KILPATRICK TOWNSEND & STOCKTON LLP
www.kilpatricktownsend.com

Suite 1400 4208 Six Forks Road
Raleigh NC 27609
t 919 420 1700 f 919 420 1800
www.KilpatrickTownsend.com

Steven J. Levitas
direct dial 919 420 1707
direct fax 919 510 6145
SLevitas@KilpatrickTownsend.com

May 18, 2015

Ms. Gail L. Mount, Deputy Clerk
North Carolina Utilities Commission, Public Staff
430 North Salisbury Street
Dobbs Building
Raleigh, North Carolina 27606-5918

Re: Sunflower Solar LLC, Docket No. SP-5272, Sub 0 – Direct Testimony

Dear Ms. Mount:

Please find attached the Direct Testimony and Exhibits for Georg Veit, Richard Kirkland and Tommy Cleveland in the above-referenced docket.

Please contact me at (919) 420-1707 if you have any questions.

Sincerely yours,

KILPATRICK TOWNSEND & STOCKTON LLP

Steven J. Levitas

Attachments

cc: Georg Veit
Richard Kirkland
Tommy Cleveland
Tim Dodge
Paul Walden
Jim Manley

Before the
North Carolina Utilities Commission
Docket No. SP-5272, Sub 0

Direct Testimony and Exhibits
of
Tommy Cleveland, P.E.

On Behalf Of
Sunflower Solar LLC
an affiliate of Geenex Solar LLC

May 18, 2015

Q. Please state your name and address for the record.

A. My name is Tommy Cleveland. My address is 4141 Laurel Hills Road, Raleigh, NC 27612.

Q. By whom are you employed and in what capacity?

A. I am the Renewable Energy Project Coordinator for the North Carolina Clean Energy Technology Center at North Carolina State University (the "Center"). However, I am testifying in this matter as a consulting engineer to the applicant, Sunflower Solar, LLC.

Q. Please discuss your credentials.

A. As the Renewable Energy Project Coordinator, I lead the Center's solar energy testing and demonstration program, conduct renewable energy site assessments, and provide technical support to a wide variety of solar projects and stakeholders across North Carolina and beyond. From 2008 to 2012, I taught the solar energy course in the Mechanical and Aerospace Engineering Department at N.C. State University, and am now teaching solar courses in the Environmental Technology and Management Department. Since 2007, I have been a licensed professional engineer (PE) in North Carolina. I graduated *Sum Cum Laude* with a B.S. in Mechanical Engineering and a minor in Business Management and a M.S. in Mechanical Engineering from N.C. State University.

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to provide an expert opinion on the potential impacts, if any, of the proposed solar facility on human health.

Q. Please describe the proposed facility for which Sunflower Solar LLC seeks the CPCN.

A. The proposed facility is described in detail in the application for the Certificate of Public Convenience and Necessity ("CPCN") filed in this docket (the "Facility"). The Facility will be located approximately two miles south of the town of Weldon on a parcel just east of the intersection of Dickens Wildwood Road and Highway 301 and south of the intersection of Lilly Lane and Highway 301, Halifax County, North Carolina. Sunflower Solar LLC is leasing the real property from the current owners and currently owns 100% of the Facility. As proposed, the Facility will consist of approximately ninety-thousand (90,000) 310 to 330 Watt photovoltaic ("PV") modules (or the equivalent) affixed to racks, which will be supported by piles driven in the ground. The system will utilize inverters ranging from one (1) to two and a half (2 ½) MW. The Facility will be surrounded by chain link fencing. It is anticipated that the Facility will be commissioned in June 2016.

Q. Have you read the comments filed by Paul Weldon and Jim Manley in this docket?

A. Yes.

Q. What is your response to these comments?

A. With respect to the specific concerns related to the impact of the Facility on human health raised in Mr. Weldon's and Mr. Manley's submissions to the Commission, it is my professional and expert opinion that the Facility will have no adverse impact on human health. Because solar systems do not burn fossil fuels, they do not produce the toxic air or greenhouse gas emissions associated with conventional fossil fuel-fired generation technologies. In fact, the energy the solar systems produce reduces the demand for electricity from fossil fuel-fired generation and thereby reduces the pollution they emit. Because solar panels are encased in tempered glass, or a combination of tempered glass and plastic, there is very little risk that any material from the solar panels can be released into the environment. The panels have an industry-standard 25 year performance warranty and there are many panels over 30 years old still functioning well today. Further, the presence of ground-mounted solar panels does not cause higher ambient temperatures in the surrounding area. The strength of electromagnetic fields produced by solar systems does not approach levels considered harmful to human health, as established by the International Commission on Non-Ionizing Radiation Protection. Moreover, the small electromagnetic fields produced by solar systems rapidly diminish with distance and would be indistinguishable from normal background levels at a distance of 100 feet.

Q. Have you reviewed technical or scientific literature that supports your opinions?

A. Yes.

Q. Could you identify and summarize the findings of that literature?

A. I reviewed and relied upon the following literature: *Clean Energy Results – Questions and Answers – Ground-Mounted Solar Photovoltaic Systems*, Massachusetts Department of Energy Resources, Massachusetts Department of Environmental Protection, Massachusetts Clean Energy Center, Dec. 2012; *Health* *and Safety Concerns of Photovoltaic Panels*, The Good Company; U.S. Department of Energy, Letter dated Nov. 12, 2009 and attached memorandum. The Massachusetts regulatory agencies addressed a wide variety of questions concerning the installation and operation of ground-mounted solar photovoltaic projects and determined that there is no evidence that these projects cause adverse impacts to human health. The Good Company, a sustainability consulting firm located in Eugene, Oregon, found that the life-cycle impacts of solar photovoltaics, including the installation and use of solar panels, are minimal. As found by the Brookhaven National Laboratory and the Electric Power Research Institute, installed solar panels pose minimum risk to human health and the environment. Finally, based on a literature review, the Department of Energy determined that the health risks of solar photovoltaic projects due to electromagnetic fields are minimal. The Department of Energy found there is little cause for concern of adverse impacts caused from electromagnetic fields at homes near solar photovoltaic projects. These three articles are attached as Exhibits 1 through 3.

Q. What is your recommendation with respect to the application for a CPCN?

A. It is my recommendation that the Commission issue an order awarding the CPCN for the Facility.

Q. Does this conclude your testimony?

A. Yes.

CLEANENERGYRESULTS

Questions & Answers

Ground-Mounted Solar Photovoltaic Systems

Westford Solar Park, photo courtesy of EEA

December 2012

Massachusetts Department of Energy Resources
Massachusetts Department of Environmental Protection
Massachusetts Clean Energy Center

Table of Contents

Background 3
Hazardous Materials 5
End-of-Life/Decommissioning 7
Ambient Temperature (“Heat Island”) 9
Electric and Magnetic Fields (EMF) 10
Property Values 13
Public Safety (including fires) 14
Historic Preservation 16
Noise 18
Water-Related Impacts 20
Glare 22
Endangered Species and Natural Heritage 23

Background

Solar photovoltaic (PV) technology, which converts sunlight directly into electricity, is a key priority for the state of Massachusetts' clean energy efforts. The environmental benefits of solar PV abound. Unlike conventional fossil fuel power generation (such as coal, gas and oil), generating electricity with solar PV involves no moving parts, uses no water, and generates electricity without emitting climate-warming greenhouse gases or other pollutants.

Solar PV's environmental and energy benefits, combined with strong incentives, have significantly increased the use of this technology. The Commonwealth's vibrant solar industry has a variety of ownership and financing options for Massachusetts residents and businesses looking to install solar PV systems. Purchasing a solar PV system generally involves upfront installation and equipment costs, but there are significant incentives[1].

As the Massachusetts clean energy sector grows, the Patrick-Murray Administration is working to ensure that solar PV and other clean energy technologies are sited in a way that best protects human health and the environment, and minimizes impacts on scenic, natural, and historic resources.

Purpose of Guide

This guide is intended to help local decision-makers and community members answer common questions about ground-mounted solar PV development. Ground-mounted solar PV has many proven advantages and there has been a steady growth of well received projects in the Commonwealth. However, these systems are still relatively new and unfamiliar additions to our physical landscape.

This guide focuses on questions that have been raised concerning the installation and operation of ground-mounted solar PV projects. It provides summaries and links to existing research and studies that can help people understand solar PV technology in general, and ground-mounted solar in particular.

Solar PV panels can and are of course also installed on buildings[2], car ports or light poles. This guide focuses on ground-mounted systems since most questions relate to this type of solar installations.

Developed through the partnership of the Massachusetts Department of Energy Resources (DOER), the Massachusetts Department of Environmental Protection (MassDEP), and the Massachusetts Clean Energy Center (MassCEC), this guide draws from existing, recent literature in the United States and abroad and is not the result of new original scientific studies. The text was reviewed by the National Renewable Energy Laboratory (NREL).

As new information becomes available, the guide will be updated and expanded.

---

[1] For a comprehensive overview, start at http://masscec.com/index.cfm/page/Solar-PV/pid/12584 and http://www.dsireusa.org/solar/

[2] For an overview of the multiple options for siting PV and buildings in the same footprint, see the Solar Ready Buildings.Planning Guide, NREL, 2009.

Solar PV Projects Are Sited Locally

The siting authority for solar PV projects resides at the local − not the state − level. One purpose of this guide is to inform and facilitate local efforts to expand clean energy generation in a sustainable way, and provide a consolidated source of existing research and information that addresses common questions faced by communities.

As part of the Green Communities Act of 2008, DOER and the Massachusetts Executive Office of Energy and Environmental Affairs (EOEEA) developed a model zoning by-law/ordinance called "as-of-right siting" that does not require a special permit. It is designed to help communities considering adoption of zoning for siting of large-scale solar. This model zoning by-law/ordinance provides standards for the placement, design, construction, operation, monitoring, modification and removal of new large-scale ground-mounted solar PV installations. The latest version of the model by-law was published in March 2012[3]. It provides useful information that will not be repeated extensively in this guide.

