "backtracking" that increases the electricity production of the site by flattening the tilt of the panels early and late in the day to keep the rows of solar panels from shading one another. Backtracking can result in brief periods near sunrise and sunset where the sun strikes the panels at a glancing angle, creating a situation that could result in a few minutes of visible glare at sunrise and sunset. For anyone to see this glare they must be looking across the solar panels in the direction of the rising or setting sun, which is a situation where the sun obviously will create significant glare for the viewer with or without the solar project.

Figure 7. 20 MW PV System at Indianapolis International Airport (Photo source: inhabitat.com)

A clear indication of the ability to avoid glare problems from large ground-mounted PV systems are the PV systems installed on airports across the U.S., including Denver International and Indianapolis International. While there is the potential for a PV system to create glare, there is also the ability to predict when and where a system may create glare and incorporate any needed mitigation before construction. The Federal Aviation Administration ("FAA") and the U.S. Department of Energy ("DOE") developed specialized solar glare analysis software to predict when and where a PV project may produce glint or glare for sensitive receptors nearby. That original software technology has been licensed to a 3rd firm (Forge Solar) that continues to improve and refine the software, which has been validated to accurately predict solar glare.

[25] G. Barron-Gafford, Statement of Evidence by Greg Barron-Gafford on Solar Heat Islanding Issues, May 2018, www.planning.vic.gov.au/__data/assets/pdf_file/0024/126555/301-Expert-Witness-Statement-of-G-Barron-Gafford-PVHI-May-2018-Lemnos.pdf

In May of 2021, the FAA replaced the long-standing interim solar glare policy with a (final) policy that no longer restricts solar developed on airport property from creating glare visible to pilots. The policy explains that the new acceptance of glare visible to pilots is in recognition that pilots often experience glare during landing from bodies of water and that glare from solar is not meaningfully different.[26] The new policy does still prohibit on-airport PV systems from creating any glare visible in an air traffic control tower. While the FAA policy only applies to PV developed on airport property, it is reasonable to follow the same policy for PV plants sited near airport property.

The two closest airports in the National Plan of Integrated Airport Systems ("NPIAS")[27] are the Quitman-Brooks County Airport (4J5) and the Valdosta Regional Airport (VLD). The Valdosta Regional Airport is about 15 miles southeast of the closest solar panel at Morven Sola and Quitman-Brooks County Airport is about 12 miles southwest of the closest panel, both of which are too far for glare from the site to have an impact. The Valdosta airport has an air traffic control tower but the Quitman-Brooks airport does not. Due to the lack of airports close to the proposed Morven facility, no glint and glare study is planned for this project. The author agrees that the project is not close enough to an airport for the project to pose any glare hazard to these airport or to warrant closer glare hazard analysis.

Sources for Further Reading on Solar Glare:

- National Renewable Energy Laboratory (NREL): Research and Analysis Demonstrate the Lack of Impacts of Glare from Photovoltaic Modules, July 2018
- ForgeSolar: PV Planning and glare analysis software help documentation, (accessed September 2022)

Noise

Solar panels are silent, but some of the other components of a PV system produce some sound, although they are rarely heard by anyone outside of the project fence. The loudest equipment is the inverters, but the transformers and tracking motors also make some sound. These numerous sources of sound are dispersed throughout the facility, but the physics of sound are such that these dispersed sources of sound are non-additive. For example, if there are 50 inverters spaced across a utility-scale solar facility and you are close enough to hear some inverter noise, you could turn off the 49 inverters farthest from you and you likely wouldn't notice the difference between the sound from 1 inverter and the sound from 50 inverters. Even if two inverters are right next to each other and an even distance from you, the perceived volume of the sound coming from the two inverters is very similar to the sound from just one inverter. So, the potential for someone offsite to hear any sound generated inside a utility-scale PV project is determined by the closest and loudest source of sound. Thus, some simple analysis of the sound coming from the closest sources to a point of interest, such as a home, can effectively estimate the level of sound from the PV project at that location.

Before providing site-specific analysis of the potential for noise impacts from the Morven Solar project, it is useful to put the sound from the PV project in context. Our world is full of sounds, day and night, even in quiet rural areas, and any sounds from the PV project would be in concert with the existing sounds. The appropriate analysis metric is not if the sounds are audible, but if they are noticeable or bothersome, and US and international organizations have published guidance on this topic based on research on how sound impacts the public.

In 1972, the US passed the Noise Control Act, which required the EPA to define criteria for protecting the public health and wellbeing from noise interference. In response, the EPA developed guidance that included recommended sound levels limits

[26] "Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports", https://www.federalregister.gov/documents/2021/05/11/2021-09862/federal-aviation-administration-policy-review-of-solar-energy-system-projects-on-federally-obligated

[27] The National Plan of Integrated Airport Systems (NPIAS) identifies nearly 3,310 existing and proposed airports that are included in the national airport system. The NPIAS contains all commercial service airports, all reliever airports, and selected public-owned general aviation airports. www.faa.gov/airports/planning_capacity/npias

at residential structures (or places in which quiet is a basis for use)[28]. This guidance recommends that noises at residences be limited to 55 dBA L_{dn}, where L_{dn} is the average sound level of a 24-hour period with the inclusion of a 10-dB penalty during the nighttime hours of 10PM to 7AM. So, the 55 dBA L_{dn} limit could be met with 55 dBA daytime noise and 45 dBA nighttime noise, or a 24-hour noise (L_{eq}) of 48.6 dBA. In addition to the EPA guidance, the United Nations WHO published "Guidelines for Community Noise" (1999) which suggested daytime and nighttime protective noise levels, which are to be applied outside the bedroom window.[29] During the day (7AM to 11PM), the equivalent continuous sound level threshold to protect against serious annoyance is 55 dBA L_{eq}, and 50 dBA L_{eq} to protect against moderate annoyance. During the night (11PM to 7AM), the averaged equivalent continuous sound level threshold is 45 dBA L_{eq}. So, the EPA and the WHO recommend similar daytime noise limits (~55 to 48.6 dBA and 55 to 50 dBA, respectively), and similar nighttime limits as well (~45 to 48.6 dBA and 45 dBA, respectively). Without local noise regulations or recommendations, these recommended noise limits from EPA and WHO provide well-established criteria for acceptable noise in rural residential areas.

