

Exponent<sup>®</sup>

*Electrical Engineering and Computer  
Science Practice*

*and*

*Health Science Practice*

**Burlington Solar One**

**Report on Electric and  
Magnetic Fields**



## **Burlington Solar One**

### **Report on Electric and Magnetic Fields**

Prepared for

Burlington Solar One, LLC  
150 Trumbull Street, 4<sup>th</sup> Floor  
Hartford, CT 06103

Prepared by

Exponent  
17000 Science Drive  
Suite 200  
Bowie, MD 20715

January 15, 2020

© Exponent, Inc.

# Contents

---

	<u>Page</u>
<b>Limitations</b>	<b>ii</b>
<b>Executive Summary</b>	<b>iii</b>
<b>Introduction</b>	<b>1</b>
<b>EMF Sources and Characteristics</b>	<b>1</b>
Electric Fields	1
Magnetic Fields	1
<b>Exposure Guidelines</b>	<b>4</b>
Background	4
<b>CSC EMF Best Management Practices</b>	<b>5</b>
<b>Assessment of Project EMF</b>	<b>6</b>
The Project Site	6
Southern Boundary of the Project Site	7
Discussion	7
<b>Summary</b>	<b>9</b>
<b>References</b>	<b>10</b>
Appendix A – Current Status of EMF Health Research	

## Limitations

---

At the request of Burlington Solar One, LLC (a wholly owned subsidiary of VCP, LLC d/b/a Verogy), Exponent prepared this summary report on electric and magnetic fields in the context of the proposed 3.5-Megawatt Burlington Solar One Project in Burlington, Connecticut. The findings presented herein are made to a reasonable degree of engineering and scientific certainty. Exponent reserves the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available, through any additional work, or review of additional work performed by others.

The scope of services performed during this investigation may not adequately address the needs of other users of this report outside of the permitting process, and any re-use of this report or its findings, conclusions, or recommendations presented herein other than for permitting of this project are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation. No guarantee or warranty as to future life or performance of any reviewed condition is expressed or implied.

## Executive Summary

---

Burlington Solar One, LLC (a wholly owned subsidiary of VCP, LLC d/b/a Verogy) proposes to develop a 3.5-Megawatt alternating current (AC), ground-mounted, solar photovoltaic generator system (the Project) in the town of Burlington, Connecticut. The Project Area is an 11.58-acre subset of the approximately 63-acre Project Site, which is bordered to the north and east by forested residential areas, to the west by agricultural fields, and to the south by a residential street (Prospect Street). The Project Area is located on the northern half of the Project Site and is divided into east and west solar arrays.

The direct current (DC) electricity generated by the solar panels will be converted to AC and stepped up to 23-kilovolts (kV) at two transformers and associated inverters located at the southern end of the Project Area. From the transformers, the AC power from the Project will be carried underground to connect to an existing Eversource Energy (Eversource) 23-kV distribution line along Prospect Street.

During operation electric and magnetic fields (EMF) from the Project will derive from 1) the DC solar panels; 2) the DC cables connecting the solar arrays to the power inverters; 3) the AC power inverters that convert the DC power to AC power; and 4) the underground 23-kV interconnection and existing Eversource 23-kV distribution line along Prospect Street, to which the Project will connect. The solar panels and DC cables on site will produce static fields (i.e., at 0 Hertz [Hz]). These sources will not be expected to produce any disturbance to the existing levels of static magnetic fields away from the site that are produced by natural sources within the earth (i.e., the earth's geomagnetic field). Existing levels of the earth's static geomagnetic field are about 8,000 times lower than the standard for exposure of the general public to static magnetic fields recommended by the International Commission on Non-ionizing Radiation Protection (ICNIRP, 2009).

The power inverters will produce AC fields at frequencies greater than 60 Hz close to the inverters on site, so these local on-site sources will not be an important contributor to AC fields offsite. Therefore, this evaluation focused on the underground 23-kV interconnection and 23-kV distribution line that will produce fields at a frequency of 60 Hz on and off site, respectively.

At the maximum output of the Project, the additional current injected onto the existing 23-kV distribution line along Prospect Street will be less than 90 Amperes (A), which would not be expected to increase the magnetic-field level outside the range typical of distribution lines (NIEHS, 2002), and also would be far below the limits on magnetic-field exposure recommended by the International Commission on Non-ionizing Radiation Protection and the International Committee on Electromagnetic Safety after the project is completed.