Consider Impacts of Other Possible Developments at Site

Use of land for the purpose of solar photovoltaic power generation should be compatible with most other types of land usage. However DOER strongly discourages designating locations that require significant tree cutting, because of the important water management, cooling and climate benefits trees have. DOER encourages designating locations in industrial and commercial districts, or on vacant, disturbed land.

When assessing the impact of new ground-mounted solar arrays, communities and other stakeholders should carefully consider other types of development that might take place in a particular location if there was no solar installation. Stakeholders should bear in mind the higher or lower impacts that those alternatives might have in terms of noise, air pollution or landscape. These alternative impacts fall outside the scope of this guide, but are relevant when looking at individual projects.

[3] http://www.mass.gov/eea/docs/doer/green-communities/grant-program/solar-model-bylaw-mar-2012.pdf

Hazardous Materials

Question: What, if any, health risks do chemicals used in solar panels and other devices used in solar PV arrays pose if they are released into the environment?

Bottom Line: Because PV panel materials are enclosed, and don't mix with water or vaporize into the air, there is little, if any, risk of chemical releases to the environment during normal use. The most common type of PV panels is made of tempered glass, which is quite strong. They pass hail tests, and are regularly installed in Arctic and Antarctic conditions. Only in the unlikely event of a sufficiently hot fire is there a slight chance that chemicals could be released. This is unlikely because most residential fires are not hot enough to melt PV components and PV systems must conform to state and federal fire safety, electrical and building codes.

Transformers used at PV installations, that are similar to the ones used throughout the electricity distribution system in cities and towns, have the potential to release chemicals if they leak or catch fire. Transformer coolants containing halogens have some potential for toxic releases to the air if combusted. However, modern transformers typically use non-toxic coolants, such as mineral oils. Potential releases from transformers using these coolants at PV installations are not expected to present a risk to human health.

More Information: Ground-mounted PV solar arrays are typically made up of panels of silicon solar cells covered by a thin layer of protective glass attached to an inert solid underlying substance (or "substrate"). While the vast majority ofPV panels currently in use are made of silicon, certain types of solar cells may contain cadmium telluride (CdTe), copper indium diselenide (CIS), and gallium arsenide (GaAs).

All solar panel materials, including the chemicals noted above, are contained in a solid matrix, insoluble and non-volatile at ambient conditions, and enclosed. Therefore, releases to the ground from leaching, to the air from volatilization during use, or from panel breakage, are not a concern. Particulate emissions could only occur if the materials were ground to a fine dust, but there is no realistic scenario for this. Panels exposed to extremely high heat could emit vapors and particulates from PV panel components to the air. However, researchers have concluded that the potential for emissions derived from PV components during typical fires is limited given the relatively short-duration of most fires and the high melting point (>1000 degrees Celsius) of PV materials compared to the roof level temperatures typically observed during residential fires (800-900 degrees Celsius). In the rare instance where a solar panel might be subject to higher temperatures, the silicon and other chemicals that comprise the solar panel would likely bind to the glass that covers the PV cells and be retained there.

Release of any toxic materials from solid state inverters is also unlikely provided appropriate electrical and installation requirements are followed. For more information on public safety and fire, see the Public Safety section of this document.

We should also note that usually the rain is sufficient to keep the panels clean, so no extra cleaning in which cleaning products might be used, is necessary.

Resources:

Energy Information Administration (EIA), 2002. Renewable Energy Annual 2001 withPreliminary Data for 2001, ftp://ftp.eia.doe.gov/renewables/060301.pdf

Electric Power Research Institute (2003). "Potential Health and Environmental Impacts Associated with the Manufacture and Use of Photovoltaic Cells." Report to the California Energy Commission, Palo Alto, CA. http://mydocs.epri.com/docs/public/000000000001000095.pdf.

Fthenakis, V.M., Overview of Potential Hazards in *Practical Handbook of Photovoltaics: Fundamentals and Applications, General editors T. Markvart and L. Castaner, Elsevier, 2003*.

Fthenakis, V.M. Life cycle impact analysis of cadmium in CdTe PV production. Renewable and Sustainable Energy Reviews 8, 303-334, 2004.

Fthenakis V.M., Kim H.C., Colli A., and Kirchsteiger C., Evaluation of Risks in the Life Cycle of Photovoltaics in a Comparative Context, 21st European Photovoltaic Solar Energy Conference, Dresden, Germany, 4-8 September 2006.

Moskowitz P. and Fthenakis V., Toxic materials released from photovoltaic modules during fires; health risks, Solar Cells, 29, 63-71, 1990.

Sherwani, A.F., Usmani, J.A., &Varun. Life cycle assessment of solar PV based electricity generation systems: A review. Renewable and Sustainable Energy Reviews.14, 540-544, 2010.

Zayed, J; Philippe, S (2009-08)."Acute Oral and Inhalation Toxicities in Rats With Cadmium Telluride" (PDF). *International journal of toxicology* (International Journal of Toxicology) **28** (4): 259–65.

End-of-Life/Decommissioning

Question: What happens after solar panels are no longer used and are being decommissioned? Do hazardous waste disposal requirements apply?

Bottom Line: The interest in recycling of solar panels has increased in Europe and the U.S. as more panels are decommissioned. State regulations are in place to ensure proper disposal and recycling of panels with components that constitute solid or hazardous waste under state regulations.

More information: The average life of solar PV panels can be 20-30 years (or longer) after initial installation. PV cells typically lose about 0.5% of their energy production capacity per year. At their time of decommissioning, panels may be disposed, recycled or reused. Since widespread use of solar PV is recent in Massachusetts, only a small percentage of solar panels in use in the state have reached the end of their useful lifetime. A significant increase in the amount of end-of-life PV modules is expected over the next few decades.

When solar panels are decommissioned, state rules require that panel disposal be "properly managed" pursuant to Massachusetts hazardous waste regulations. There are many different types of solar panels used in ground-mounted solar PV systems; some of these panels have components that may, by state regulation, require special hazardous waste disposal or recycling. Solar module manufacturers typically provide a list of materials used in the manufacturing of their product, which is used to determine the proper disposal at the time of decommissioning.

People who lease land for solar projects are encouraged to include end-of-life panel management as part of the lease. In cases where panels are purchased, owners need to determine whether the end-of-life panels are a solid or hazardous waste and dispose of the panels appropriately. Massachusetts regulations require testing of waste before disposal.

Because of the various materials used to produce solar panels (such as metal and glass), interest in recycling of solar modules has grown. Throughout Europe, a not-for-profit association (PV Cycle) is managing a voluntary collection and recycling program for end-of-life PV modules. The American photovoltaic industry is not required by state or federal regulation to recycle its products, but several solar companies are starting to recycle on a voluntary basis. Some manufacturers are offering end-of-life recycling options and independent companies looking to recycle solar modules are growing. This allows for the recycling of the PV panels and prevents issues with the hazardous materials. Currently, the California Department of Toxic Substances Control is considering standards for the management of solar PV panels at the end of their use.

DOER's model zoning provides language on requirements for abandonment and decommissioning of solar panels for use by local officials considering local approvals for these projects.

Resources

End-of-life PV: then what? - Recycling solar PV panels
http://www.renewableenergyfocus.com/view/3005/end-of-life-pv-then-what-recycling-solar-pv-panels/

MassDEP Hazardous Waste Regulations 310 CMR 30
http://www.mass.gov/dep/service/regulations/310cmr30.pdf

PV Cycle, Europe: http://www.pvcycle.org/

California Department of Toxic Substances Control, Proposed Standards for the Management of Hazardous Waste Solar Modules,
http://www.dtsc.ca.gov/LawsRegsPolicies/Regs/Reg_Exempt_HW_Solar_Panels.cfm

Ambient Temperature (“Heat Island”)

Question: Does the presence of ground-mounted solar PV arrays cause higher ambient temperatures in the surrounding neighborhood (i.e., the “heat island” effect)?

Bottom Line: All available evidence indicates that there is no solar “heat island” effect caused by the functioning of solar arrays. Cutting shade trees for solar PV might increase the need for cooling if those trees were shading buildings. This is primarily a concern in town centers and residential areas (locations where large ground-mounted PV is not encouraged) and is a potential impact of any development activity that requires tree-cutting.

More Information: All available evidence indicates that there is no solar “heat island” effect caused by the functioning of solar arrays. Solar panels absorb photons from direct sunlight and convert it to electricity. This minimizes the likelihood of substantially changing temperatures at the site or the surrounding neighborhood. For an area with no PV system, solar energy impacting the ground is either reflected or absorbed. There is no research to support heat production from the solar panels themselves.

Sunpower, a private solar manufacturer, conducted a study on the impact of solar PV on the local temperature and concluded that a solar PV array can absorb a higher percentage of ambient heat than could a forested parcel of land without an array. The study points out that while solar PV modules can reach operating temperatures up to 120 degrees Fahrenheit, they are thin and lightweight and therefore do not store a large amount of heat. Because of this, and the fact that panels are also shown to cool to ambient air temperature shortly after the sun sets, the Sunpower study concludes that the area surrounding a large-scale solar array is unlikely to experience a net heating change from the panels.

If trees are removed that were previously shading a building, that building could get warmer in full sunshine than when the trees were shading it. The June 1, 2011 tornado that ripped through Western Massachusetts created an opportunity to empirically measure the affects of the loss of neighborhood trees on temperatures and air humidity in the streets. A report by the U.S. Department of Agriculture Forest Service concluded that in the tornado-impacted neighborhood in Springfield, Massachusetts, daily mean morning and afternoon temperatures were typically greater than in the unaffected neighborhood and forest sites, but were similar at night. Residents noted increased use of air-conditioning units and an overall increase in energy costs in July and August of 2011.

Resources:

SUNPOWER, Impact of PV Systems on Local Temperature, July 2010

USDA Forest Services report: http://www.regreenspringfield.com/wp-content/uploads/2011/11/tornado%20climate%20report%203.pdf

Electric and Magnetic Fields (EMF)

Question: What, if any, health risks do the electric and magnetic fields (EMF) from solar panels and other components of solar PV arrays pose?