At this stage of project development, the final site plan package can be used to conduct a preliminary screening level noise impact assessment. Available sound power data from representative equipment is used in this assessment, so the installed equipment could have somewhat different noise generation, but the difference is expected to be insignificant. The loudest piece of equipment is the inverter, which is planned to be a 2 to 4 MW central model, and this assessment used sound data from one of the most common central inverters on the market today, with a capacity of 3.6 MW. Generally, the difference in sound from different transformers of a similar capacity is minimal, so like the inverter, the representative sound data for the substation transformer is expected to be very similar to the equipment installed at Morven Solar. The third and final component that makes some noise is the motor in the tracker system, which is often located in the center of some rows of solar panels. There is a wide variety of tracker system systems with varying numbers, sizes, and styles of motors. Due to the uncertainty about the tracker that will be installed, a very conservative sound power level is used for the tracker motors in this assessment. The ISU transformers located with each inverter also makes some noise but is significantly quieter than the inverter, so it has negligible impact on the sound level heard some distance from the inverter/transformer pair, so for simplicity the ISU transformers are not included in this screening level noise impact assessment.

The following analysis starts with the sound power level of the equipment, which is measured in decibels but is different than sound pressure level, which is also measured in decibels and is used to describe how loud a sound is to humans. The sound power level of the equipment is a measure of the total acoustic energy emitted from a source of noise. The sound power level value and the distance between the equipment and the person is all that is needed to calculate the loudness of the sound in the person's ears, which is the sound pressure level. The sound power levels of representative equipment are as follows[30]: 3.6MW inverter: 101 dBA, substation transformer: 88 dBA, and tracker motors: 90 dBA. The distance used in this sound assessment is an estimation of the closest distance between the equipment and a residence, which will provide an estimation of the worst-case noise at the homes closest to the project. The 500-ft residential equipment setback distance is used as a conservative distance for the inverters and the tracker motors, although most are likely to be significantly further from the closest residence. The substation transformer is located in the substation, which is much further from the closest residence, at least 1,500 feet. The sound pressure level (in dBA) can be calculated from the sound power level (in dBA) and the distance from the source as follows:

- Sound pressure level = sound power level – 20 x log (distance in feet)
    - Inverters: 101 dBA – 20 x log (500 feet) = 47.0 dBA
    - Substation transformer: 88 dBA – 20 x log (1,500 feet) = 24.5 dBA
    - Tracker motors: 90 dBA – 20 x log (500 feet) = 36.0 dBA

All three of these worst-case sound estimates meet the EPA and WHO recommended guidelines for daytime noise in a residential setting, which is the only time the inverters and tracker motors are expected to make any noise. It is important to

[28] US Environmental Protection Agency (EPA), "Information on Levels of Environmental Loise Requisite to Protect Public Health and Welfare With An Adequate Margin of Safety", 1974, https://nepis.epa.gov/Exe/ZyPDF.cgi/2000L3LN.PDF?Dockey=2000L3LN.PDF
[29] World Health Organization (WHO), "Guidelines for Community Noise", 1999, https://apps.who.int/iris/handle/10665/66217
[30] Inverter and substation transformer sound data provided in *Speedway Solar Sound Study Report*, Revision 1 dated 10/29/2020. Produced by Burns McDonnell for Duke Energy project in Cabarrus County, NC. Tracker motor data and inverter data provided in Kaliski, et. al. Noise-Con 2020 Conference paper titled "An Overview of Sound From Commercial Photovoltaic Facilities", https://rsginc.com/wp-content/uploads/2021/04/Kaliski-et-al-2020-An-overview-of-sound-from-commercial-photovolteic-facilities.pdf

note that this analysis assumes a clear line-of-sight area between the equipment and the residence, so any vegetation or other obstacles between the PV equipment and the residence will reduce the sound reaching the residence compared to the above estimates, which at Morven Solar will include a 10-ft earthen berm topped with 20-ft thick of vegetation that will provide very significant sound attenuation. It is also important to note that the tracker motors only operate for short periods of time throughout the day and the inverters only produce their maximum sound when operating at maximum power in warm weather. While this simplified noise impact assessment is limited in capability compared to specialized noise analysis software, this analysis reflects the physics of sound propagation and uses noise data from representative equipment, allowing for a simple yet accurate estimate of worst case sound impacts. An engineering firm did in fact use a noise analysis software to produce a sound study of the Morven Solar project that was submitted as part of the project's special exception application. The results of that study were very similar to the worst case estimates calculated above. In conclusion, the Morven Solar project is not expected to create noise interference or be bothersome to any neighbors, day or night.

Sources for Further Reading on Noise:

- World Health Organization (WHO), Guidelines for Community Noise, 1999

Conclusions

Based on my knowledge of science and engineering, personal experience with PV technology, review of academic research, analysis of the proposed project, and review of materials provided by the project developers about the proposed Morven Solar project in Brooks County, Georgia, my conclusions are summarized as follows:

- The Morven Solar project will not result in any negative impacts to public health or safety.
- The Morven Solar project will not increase the temperature of the area surrounding the site.
- The Morven Solar project will not create a glare hazard for aviation or other negative glare impacts.
- The Morven Solar project will not create bothersome noise for any neighbors.