The engineering design characteristics and siting of the proposed electrical elements of the Burlington Solar One Project that minimize the magnetic-field levels in the area around the Project are consistent with the Connecticut Siting Council's *EMF Best Management Practices for the Construction of Electric Transmission Lines in Connecticut* (CSC, 2014).

Note that this Executive Summary provides only an outline of the material discussed in this report. Exponent's technical evaluations, analyses, conclusions, and recommendations are included in the main body of this report, which at all times is the controlling document.

## Introduction

---

Burlington Solar One, LLC (a wholly owned subsidiary of VCP, LLC d/b/a Verogy) proposes to develop a 3.5-Megawatt (MW) alternating current (AC), ground-mounted, solar photovoltaic generator system (the Project) in the town of Burlington, Connecticut. The Project Area is contained within an 11.58-acre subset of the approximately 63-acre Project Site, which is bordered to the north and east by forested residential areas, to the west by agricultural fields, and to the south by a residential street (Prospect Street). The Project Area is located on the northern half of the Project Site and is divided into east and west solar arrays.

The direct current (DC) electricity generated by the solar panels will be converted to AC and stepped up to 23-kilovolts (kV) at two transformers and associated inverters located at the southern end of the Project Area. From the transformers, the AC power from the Project will be carried underground to connect to an existing Eversource Energy 23-kV distribution line on Prospect Street.

Figure 1 (below) shows the placement of the east and west solar arrays (gray vertical lines) on the northern end of the Project Site and the approximate location of the transformers and associated inverters (red box). The connection from the solar panels to the existing 23-kV distribution line will follow an existing access road (yellow line) from the south end of the Project Area to Prospect Street (blue line).

In this report, Exponent discusses these sources within the context of exposure guidelines and the Connecticut Siting Council's (CSC) *EMF Best Management Practices for the Construction of Electric Transmission Lines in Connecticut*, hereafter BMP (CSC, 2014), and provides a concise summary of the current status of EMF health research.