Bottom Line: Electric and magnetic fields are a normal part of life in the modern world. PV arrays generate EMF in the same extremely low frequency (ELF) range as electrical appliances and wiring found in most homes and buildings. The average daily background exposure to magnetic fields is estimated to be around one mG (milligauss – the unit used to measure magnetic field strength), but can vary considerably depending on a person's exposure to EMF from household electrical devices and wiring. The lowest exposure level that has been potentially associated with a health effect is three mG. Measurements at three commercial PV arrays in Massachusetts demonstrated that their contributions to off-site EMF exposures were low (less than 0.5 mG at the site boundary), which is consistent with the drop off of EMF strength based on distance from the source.

More Information: Solar PV panels, inverters and other components that make up solar PV arrays produce extremely low frequency EMF when generating and transmitting electricity. The extremely low frequency EMF from PV arrays is the same as the EMF people are exposed to from household electrical appliances, wiring in buildings, and power transmission lines (all at the power frequency of 60 hertz). EMF produced by cell phones, radios and microwaves is at much higher frequencies (30,000 hertz and above).

Electric fields are present when a device is *connected* to a power source, and are shielded or blocked by common materials, resulting in low potential for exposure. On the other hand, magnetic fields, which are only generated when a device is *turned on*, are not easily shielded and pass through most objects, resulting in greater potential for exposure. Both types of fields are strongest at the source and their strength decreases rapidly as the distance from the source increases. For example, the magnetic field from a vacuum cleaner six inches away from the motor is 300 mG and decreases to two mG three feet away. People are exposed to EMF during normal use of electricity and exposure varies greatly over time, depending on the distance to various household appliances and the length of time they are on. The daily average background level of magnetic fields for U.S. residents is one mG.

EMF from PV Arrays: Solar PV panels produce low levels of extremely low frequency EMF, with measured field strengths of less than one mG three inches from the panel. Solar PV power inverters, transformers and conduits generate higher levels of ELF-EMF. The amount of ELF-EMF is proportional to the electrical capacity of the inverter and is greater when more current (electricity) is flowing through a power line.

In a study of two PV arrays (using 10-20kW invertors) in Kerman and Davis, California, the magnetic field was highest at the inverters and transformers, but decreased rapidly to less than one mG within 50 feet of the units, well within the boundary of the PV array (Chang and Jennings 1994). This data indicates that extremely low frequency EMF field strengths at residences near systems of this size would be below the typical levels experienced by most people at home. The highest extremely low frequency EMF (up to 1,050 mG) was found next to an inverter unit at the point of entry to the electrical conduits. Even this value is less than the ELF-EMF reported for some common household devices, such as an electric can opener with a maximum of 1500 mG at 6 inches.

In a recent study of 3 ground mounted PV arrays in Massachusetts, the above results were confirmed. The PV arrays had a capacity range of 1 to 3.5 MW. Magnetic field levels along the PV array site boundary were in the very low range of 0.2 to 0.4 mG. Magnetic fields at 3 to 7 feet from the inverters ranged from 500 to 150 mG. At a distance of 150 feet from the inverters, these fields dropped back to very low levels of 0.5 mG or less, and in many cases to much less than background levels (<0.2 mG).

Potential Health Effects: Four research studies have reported an association between three to four mG EMF exposure and childhood leukemia, while 11 other studies have not. These studies are inconsistent and do not demonstrate a causal link that would trigger a World Health Organization (WHO) designation of EMF as a possible carcinogen[4]. Studies looking at other cancers in humans and animals have not found evidence of a link to residential ELF-EMF exposure.

Reference Exposure Levels: To protect the general public from health effects from short-term high level magnetic fields, the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2010) advised an exposure limit for extremely low frequency magnetic fields at 2000mG. ICNIRP determined that the evidence on the impact of long-term exposure to low level magnetic fields was too uncertain to use to set a guideline. Guidelines for the magnetic field allowed at the edge of transmission line right-of-ways have been set at 200 mG by Florida and New York. Exposure to magnetic fields greater than 1000 mG is not recommended for people with pacemakers or defibrillators (ACGIH, 2001).

ELF-EMF does not appear to interfere with hearing aids, though interference from higher frequency EMF associated with cell phones has been reported.

Resources:

American Conference of Government Industrial Hygienist (ACGIH). 2001. as cited in NIEHS 2002.

California Department of Health Services (CA DHS). 2000. Electric and Magnetic Fields, measurements and possible effect on human health — what we know and what we don’t know in 2000. This factsheet has a moderate level of technical detail and is intended for those with an interest in science. For more information,see http://www.dhs.ca.gov/ps/deodc/ehib/. California Electric and Magnetic Fields Program, A Project of the California Department of Health Services and the Public Health Institute.

Chang, GJ and Jennings, C. 1994. Magnetic field survey at PG&E photovoltaic sites.PG&E R&D Report 007.5-94-6. Available

[4] WHO has designated ELF-EMF as a possible carcinogen. The use of the label “possible carcinogen” indicates that there is not enough evidence to designate ELF-EMF as a “probable carcinogen “or “human carcinogen,” the two indicators of higher potential for being carcinogenic in humans.

Electric Power Research Institute (EPRI). 2012. EMF and your health. Available http://my.epri.com/portal/server.pt?Abstract_id=000000000001023105.

International Commission on Non-Ionizing Radiation Protection (ICNIRP). 2010. ICNIRP Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100kHz). Health Physics 99(6):818-836.

National Cancer Institute (NCI). 2005. Magnetic Field Exposure and Cancer: Questions and Answers. U.S. Department of Health and Human Services, National Institutes of Health. Available http://www.cancer.gov/cancertopics/factsheet/Risk/magnetic-fields, accessed May 14, 2012.

National Institute of Environmental Health Science (NIEHS) 2002. Electric and Magnetic Fields Associated with the Use of Electric Power: Questions and Answers. Available http://www.niehs.nih.gov/health/assets/docs_p_z/results_of_emf_research_emf_questions_answers_booklet.pdf, accessed May 11, 2012.

National Institute of Environmental Health Science (NIEHS) web page on EMF. Available http://www.niehs.nih.gov/health/topics/agents/emf/, accessed May 11, 2012.

Oregon Department of Transportation (Oregon DOT). Scaling public concerns of electromagnetic fields produced by solar photovoltaic arrays. Produced by Good Company for ODOT for the West Linn Solar Highway Project. Available www.oregon.gov/ODOT/HWY/OIPP/docs/emfconcerns.pdf.

World Health Organization (WHO). 2007. Electromagnetic fields and public health: Exposure to extremely low frequency fields. Fact sheet N°322. June 2007. Available http://www.who.int/mediacentre/factsheets/fs322/en/index.html, accessed May 16, 2012. This fact sheet provides a short summary of the in-depth review documented in the WHO 2007, Environmental Health Criteria 238. Available http://www.who.int/peh-emf/publications/elf_ehc/en/index.html.

EMF in Your Environment, Magnetic Field Measurements of Everyday Electrical Devices (USEPA, 1992)

Tech Environmental, Study of Acoustic and EMF levels from Solar Photovoltaic Projects, Prepared for the Massachusetts Clean Energy Center, December 2012

Property Values

Question: How do ground-mounted solar PV arrays adjacent to residential neighborhoods influence the property values in those neighborhoods?

Bottom Line: No research was found specific to ground-mounted solar PV and property values. Residential property value research on roof-mounted solar PV and wind turbines illustrates no evidence of devaluation of homes in the area. Municipalities that adopt zoning for solar facilities may want to consider encouraging project developers to include screening vegetation along site borders to minimize visual impacts on surrounding neighborhoods.

More Information: A review of literature nationwide shows little evidence that solar arrays influence nearby property values. An analysis focused on roof-mounted solar PV panels done by the U.S. Department of Energy Lawrence Berkeley National Laboratory concludes that household solar installation actually increases home property values. This research analyzes a large dataset of California homes that sold from 2000 through mid-2009 with PV installed. Across a large number of repeat sales model specifications and robustness tests, the analysis finds strong evidence that California homes with PV systems have sold for a premium over comparable homes without PV systems.

While neither of these reports focused on ground-mounted solar PV, this information may be relevant to this discussion.

Resources:

The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis http://eetd.lbl.gov/ea/ems/reports/lbnl-2829e.pdf

An Analysis of the Effects of Residential Photovoltaic Energy Systems on Home Sales Prices in California http://eetd.lbl.gov/ea/emp/reports/lbnl-4476e.pdf

Public Safety (including fires)

Question: What public safety issues arise from people's (including children) access areas where the solar arrays are installed? Can electrical and other equipment associated with solar projects cause electrical fires?

Bottom Line: Large-scale ground-mounted arrays are typically enclosed by fencing. This prevents children and the general public from coming into contact with the installations, thus preventing unsafe situations. The National Electric Code has mandatory requirements to promote the electrical safety of solar PV arrays. The solar industry and firefighters provide training and education for emergency personnel to ensure that the proper safety precautions are taken.

More Information: The National Electric Code has mandatory requirements for the electrical safety of solar PV arrays. To protect intruders, Article 690 of the National Electric Code covers the safety standards for solar PV installation and requires that conductors installed as part of solar PV be "not readily accessible." With a large-scale ground-mounted array, a fence is typically installed around the system to prevent intruders. Some communities have solar PV or signage by-laws that require identification of the system owner and 24-hour emergency contact information.

DOER's model by-law/ordinance requires owners of solar PV facilities to provide a copy of the project summary, electrical schematic, and site plan to the local fire chief, who can then work with the owner and local emergency services to develop an emergency response plan.

These measures can be combined with products to prevent theft of the panels. Some are very low cost options (fastener type) while there are other options that are more expensive (alarm system type) but also more effective. The biggest potential risk associated with solar PV systems is the risk of shock or electrocution for firefighters and other emergency responders who could come in contact with high voltage conductors. A 2010 study on firefighter safety and emergency response for solar PV systems by the Fire Protection Research Foundation, based in Quincy, Massachusetts, recommended steps firefighters can take when dealing with wiring and other components that may be energized. The Solar Energy Business Association of New England (SEBANE) has been working to provide training and education to first-responders to identify and avoid potential hazards when responding to a solar PV fire.

For more information about toxics/fires, see the Hazardous Materials Section.

Resources:

"*Moskowitz*, *P.D.* and Fthenakis, V.M., Toxic Materials Released from Photovoltaic Modules During *Fires*: Health Risks, Solar Cells, 29, 63-71, 1990. 21."

Solar America Board for Codes and Standards
http://www.solarabcs.org/about/publications/reports/blindspot/pdfs/BlindSpot.pdf

"Fire Fighter Safety and Emergency Response for Solar Power Systems: Final Report" May 2010.
Prepared by The Fire Protection Research Foundation

National Electric Code Article 250: Grounding and Bonding, Article 300: Wiring Methods, Article 690 Solar PV Systems, Article 705 Interconnected Electric Power Production Sources

Historic Preservation

Question: What are the appropriate standards when land with certain historical or archaeological significance is developed for large-scale solar PV arrays?

Bottom Line: Parties undertaking solar PV projects with state or federal agency involvement must provide the Massachusetts Historical Commission (MHC) with complete project information as early as possible in the planning stage, by mail, to the MHC's office (see Resources). Parties should also contact local planning, historical or historic district commissions to learn about any required local approvals. Municipalities should also take the presence of historic resources into account when establishing zoning regulations for solar energy facilities in order to avoid or minimize impacts.

More Information: Land being evaluated for the siting large-scale solar PV may have historical or archaeological significance, including properties listed in the National or State Registers of Historic Places and/or the Inventory of Historic and Archaeological Assets of the Commonwealth.

Federal and state laws require that any new construction, demolition or rehabilitation projects (including new construction of solar PV) that propose to use funding, licenses or permits from federal or state government agencies must be reviewed by the MHC so that feasible alternatives are developed and implemented to avoid or mitigate any adverse affects to historic and archaeological properties. Projects receiving federal funding, licenses or permits are reviewed by the involved federal agency in consultation with the MHC and other parties in compliance with Section 106 of the National Historic Preservation Act of 1966 (16 U.S.C. 470f) and the implementing regulations (36 CFR 800) in order to reach agreement to resolve any adverse effects. Projects receiving state funding, licenses or permits must notify the MHC in compliance with M.G.L. c. 9, ss. 26-27C and the implementing regulations 950 CMR 71. If the MHC determines that the project will have an adverse effect, the involved state agency, the project proponent, the local historical preservation agencies, and other interested parties consult to reach an agreement that outlines measures to be implemented to avoid, minimize, or mitigate adverse effects. For projects with both federal and state agency involvement, the Section 106 process is used.

Some communities have local preservation ordinances or established historic districts that require local approval for new construction visible from a public way. Local historic district commissions have adopted design guidelines for new construction within their historic districts and historic neighborhoods. However, these guidelines must account for Chapter 40C Section 7 of the General Laws, which requires a historic district commission to consider the policy of the Commonwealth to encourage the use of solar energy systems and to protect solar access.

Resources:

Federal Agency Assisted Projects:

Section 106 review information and federal regulations 36 CFR 800 are available at the Advisory Council on Historic Preservation (ACHP) web site: www.achp.gov. Check with the involved federal agency for how they propose to initiate the MHC notification required by 36 CFR 800.3.

State Agency Assisted Projects:

Massachusetts General Laws Chapter 9, sections 26-27C
http://www.malegislature.gov/Laws/GeneralLaws/Search

MHC Regulations 950 CMR 71 (available from the State House Bookstore)

MHC Review & Compliance FAQs http://www.sec.state.ma.us/mhc/mhcrevcom/revcomidx.htm

MHC Project Notification Form (PNF) & Guidance for Completing the PNF and required attachments (USGS locus map, project plans, current photographs keyed to the plan). Mail or deliver the complete project information to the MHC's office: http://www.sec.state.ma.us/mhc/mhcform/formidx.htm

General Guidance about Designing Solar PV Projects on Historic Buildings and in Historic Areas: http://www.nrel.gov/docs/fy11osti/51297.pdf

Noise

Question: Do the inverters, transformers or other equipment used as part of ground-mounted solar PV create noise that will impact the surrounding neighborhood?

Bottom Line: Ground-mounted solar PV array inverters and transformers make a humming noise during daytime, when the array generates electricity. At 50 to 150 feet from the boundary of the arrays, any sound from the inverters is inaudible. Parties that are planning and designing ground-mounted solar PV can explore options to minimize noise impacts to surrounding areas even more. These could include conducting pre-construction sound studies, evaluating where to place transformers, and undertaking appropriate noise mitigation measures.

More Information: Most typically, the source of noise associated with ground-mounted solar PV comes from inverters and transformers. There also may be some minimal noise from switching gear associated with power substations. The crackling or hissing sound caused by high-voltage transmission lines (the "Corona effect") is not a concern in the case of solar PV, which uses lower voltage lines.

Parties siting ground-mounted solar PV projects should consult equipment manufacturers to obtain information about sound that can be expected from electrical equipment, which can vary. For example, according to manufacturer's information, a SatConPowergate Plus 1 MW Commercial Solar PV Inverter has an unshielded noise rating of 65 decibels (dBA) at five feet. This is approximately the sound equivalent of having a normal conversation with someone three feet away. Another source of information is the National Electrical Manufacturers Association (NEMA) standards, which will provide maximum sound levels from various equipment arrays. From NEMA, a large dry-type transformer (2001-3333 kVA) that is forced air cooled and ventilated has an average sound level of 71 dBA, which is approximately the sound level one would expect from a vacuum cleaner at ten feet. There may be several such units on a substantially sized PV site, which would increase the sound level to some degree.

Sound impacts from electrical equipment can be modeled to the property line or nearest sensitive receptor (residence). Sound impacts can be mitigated with the use of enclosures, shielding and placement of the sound-generating equipment on-site. The rule of thumb for siting noise-generating equipment is that the sound impact can be reduced by half by doubling the distance to the receptor.

In some areas both in the U.S. and Canada, sound impact analysis is required as part of the permitting process for large PV systems. For example, in the Province of Ontario, Canada, any project greater than 12 MW is required to perform a sound impact analysis (Ontario 359/09). California also requires a sound impact analysis for Large PV projects. Massachusetts currently has no such requirement, but the reader should note that ground mounted systems in Massachusetts very rarely go over 6 MW, which is half the size of the 12 MW that triggers a sound analysis in Ontario.

A recent study measured noise levels at set distances from the inverters and from the outer boundary of three ground mounted PV arrays in Massachusetts with a capacity range of 1 to 3.5 MW. Close to the inverters (10 feet), sound levels varied from an average of 55 dBA to 65 dBA. Sound levels along the fenced boundary of the PV arrays were generally at background levels, though a faint inverter hum could be heard at some locations. Any sound from the PV array and equipment was inaudible and sound levels were at background levels at setback distances of 50 to 150 feet from the boundary. Project developers should consult with local planning and zoning officials to determine if local noise ordinances may be applicable. Many local noise ordinances establish absolute limits on project impact noise (such as a 40 dBA nighttime limit). In these communities, a noise impact assessment may be required.

Resources:

NEMA Standards Publication No. TR=1-1993(R2000), *Transformers, Regulators and Reactors*

Noise Assessment: Borrego 1 Solar Project, MUP 3300-10-26 Prepared by Ldn Consulting, Inc, Fallbrook, CA. January 14, 2011

Ontario Regulation 359/09 Renewable Energy Approval (REA) Regulation, Ontario Ministry of the Environment, Canada

Tech Environmental, Study of Acoustic and EMF levels from Solar Photovoltaic Projects, Prepared for the Massachusetts Clean Energy Center, December 2012

Water-Related Impacts

Question: Can chemicals that might be contained in solar PV threaten public drinking water systems? Will flooding occur in cases where trees must be removed in order to install the solar arrays? How do we ensure that wetland resources are protected?

Bottom Line: Rules are in place to ensure that ground-mounted solar arrays are installed in ways that protect of public water supply, wetlands, and other water resource areas. All solar panels are contained in a solid matrix, are insoluble and are enclosed. Therefore releases are not a concern.

More Information: Because trees offer multiple water management, cooling and climate benefits, clear cutting of trees for the installation of ground-mounted solar PV is discouraged. For projects that do propose to alter trees, the Massachusetts Environmental Policy Act (MEPA) has thresholds for the proposed alteration of a certain number of acres of land, the size of electrical facilities, and other criteria that trigger state review of proposed projects. Clear cutting of trees and other aspects of proposed projects would be reviewed through an Environmental Notification Form/Environmental Impact Statement if thresholds are triggered.

MassDEP has determined that the installation of solar arrays can be compatible with the operation and protection of public drinking water systems. This includes the installation of solar arrays within Zone I, which is a 400-foot protective radius around a public ground water well. Solar projects proposed on lands owned by public water systems outside Zone I may be approved subject to standard best management practices, such as proper labeling, storage, use, and disposal of products. MassDEP has a guidance/review process in place to ensure that the installation of ground-mounted solar PV in these areas protects public water supplies.

Installing solar arrays on undeveloped land can preserve the permeable nature of the land surface provided the project design minimizes disturbance to natural vegetative cover, avoids concentrated runoff, and precipitation is otherwise recharged into the ground to the greatest extent practicable. Storm water flow, as well as information about site-specific soils and slope, is taken into account during the design and installation of solar arrays.

MassDEP discourages installation of ground-mounted solar PV systems in wetland areas, including riverfront locations. Solar projects within wetland areas are unlikely to comply with the performance standards in the Wetlands Protection Act regulations. If a solar installation is proposed in a wetland, a riverfront area, a floodplain, or within 100 feet of certain wetlands, the project proponent must file a notice of intent (or application to work in wetland areas) with the local Conservation Commission, which administers the Wetlands Protection Act at the municipal level. Copies should also go to MassDEP. Solar installations may be sited near, but outside of wetlands, in a manner that protects the functions of wetlands and that minimizes impacts from associated activities such as access and maintenance. Ancillary structures related to construction of a solar installation or transmission of power may be permitted to cross rivers and streams using best design and management practices.

Resources:

More information about the Wetlands Protection Act requirements may be found in the implementing regulations at 310 CMR 10.00: http://www.mass.gov/dep/service/regulations/310cmr10a.pdf

More information about Environmental Notification Form/Environmental Impact Statement: http://www.env.state.ma.us/mepa/regs/11-03.aspx.

MassDEP Policy for Siting Solar Projects in Zone I: http://www.mass.gov/dep/water/laws/1101.htm

MassDEP Guidance for Siting Wind and Solar in Public Water Supply Land: http://www.mass.gov/dep/water/laws/wseppws.htm

MassDEP Chapter 91 Guidance for Renewable Energy Projects: http://www.mass.gov/dep/water/priorities/ene_91.htm

Glare

Question: How important is reflectivity and potential visual impacts from solar projects, especially near airports?

Bottom Line: Solar panels are designed to reflect only about 2 percent of incoming light, so issues with glare from PV panels are rare. Pre-construction modeling can ensure that the placement of solar panels prevents glare.

More Information: Solar panels are designed to absorb solar energy and convert it into electricity. Most are designed with anti-reflective glass front surfaces to capture and retain as much of the solar spectrum as possible. Solar module glass has less reflectivity than water or window glass. Typical panels are designed to reflect only about 2 percent of incoming sunlight. Reflected light from solar panels will have a significantly lower intensity than glare from direct sunlight.

An analysis of a proposed 25-degree fixed-tilt flat-plate polycrystalline PV system located outside of Las Vegas, Nevada showed that the potential for hazardous glare from flat-plate PV systems is similar to that of smooth water and is not expected to be a hazard to air navigation.

Many projects throughout the U.S. and the world have been installed near airports with no impact on flight operations. United Kingdom and U.S. aircraft accident databases contain no cases of accidents in which glare caused by a solar energy facility was cited as a factor.

When siting solar PV arrays pre-construction modeling can ensure the panels are placed in a way that minimizes any potential glare to surrounding areas.

Resources:

Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration, November 2010 (currently under review): http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide.pdf

A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems, Black & Veatch Corporation, August 2011: http://www.isrn.com/journals/re/2011/651857/

Solar Photovoltaic Energy Facilities, Assessment of Potential Impact on Aviation, Spaven Consulting, January 2011: http://plan.scambs.gov.uk/swiftlg/MediaTemp/1121414-374831.pdf

Endangered Species and Natural Heritage

Question: Who ensures that rare animal and plant species and their habitats are not displaced or destroyed during the construction of ground-mounted solar PV?

Bottom Line: Rules are in place to ensure that the installation of ground mounted solar arrays protects state-listed rare species and animals and plants. Project proponents can check with the local Conservation Commission to determine if the footprint of the solar PV project lies within a rare species habitat.

More Information: The Massachusetts Natural Heritage and Endangered Species Program (NEHSP) was created under the Massachusetts Endangered Species Act (MESA) and is responsible for protecting rare animal and plant species and their habitats from being displaced or destroyed. Specifically, NEHSP reviews projects proposed for:

- **Priority Habitats:** These are areas known to be populated by state-listed rare species of animals or plants. Any project that could result in the alteration of more than two acres of Priority Habitat is subject to NHESP regulatory review. Projects will need to file a MESA Information Request Form, along with a project plan, a U.S. Geological Service (USGS) topographical map of the site, and a $50 processing fee. NHESP will let project administrators know within 30 days if the filing is complete, then will determine within the next 60 days whether the project, as proposed, would result in a "take" of state-listed rare species that might require the project to redesign, scale down, or abandon its plan.

- **Estimated Habitats.** These are a sub-set of Priority Habitats that are based on the geographical range of state-listed rare wildlife – particularly animals that live in and around wetlands. If the project is proposed for one of these areas and the local Conservation Commission requires filing a Notice of Intent (NOI) under the Wetlands Protection Act, the project will need to submit copies of the NOI, project plans and a U.S. Geological Service (USGS) topographical map to NHESP. Within 30 days of receiving this information, NHESP will send its comments to the Conservation Commission, with copies to the project administrator, project consultants, and the Department of Environmental Protection (MassDEP).

Projects can check with the Conservation Commission in your town or city to find out if its footprint lies within an Estimated Habitat for rare species. Each Commission has a large-scale map of its community available for public inspection. Each map NHESP develops to delineate a Priority Habitat or Estimated Habitat is based on at least 25 years of local rare animal and plant observation, and the best scientific evidence available. It is important to note that to ensure adequate protection of rare species, NHESP does not disclose detailed site-specific information about them.

Resources:

To learn more about the NHESP review process and download a MESA Information Request Form, visit:
http://www.mass.gov/dfwele/dfw/nhesp/regulatory_review/mesa/mesa_project_review.htm

For lists of rare animal and plant species in Massachusetts, visit:
http://www.mass.gov/dfwele/dfw/nhesp/species_info/mesa_list/mesa_list.htm

DOER
Massachusetts Department of Energy Resources

MassDEP

MASSACHUSETTS CLEAN ENERGY CENTER

Health and Safety Concerns of Photovoltaic Solar Panels

Introduction

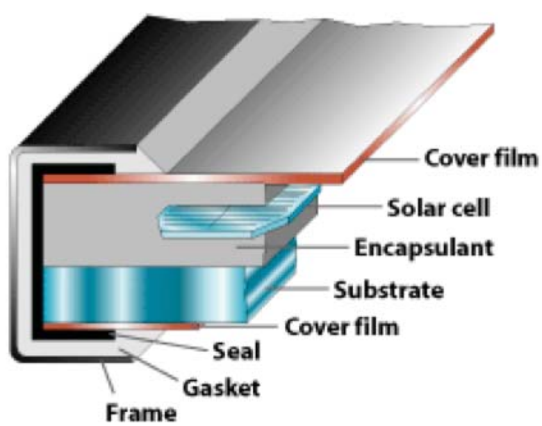
The generation of electricity from photovoltaic (PV) solar panels is safe and effective. Because PV systems do not burn fossil fuels they do not produce the toxic air or greenhouse gas emissions associated with conventional fossil fuel fired generation technologies. According to the U.S. Department of Energy, few power-generating technologies have as little environmental impact as photovoltaic solar panels.[1]

However, as with all energy sources, there are *potential* environmental, health and safety hazards associated with the full product life cycle of photovoltaics. Recent news accounts have raised public interest and concerns about those potential hazards.[2] A substantial body of research has investigated the life cycle impacts of photovoltaics including raw material production, manufacture, use and disposal. While some potentially hazardous materials are utilized in the life cycle of photovoltaic systems, none present a risk different or greater than the risks found routinely in modern society.

The most significant environmental, health and safety hazards are associated with the use of hazardous chemicals in the manufacturing phase of the solar cell. Improper disposal of solar panels at the end of their useful life also presents an environmental, health and safety concern. The extraction of raw material inputs, especially the mining of crystalline silica, can also pose an environmental, health and safety
The environmental, health and safety concerns for the life-cycle phase are minimal and limited to rare and infrequent events. With effective regulation, enforcement, and vigilance by manufacturers and operators, any danger to workers, the public and the environment can be minimized. Further, the benefits of photovoltaics tend to far outweigh risks especially when compared to conventional fossil fuel technologies. According to researchers at the Brookhaven National Laboratory, regardless of the specific technology, photovoltaics generate significantly fewer harmful air emissions (at least 89%) per kilowatt-hour (KWh) than conventional fossil fuel fired technologies.[3]

Materials used in photovoltaics solar panels

The basic building block of a photovoltaic solar system is the solar cell. Solar cells are solid state, semiconductor devices that convert sunlight into electricity. Typically a number of individual cells are connected together to form modules, or solar panels. In order to provide electrical insulation and protect against environmental corrosion, the solar cells are encased in a transparent material referred to as an encapsulant. To provide structural integrity the solar cells are mounted on top of a rigid flat surface or substrate. A transparent cover film, commonly glass, further protects these components from the elements.



Courtesy of the U.S. Department of Energy

Several types of semiconductor materials are used to manufacture solar cells but the most common material is crystalline silicon, typically from quartz or sand, capturing a 60% market share.[4] Crystalline silicon semiconductors are also utilized in the manufacture of integrated circuits and microchips used in personal computers, cellular telephones and other modern electronics.

The outer glass cover constitutes the largest share of the total mass of a finished crystalline photovoltaic module (approximately 65%), followed by the aluminum frame (~20%), the ethylene vinyl acetate encapsulant (~7.5%), the polyvinyl fluoride substrate (~2.5%), and the junction box (1%). The solar cells themselves only represent about four percent (4%) of the mass of a finished module.[5]

Oregon Department of Transportation Solar Highway photovoltaic solar panel selection
The solar panels proposed for use in the Oregon Department of Transportation's Solar Highway program feature domestically manufactured and assembled monocrystalline silicon modules. The information presented below, therefore, focuses on the life cycle environmental, health and safety hazards generally associated with this technology.

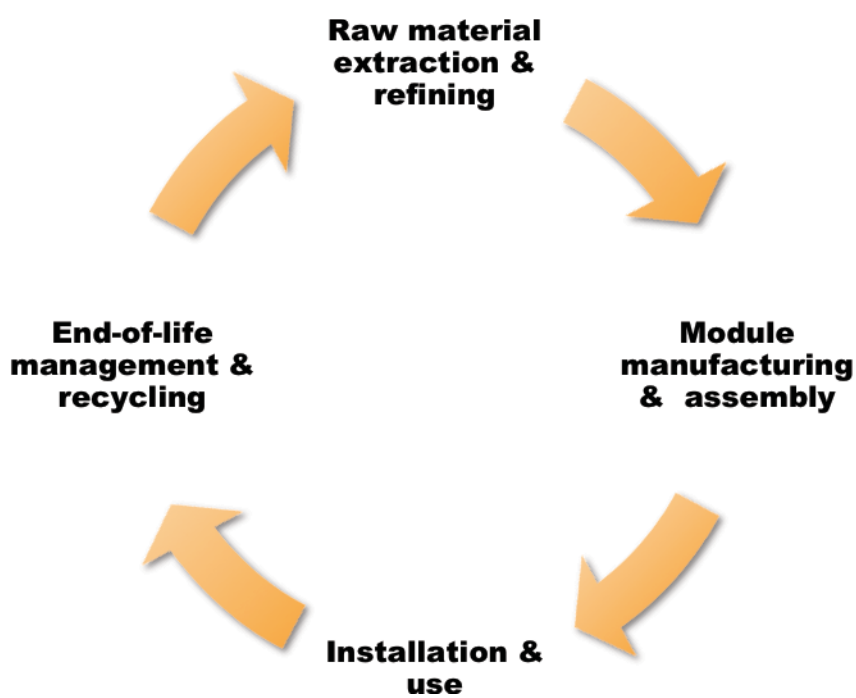
Life Cycle of Monocrystalline Silicon Solar Panels

The simplified process diagram below illustrates the basic life-cycle stages for the manufacturing of monocrystalline silicon (c-Si) solar panels.

The life cycle of a c-Si panel starts with mining of crystalline silica in the form of quartz or sand. The raw material is then refined in industrial furnaces to remove impurities to produce metallurgical grade silicon (~98% pure silicon). The metallurgical grade silicon is then further refined to produce high purity polysilicon for use in the solar and semiconductor industry. Next, the polysilicon is used to grow monocrystalline rods or ingots. These ingots are then shaped and sawn into very thin wafers. The wafers are then manufactured into solar cells and assembled into photovoltaic modules ready for installation. At the end of their useful life the materials in the panels can recycled and used as feedstock material for new panels.

The potential environmental, health and safety hazards associated with each of these steps are described on the following pages.

Figure 1: Simplified Photovoltaic Solar Panel Life Cycle



Raw material extraction and refining for solar panels

The material inputs phase consists of the extraction and processing of raw materials that are then used in the production of solar panels.

Crystalline Silica Mining

Process

Crystalline silica is the primary raw material input for the manufacture of monocrystalline solar panels. Crystalline silica is found in the environment primarily as sand or quartz. The extraction process varies by location, but typically involves some combination of earth moving, crushing, milling, washing, and screening to separate the crystalline silica particles from other minerals and impurities and to achieve the desired grain size.[6] The end product is variously referred to as silica sand, quartz silica or simply silica or quartz.

Health and Safety

A potentially harmful by-product associated with the mining and processing of silica sand is crystalline silica dust. Silica dust has been associated with silicosis, a lung disease where scar tissue forms in the lungs and reduces the ability to breath.[7] Crystalline silica dust is classified as a known human carcinogen by the International Agency for Research on Cancer.[8] Studies show increased risk of developing lung cancer through regular exposure to crystalline silica dust. Other health problems associated with regular, high exposure include chronic obstructive pulmonary disease, rheumatoid arthritis, scleroderma, Sjogern's syndrome, lupus, and renal disease.[9]

The widely recognized risk of human exposure to silica dust has resulted in the implementation of stringent health, safety, and environmental measures in the United States and across the globe. Examples of mitigation measures include monitoring air quality, automation of processes to limit human exposure, dust suppression measures and personal protective devices for workers such as respirators.[10]

It should be noted that the majority of global silica sand production (more than 80%) is used for the manufacture of glass and ceramics, metal casting and abrasives, while only 2% is utilized in the production of metallurgical grade silicon.[11]

Upgrading Silica Sand to Metallurgical Grade Silicon

Process

Metallurgical grade silicon is used in the manufacture of metal alloys such as aluminum and steel, chemical silicones for use in lubricants and epoxies as well as high purity polysilicon for the manufacture of semiconductors including solar panels. Consumption by the semiconductor industry, including photovoltaics, accounts for approximately 6% of global metallurgical grade silicon production.[12] In order to transform industrial grade silica sand into metallurgical grade silicon, the silica is combined with carbon in the form of charcoal, coal, or coke in an electric arc furnace in a process called carbothermic reduction.

Health and Safety

The primary emissions from this process are carbon dioxide and sulfur dioxide from the combustion of carbon sources. Another by-product of the process is fume silica captured via a piece of emission control technology called a bag house. If respirated, fume silica can pose the same health concerns as silica dust.[13] Additionally, there are indirect emissions of carbon dioxide from the consumption of electricity to power the electric arc furnace. The source and carbon intensity of this electricity varies by region.

Upgrading Metallurgical Grade Silicon to Polysilicon

Process

In order to reach a purity level acceptable for use in manufacture of semiconductor devices, metallurgical grade silicon must go through two additional purification steps. The primary output from this purification process is polysilicon, the precursor to the silicon wafers used to manufacture the integrated circuits at the heart of most electronics as well as monocrystalline photovoltaic solar cells.

In the first step, pulverized metallurgical grade silicon is combined with hydrogen chloride gas and a copper catalyst in a fluid bed reactor to produce trichlorosilane. Trichlorosilane is the primary chemical feedstock for the production of polysilicon. This step also yields silicon tetrachloride, which can either be captured and further processed into trichlorosilane or utilized as a feedstock in the manufacture of fiber optics. Other byproducts from this phase include silane, dichlorosilane and chlorinated metals. Dichlorosilane is an important precursor to silicon nitride, a ceramic material used, among other applications, in the manufacture of automobile engine parts.[14,15]

To produce polysilicon, the trichlorosilane is subjected to a distillation process until the desired purity level is achieved. The purified trichlorosilane is then used to deposit very pure polysilicon in a chemical vapor deposition reactor. This process, commonly referred to as the Siemens process, accounts for as much as 98% of the world's polysilicon production.[16] Historically, polysilicon destined for photovoltaic solar cells was considered "waste" material that did not meet the purity requirement of the electronics industry and accounted for approximately 10% of polysilicon production.[17] There are indications that this trend may be changing as the size of photovoltaic markets expand.

Health and Safety

This process involves multiple potentially hazardous materials and byproducts that without proper safeguards can pose a significant risk to human and environmental health. Chlorosilanes and hydrogen chloride are toxic and highly volatile, reacting explosively with water. Chlorosilanes and silane can also spontaneously ignite and under some conditions explode.[18] Silicon tetrachloride can cause skin burns and is also an eye and respiratory irritant.[19] Silicon tetrachloride has recently gained notoriety due to news accounts of its dumping near a polysilicon plant in China.[20]

Notably, Western production facilities accounted for more 99% of global polysilicon production in 2005, the latest year for which data is available.[21] These facilities use a closed loop process that captures system byproducts for recycling and reuse within the process loop because these recovery systems are necessary for the economic operation of a facility.[22] Furthermore, any waste gasses not recoverable for recycling are led through a series of pollution control technologies (e.g. wet scrubbers) prior to any environmental releases. Environmental releases include very low levels of particulate matter, hydrogen chloride and silicon tetrachloride.[23]

Furthermore, facilities in the United States, Japan and Europe are subject to strict environmental and occupational health and safety regulation and enforcement. In contrast, production capacity is rapidly expanding in developing countries such as China and India where such safeguards may not exist or be enforced. Regardless of their location, reputable and responsible firms will have implemented beyond compliance environmental management systems (e.g. ISO 14001 certification) and adopted voluntary industry best management guidelines (e.g. Responsible Care).

Manufacturing and assembly of solar panels

From Wafer to Cell

Process

Solar cells are produced by transforming polysilicon into a cylindrical ingot of monocrystalline silicon, which is then shaped and sliced into very thin wafers. Next, a textured pattern is imparted to the surface of the wafer in order to optimize the absorption of light. The wafer is then subjected to high temperatures in the presence of phosphorous oxychloride in order to create the physical properties required to produce electricity. Next an anti-reflective coating of silicon nitride is applied to the top surface of the cell to minimize reflection and increase efficiency of light absorption. Finally, metallic electrical conductors are screen printed onto the surface wafer to facilitate the transport of electricity away from the cell. The production of solar cells is concentrated in Japan, Europe and the United States, which currently account for more than 80% of global production.[24]

Health and Safety

Many different potentially hazardous chemicals are used during the production of solar cells. The primary environmental, health and safety concerns are exposure to and inhalation of kerf dust, a byproduct of sawing the silicon ingots into wafers, and exposure to solvents, such as nitric acid, sodium hydroxide and hydrofluoric acid, used in wafer etching and cleaning as well as reactor cleaning. Many of these solvents also pose a risk of chemical burns. Other occupational hazards include the flammability of silane used in the deposition of anti-reflective coatings.[25]

The most likely exposure route for factory workers is inhalation of vapors or dusts. Secondarily, there is exposure risk for factory workers from accidental spills. Risks to surrounding communities include the release of hazardous gasses from an industrial accident or fire at the manufacturing facility.[26] These hazards are regulated by a number of occupational and environmental standards as well as industry adopted voluntary best management practices. These regulations and strategies include: extensive occupational ventilation systems, accident prevention and planning programs and emergency confinement and absorption units.[27] As a result of these safeguards, there have been no known catastrophic releases of toxic gases from photovoltaic manufacturing facilities in the United States.[28]

Module components and assembly

Process

A typical solar module consists of several individual cells wired together and enclosed in protective material called an encapsulant, commonly made of ethylene vinyl acetate. To provide structural integrity the encapsulated cells are mounted on a substrate frequently made of polyvinyl fluoride. Both ethylene vinyl acetate and polyvinyl fluoride are widely considered to be environmentally preferable to other chlorinated plastic resins. A transparent cover, commonly glass, further protects these components from weather when in place for electrical generation. The entire module is held together in an aluminum frame. Most modules also feature an on board electrical junction box.[29]

Health and Safety

Individual solar cells are typically soldered together with copper wire coated with tin. Some solar panel manufacturers utilize solders that contain lead and other metals that if released into the environment can pose environmental and human health risks. Module assembly is not a likely pathway for human exposure to these metals as this step in the assembly process is typically automated. For more discussion regarding the end-of-life product phase risks of lead containing solders, see the discussion in the decommissioning and recycling section below.

Installation and use of solar panels

Installed silicon-based cells pose minimal risks to human health or the environment according to reviews conducted by the Brookhaven National Lab and the Electric Power Research Institute.[30]

Health and Safety

Because solar panels are encased in heavy-duty glass or plastic, there is little risk that the small amounts of semiconductor material present can be released into the environment.

In the event of a fire, it is theoretically possible for hazardous fumes to be released and inhalation of these fumes could pose a risk to human health.[31] However, researchers do not generally believe these risks to be substantial given the short-duration of fires and the relatively high melting point of the materials present in the solar modules. [32] Moreover, the risk of fire at ground-mounted solar installations is remote because of the precautions taken during site preparation including the removal of fuels and the lack of burnable materials – mostly glass and aluminum – contained in a solar panel.

A greater potential risk associated with photovoltaic systems and fire is the potential for shock or electrocution if a fire-fighter or emergency responder comes in contact with a high voltage conductor. These concerns are almost entirely related to roof mounted residential and commercial solar arrays. The Oregon Building Code Division is currently considering new rules to increase public safety for structures equipped with solar photovoltaic systems. The proposed rules are inspired by a model code adopted by the California Department of Forestry & Fire Protection. As it applies to ground mounted photovoltaic arrays, the California model code calls for a clear marking of system components in order to provide emergency responders with appropriate warnings.[33]

The strength of electromagnetic fields produced by photovoltaic systems do not approach levels considered harmful to human health established by the International Commission on Non-Ionizing Radiation Protection. Moreover the small electromagnetic fields produced by photovoltaic systems rapidly diminish with distance and would be indistinguishable from normal background levels within several yards. For a detailed discussion of electromagnetic fields and solar arrays read the *Scaling Public Concerns of Electromagnetic Fields Produced by Solar Photovoltaic Arrays* paper at http://www.oregonsolarhighway.com.

End-of-life management and recycling of solar panels

Process

While the solar cell is the heart of a photovoltaic system, on a mass basis it accounts for only a small fraction of the total materials required to produce a solar panel. The outer glass cover constitutes the largest share of the total mass of a finished crystalline photovoltaic module (approximately 65%), followed by the aluminum frame (~20%), the ethylene vinyl acetate encapsulant (~7.5%), the polyvinyl fluoride substrate (~2.5%), and the junction box (1%). The solar cells themselves only represent about four percent (4%) of the mass of a finished module.[34]

Proper decommissioning and recycling of solar panels both ensures that potentially harmful materials are not released into the environment and reduces the need for virgin raw materials. In recognition of these facts, the photovoltaic industry is acting voluntarily to implement product take-back and recycling programs at the manufacturing level. Collectively, the industry recently launched PV Cycle – a trade association to develop an industry-wide take back program in Europe.[35] In the United States, product take-back and recycling programs vary by manufacturer; SolarWorld, the supplier selected for the three Oregon Solar Highway projects, is one of the manufacturers which fully supports the entire life cycle of their product.

While recycling methods and take-back policies vary by manufacturer, the most frequently recycled components are the cover glass, aluminum frame, and solar cells. Small quantities of valuable metals including copper and steel are also recoverable. The ethylene vinyl acetate encapsulant and polyvinyl fluoride substrate are typically not recoverable and are removed through a thermal process with strict emission controls and the by-product ash land-filled. Following this process, the glass and aluminum frame are separated and typically sold to industrial recyclers. The solar cells are then reprocessed into silicon wafers with valuable metals recovered and sold. Depending on the condition, the wafer can then either be remade into a functioning cell or granulated to serve as feedstock for new polysilicon.[36]

Health and Safety
If not properly decommissioned, the greatest end of life health risk from crystalline solar modules arises from lead containing solders. Under the right conditions it is possible for the lead to leach into landfill soils and eventually into water bodies. Notably total lead solder use accounts for only approximately 0.5% of lead use in the United States.

References

[1] U.S. Dept. of Energy (2010). “Photovoltaic Basics.” Accessed January 5, 2010 at http://www1.eere.energy.gov/solar/pv_basics.html.

[2] Silicon Valley Toxics Coalition (2009). “Toward a Just and Sustainable Solar Energy Industry.” Available at http://www.svtc.org/site/DocServer/Silicon_Valley_Toxics_Coalition_-_Toward_a_Just_and_Sust.pdf?docID=821.

[3] Vasilis Fthenakis, Hyung Chul Kim and Erik Alsema (2008). "Emissions from Photovoltaic Life-Cycles." *Environmental Science and Technology* 2008 42 (6):2168-2174. Available at: http://pubs.acs.org/doi/full/10.1021/es071763q.

[4] Energy Information Agency (2008). "Solar Photovoltaic Cell/Module Manufacturing Activities 2007." U.S. Department of Energy. Available at http://www.eia.doe.gov/cneaf/solar.renewables/page/solarreport/solarpv.pdf.

5 Knut Sander (2007). Study on the Development of a Take Back and Recovery System for Photovoltaic Products. Brussels: Belgium: PV Cycles. Available at: http://www.pvcycle.org/fileadmin/pvcycle_docs/documents/publications/Report_PVCycle_Download_En.pdf

[6] Angello, VN (2004). "The Silica Industry in the Republic of South Africa." Republic of South Africa Department of Minerals and Energy. Available at http://www.dme.gov.za/pdfs/minerals/R44 - update 2007.pdf.

[7] Abdiaziz Yassin, Francis Yebesi and Rex Tingle (2005). “Occupational Exposure to Crystalline Silica Dust in the United States: 1988–2003.” *Environmental Health Perspectives* 113(3):255-260. Available at http://ehp.niehs.nih.gov/members/2004/7384/7384.pdf.

[8] IARC (1987). *Silica and Some Silicates*. IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Humans, Vol. 42. Lyon, France: International Agency for Research on Cancer.

[9] Abdiaziz Yassin, Francis Yebesi and Rex Tingle (2005). “Occupational Exposure to Crystalline Silica Dust in the United States: 1988–2003.” *Environmental Health Perspectives* 113(3):255-260. Available at http://ehp.niehs.nih.gov/members/2004/7384/7384.pdf.

[10] MineEx Health and Safety Council of New Zealand (2008). "Guideline for the Control Dust and Associated Hazards in Surface Mine and Quarries." Available at: http://www.minex.org.nz/pdf/SUR_Dust_Mar08.pdf

[11] Williams, Eric (2000). "Global Production Chains and Sustainability: The Case of High-purity Silicon and its Applications in IT and Renewable Energy." Tokyo: United Nations University Institute of Advanced Studies. Available at http://www.it-environment.org/publications/QITS report.pdf.

[12] Williams, Eric (2000). "Global Production Chains and Sustainability: The Case of High-purity Silicon and its Applications in IT and Renewable Energy." Tokyo: United Nations University Institute of Advanced Studies. Available at http://www.it-environment.org/publications/QITS report.pdf.

[13] Williams, Eric (2000). "Global Production Chains and Sustainability: The Case of High-purity Silicon and its Applications in IT and Renewable Energy." Tokyo: United Nations University Institute of Advanced Studies. Available at http://www.it-environment.org/publications/QITS report.pdf.

[14] Hashim, Uda, Ehsan , Abang, and Ahmad Ibrahim (2007). "High Purity Polycrystalline Silicon Growth and Characterization." *Chiang Mai Journal of Science.* Vol. 34, No.1: 47-53. Available at http://www.science.cmu.ac.th/journal-science/341_HighUda.pdf

[15] Williams, Eric (2000). "Global Production Chains and Sustainability: The Case of High-purity Silicon and its Applications in IT and Renewable Energy." Tokyo: United Nations University Institute of Advanced Studies. Available at http://www.it-environment.org/publications/QITS report.pdf.

[16] Hashim, Uda, Ehsan , Abang, and Ahmad Ibrahim (2007). "High Purity Polycrystalline Silicon Growth and Characterization." *Chiang Mai Journal of Science.* Vol. 34, No.1: 47-53. Available at http://www.science.cmu.ac.th/journal-science/341_HighUda.pdf

[17] Y.S. Tsuo, T.H. Wang, and T.F. Ciszek (1999). Crystalline-Silicon Solar Cells for the 21st Century. Washington, D.C.: National Renewable Energy Lab.

[18] Vasilis Fthenakis. "National PV Environmental Research Center: Summary Review of Silane Ignition Studies." Available at http://www.bnl.gov/pv/abs/abs_149.asp.

[19] Adolf Goetzberger and Volker Hoffman (2005). "Photovoltaic Solar Energy Generation." *Springer*, New York.

[20] Ariana Eunjung Cha. "Solar Energy Firms Leave Waste Behind in China." *Washington Post*, March 9, 2009. Available at http://www.washingtonpost.com/wp-dyn/content/article/2008/03/08/AR2008030802595.html.

[21] Flynn, Hillary and Bradford, Travis (2006). Polysilicon: Supply, Demand & Implications for the PV Industry. Cambridge, MA: Prometheus Institute for Sustainable Development.

[22] Hashim, Uda, Ehsan , Abang, and Ahmad Ibrahim (2007). "High Purity Polycrystalline Silicon Growth and Characterization." *Chiang Mai Journal of Science.* Vol. 34, No.1: 47-53. Available at http://www.science.cmu.ac.th/journal-science/341_HighUda.pdf

[23] Hashim, Uda, Ehsan , Abang, and Ahmad Ibrahim (2007). "High Purity Polycrystalline Silicon Growth and Characterization." *Chiang Mai Journal of Science.* Vol. 34, No.1: 47-53. Available at http://www.science.cmu.ac.th/journal-science/341_HighUda.pdf

[24] Maycock, Paul and Bradford, Travis (2006). PV Technology, Performance and Cost. Cambridge, MA: Prometheus Institute for Sustainable Development.

[25] Fthenakis, V.M. (2003). Practical Handbook of Photovoltaics: Fundamentals and Applications: Overview of Potential Hazards. Available at http://www.bnl.gov/pv/files/pdf/art_170.pdf.

[26] Electric Power Research Institute (2003). "Potential Health and Environmental Impacts Associated with the Manufacture and Use of Photovoltaic Cells." Report to the California Energy Commission, Palo Alto, CA. Available at http://mydocs.epri.com/docs/public/000000000001000095.pdf.

[27] Fthenakis, V.M. (2003). Practical Handbook of Photovoltaics: Fundamentals and Applications: Overview of Potential Hazards. Available at http://www.bnl.gov/pv/files/pdf/art_170.pdf.

[28] Electric Power Research Institute (2003). "Potential Health and Environmental Impacts Associated with the Manufacture and Use of Photovoltaic Cells." Report to the California Energy Commission, Palo Alto, CA. Available at http://mydocs.epri.com/docs/public/000000000001000095.pdf.

[29] U.S. Dept. of Energy (2010). "Photovoltaic Basics." Accessed January 5, 2010 at http://www1.eere.energy.gov/solar/pv_basics.html.

[30] Electric Power Research Institute (2003). "Potential Health and Environmental Impacts Associated with the Manufacture and Use of Photovoltaic Cells." Report to the California Energy Commission, Palo Alto, CA. Available at http://mydocs.epri.com/docs/public/000000000001000095.pdf.

[31] Union of Concerned Scientists (n/a). "Environmental Impacts of Renewable Energy Technologies." Available at http://www.ucsusa.org/clean_energy/technology_and_impacts/impacts/environmental-impacts-of.html.

[32] Electric Power Research Institute (2003). "Potential Health and Environmental Impacts Associated with the Manufacture and Use of Photovoltaic Cells." Report to the California Energy Commission, Palo Alto, CA. Available at http://mydocs.epri.com/docs/public/000000000001000095.pdf.

[33] California Department of Forestry and Fire Prevention (2008). Solar Photovoltiac Installation Guidelines. Sacramento: CA. Available at: http://osfm.fire.ca.gov/pdf/reports/solarphotovoltaicguideline.pdf

34 Knut Sander (2007). Study on the Development of a Take Back and Recovery System for Photovoltaic Products. Brussels: Belgium: PV Cycles. Available at: http://www.pvcycle.org/fileadmin/pvcycle_docs/documents/publications/Report_PVCycle_Download_En.pdf

[35] SolarWorld AG (2008). "Annual Group Report 2008 – With Integrated Sustainability Report SolarWorld AG." Available at http://www.solarworld.de/fileadmin/sites/solarworld/pdfs/financial-reports/ar2008.pdf.

36 Knut Sander (2007). Study on the Development of a Take Back and Recovery System for Photovoltaic Products. Brussels: Belgium: PV Cycles. Available at: http://www.pvcycle.org/fileadmin/pvcycle_docs/documents/publications/Report_PVCycle_Download_En.pdf

Department of Energy
Washington, DC 20585

November 12, 2009

Allison Hamilton
Oregon Department of Transportation
355 Capitol St. NE Room 115
Salem, OR 97301-3871

Dear Ms. Hamilton:

Thank you for contacting the U.S. Department of Energy regarding the Oregon Solar Highway program and your proposed 3 megawatt photovoltaic installation. In response to citizen concerns about potential health effects of electromagnetic fields (EMF) generated from the proposed installation, I have asked the National Renewable Energy Laboratory to conduct a literature review on the topic.

Their analysis shows that the health risks of the proposed installation due to electromagnetic fields are minimal, and that this issue should not impede the project from moving forward.

In summary, the magnitude of EMF exposure measured at the perimeter of PV installations has been shown to be indistinguishable from background EMF, and is lower than that from many household appliances such as televisions and refrigerators. Further, evidence linking EMF exposure from high-voltage power lines to cancer has been shown to be weak. High voltage power lines produce much stronger EMF than the proposed PV installation.

The Department of Energy believes strongly in the need to deploy solar technologies on a large scale to meet our national priorities for clean energy. The Department's Solar Energy Technologies Program will continue to aggressively analyze issues of concern to ensure safe, sustainable solar installations nationwide.

Please see the attached memo that further outlines the issues and references the published literature.

Sincerely,

John Lushetsky
Program Manager
U.S. Department of Energy
Solar Energy Technologies Program

Attachment

MEMO

To: John Lushetsky and JoAnn Milliken

From: Greg Brinkman and Robert Margolis, National Renewable Energy Laboratory

Subject: Health effects of electromagnetic fields from solar photovoltaic arrays

Date: August 18, 2009

This memo is in response to citizen concerns about electromagnetic field exposure from a proposed 3 MW solar photovoltaic (PV) installation in Oregon.

Electromagnetic fields (EMF) are produced by a variety of natural sources and can also be generated by the production and distribution of electricity. Residential to utility-scale solar PV arrays (i.e., a few kWs to MWs) will produce very low levels of EMF, comparable to low-voltage power lines. While PV produces direct current (DC) power, it is typically converted into alternating current (AC) power which is either used locally, or fed to the grid, typically on low voltage distribution lines.

The strength of an electromagnetic field is measured in units of Gauss (G). Electromagnetic fields at large PV arrays have been measured by Chang and Jennings.[1] PV panels produce weaker electromagnetic fields (<1 mG 3" from the panel) than many household appliances, such as televisions (7 mG at 10.5") and refrigerators (2.6 mG at 10.5").[2] Inverters and power conditioning units inside a solar PV array do produce significant electromagnetic fields, but the strength of all fields declines rapidly with distance. Electromagnetic fields at the perimeter of the PV system were indistinguishable from the background fields.

Studies have shown human exposure to EMF increases when power lines are within close proximity (less than 150 feet) to a residence. Zaffanella and Kalton[3] estimated that mean residential EMF exposure at homes with overhead power lines within 25 feet was 1.74 mG, with a 95th percentile value of 4.48 mG. Mean residential exposure at homes further than 150 feet from the nearest overhead power line was 0.93 mG, with a 95th percentile value of 2.21 mG. EMF strengths up to 10.3 mG have been measured at houses near high-voltage power lines.

The only evidence that links power lines and EMF to adverse health effects exists for high-voltage power lines. Even this evidence, however, is relatively weak (as described below). The level of EMF produced from high-voltage power lines is much stronger than the level of EMF produced by a solar array or the low voltage power lines required to transmit the electricity from a typical solar array.

Two approaches have been used to evaluate the possible health effects from EMF – epidemiology and toxicology.

- Epidemiological studies investigate correlations between exposure to a potential hazard and adverse health effects in a study population. Bias can occur due to confounding factors if the exposure being studied is correlated with other variables that affect the outcome. For example, living in a residence close to a power line may be correlated with having a lower socioeconomic status, which could affect the incidence of certain health outcomes. This can be controlled using statistical methods if the confounding variables are known.

- Toxicological studies investigate correlations between exposure to a potential hazard and health effects in a population of animals that are usually assigned to a group that receives the exposure and a control group that does not. These studies have an advantage because the two groups can be identical except for exposure levels, and very high exposure levels can be tested. However, laboratory conditions do not always represent environmental exposures and results from animal studies are not always easily extrapolated to humans.

The National Institute of Environmental Health Sciences (NIEHS) at the National Institutes for Health (NIH) performed a review summarizing the health effects of electric and magnetic fields for the Electric and Magnetic Fields Research and Public Information Dissemination Program in the Energy Policy Act of 1992.[4]

The NIEHS study found that the scientific evidence suggesting a link between EMF from high voltage power lines and health effects is weak. The study did find a possible small increased risk of childhood leukemia due to increased exposure to EMF from high voltage power lines using certain methods to measure the exposure.[4] For example, the NIEHS report reviewed five epidemiological studies that examined proximity to different types of power lines as an indicator of EMF exposure. Two of these studies[5,6] showed no evidence of a correlation between power line type and childhood leukemia. Three of the studies did indicate a possible relationship.

Of these three studies, only one study[7] showed a statistically significant correlation between the group with high-voltage power lines near the residence and childhood leukemia. However, this study also measured EMF levels and found no correlation between EMF levels and childhood leukemia. The lack of correlation between EMF levels and childhood leukemia could indicate the presence of a confounding variable that biases the relationship between power line types and childhood leukemia. More recent reviews of scientific studies have found similar results.[8]

Animal exposure studies have not demonstrated a significant link between EMF exposure levels from high voltage power lines and cancers[4], although one study showed a significant reduction in mammary gland tumors in the exposed group.

Conclusion:

Evidence that EMF from power lines can lead to adverse health effects in humans is relatively weak, and is based on exposure to high-voltage power lines in close proximity (within 150 feet) to residences. Large solar photovoltaic arrays would not likely lead to these levels of exposure anywhere outside the perimeter of the system. Based on the available literature, there is little cause for concern of adverse impacts due to the projected electromagnetic fields at homes near the proposed installation.

References:

1. Chang, GJ, Jennings, C. Magnetic Field Survey at PG&E Photovoltaic Sites. Pacific Gas and Electric Company Research and Development Department. August, 1994. Available at: http://www.osti.gov/bridge/servlets/purl/82309-WOEtJb/webviewable/82309.pdf
2. Zaffanella L. Survey of Residential Magnetic Field Sources. Volume 1: Goals, Results and Conclusions. Volume 2: Protocol, Data analysis, and Management TR102759-V1, TR-102759-V2. Palo Alto: EPRI, 1993.
3. Zaffanella LE, Kalton GW. Survey of Personal Magnetic Field Exposure Phase II: 1000-Person Survey EMF*RAPID* Program Engineering Project #6. Oak Ridge, TN: Lockheed Martin Energy Systems, Inc., 1998.
4. Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields. National Institute of Environmental Health Sciences, National Institutes of Health, 1999. Available at: http://www.niehs.nih.gov/health/topics/agents/emf/
5. McBride ML, Gallagher RP, Thériault G, Armstrong BG, Tamaro S, Spinelli JJ, Deadman JE, Fincham B, Robson D, Chaoi W. Power-frequency electric and magnetic fields and risk of childhood leukemia in Canada. American Journal of Epidemiology 149:831-842(1999).
6. Linet MS, Hatch EE, Kleinerman RA, Robison LL, Kaune WT, Friedman DR, Severson RK, Haines CM, Hartsock CT, Niwa S, Wacholder S, Tarone RE. Residential exposure to magnetic fields and acute lymphoblastic leukemia in children. New England Journal of Medicine 337:1-7(1997).
7. London SJ, Thomas DC, Bowman JD, Sobel E, Cheng T-C, Peters JM. Exposure to residential electric and magnetic fields and risk of childhood leukemia. American Journal of Epidemiology 134:923-937(1991).
8. Schuz J, Ahlbom, A. Exposure to electromagnetic fields and the risk of childhood leukemia: a review. Radiation Protection Dosimetry 132:202-211(2008).