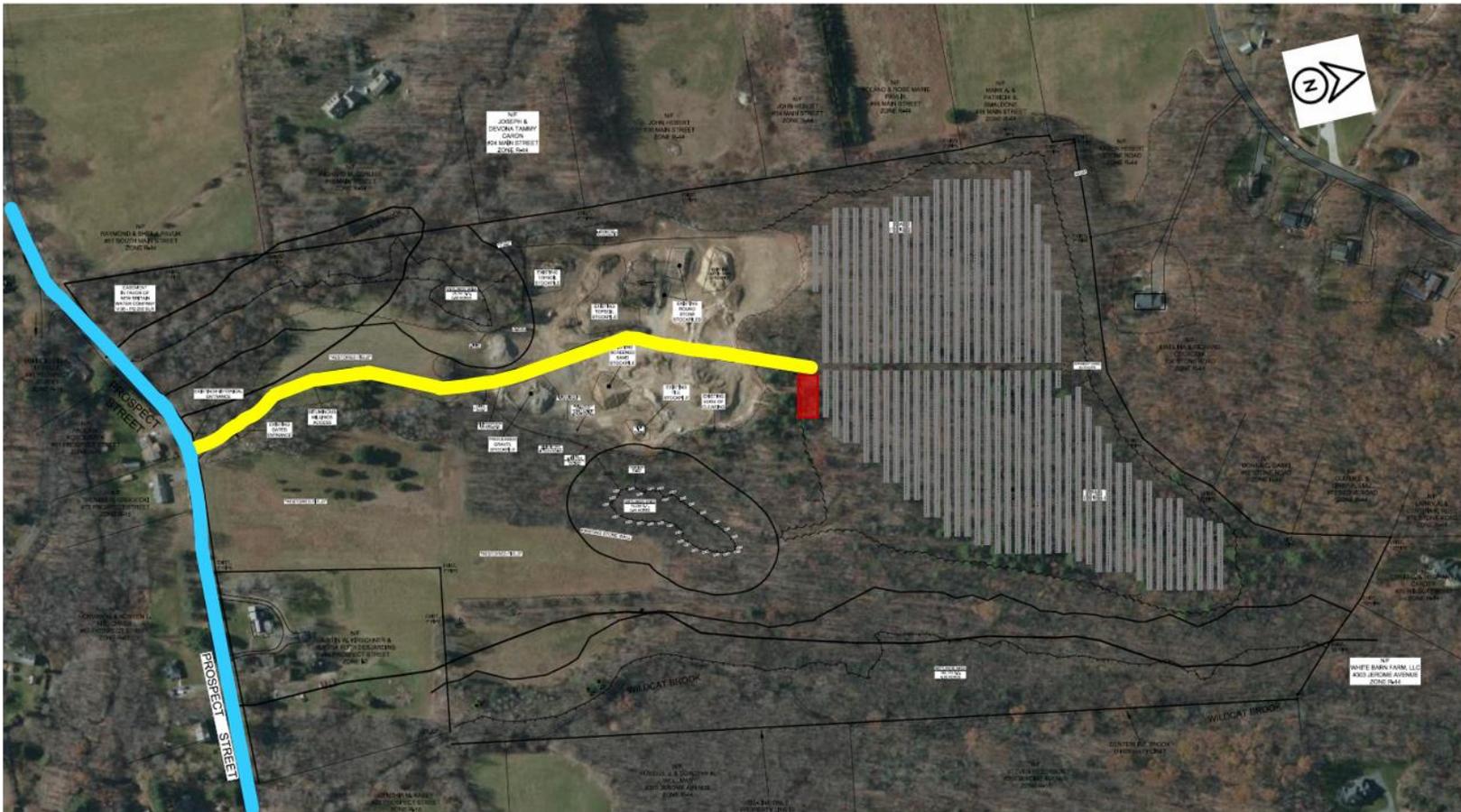


Figure 1. Proposed Site Plan for the 3.5-MW solar photovoltaic generator system in Burlington, Connecticut.

The gray vertical lines in the northern part of the site (right side of the map) depict the solar arrays. The red box shows the approximate location of the transformers and associated inverters, the yellow line shows the route of the underground 23-kV interconnection, and the blue line shows the existing overhead 23-kV distribution line on Prospect Street.

## EMF Sources and Characteristics

---

Since all sources that generate, transmit, or use electricity produce EMF, all things connected to our electrical system—power lines; wiring in our homes, businesses, and schools; and all electric appliances and machines—are sources of EMF as well. In North America, the vast majority of electricity is transmitted as alternating current (AC) at a frequency of 60 Hertz (Hz), that is, the current changes direction 60 times per second. The EMF from these AC sources is commonly referred to as power-frequency or extremely low-frequency EMF.

### Electric Fields

Electric fields are produced when voltage is applied to electrical conductors and equipment. Electric-field levels are measured in units of volts per meter (V/m) or kilovolts per meter (kV/m), where 1 kV/m is equal to 1,000 V/m. While electric-field levels increase as the voltage increases, since transmission and distribution line voltage is quite stable and does not change very much over time, electric-field levels from this infrastructure are also stable.

The intensity of an electric field diminishes with increasing distance from the source. In the case of transmission and distribution lines, electric fields decrease with distance from the conductors in proportion to the square of the distance.

Electric fields are easily blocked (i.e., shielded) by most grounded conducting objects, including buildings, walls, trees, and fences. As a result, the primary indoor sources of electric fields are the electrical appliances and equipment used within our homes and workplaces. Transmission lines, distribution lines, and other power-related equipment are the major source of electric fields outdoors.

### Magnetic Fields

Magnetic fields are the result of the flow of electric currents through wires and electrical devices. The strength of a magnetic field is expressed as magnetic flux density in units called

gauss (G) or milligauss (mG), where  $1 \text{ G} = 1,000 \text{ mG}$ .<sup>1</sup> The magnetic-field level associated with a particular object (e.g., an appliance or power line) depends largely on various operating characteristics of the source and on the amount of current (i.e., electricity) flowing through the object. Since power demand varies on a given day, throughout a week, or over the course of months and years, the amount of current will also vary, which results in varying magnetic-field levels produced by transmission and distribution lines.

Similar to electric fields, the intensity of a magnetic field diminishes with increasing distance from the source. In the case of transmission and distribution lines, magnetic fields decrease with distance from the conductors in proportion to the square of the distance. Unlike electric fields, however, magnetic fields are not easily blocked by most conductive objects.

Figure 2 (below) depicts typical electric- and magnetic-field levels measured in residential and occupational environments, compared to levels measured on or at the edge of transmission line rights-of-way (ROW) and other locations.

---

<sup>1</sup> Scientists also refer to magnetic flux density at these levels in units of microtesla ( $\mu\text{T}$ ). Magnetic flux density in mG units can be converted to  $\mu\text{T}$  by dividing by 10 (i.e.,  $1 \text{ mG} = 0.1 \mu\text{T}$ ).

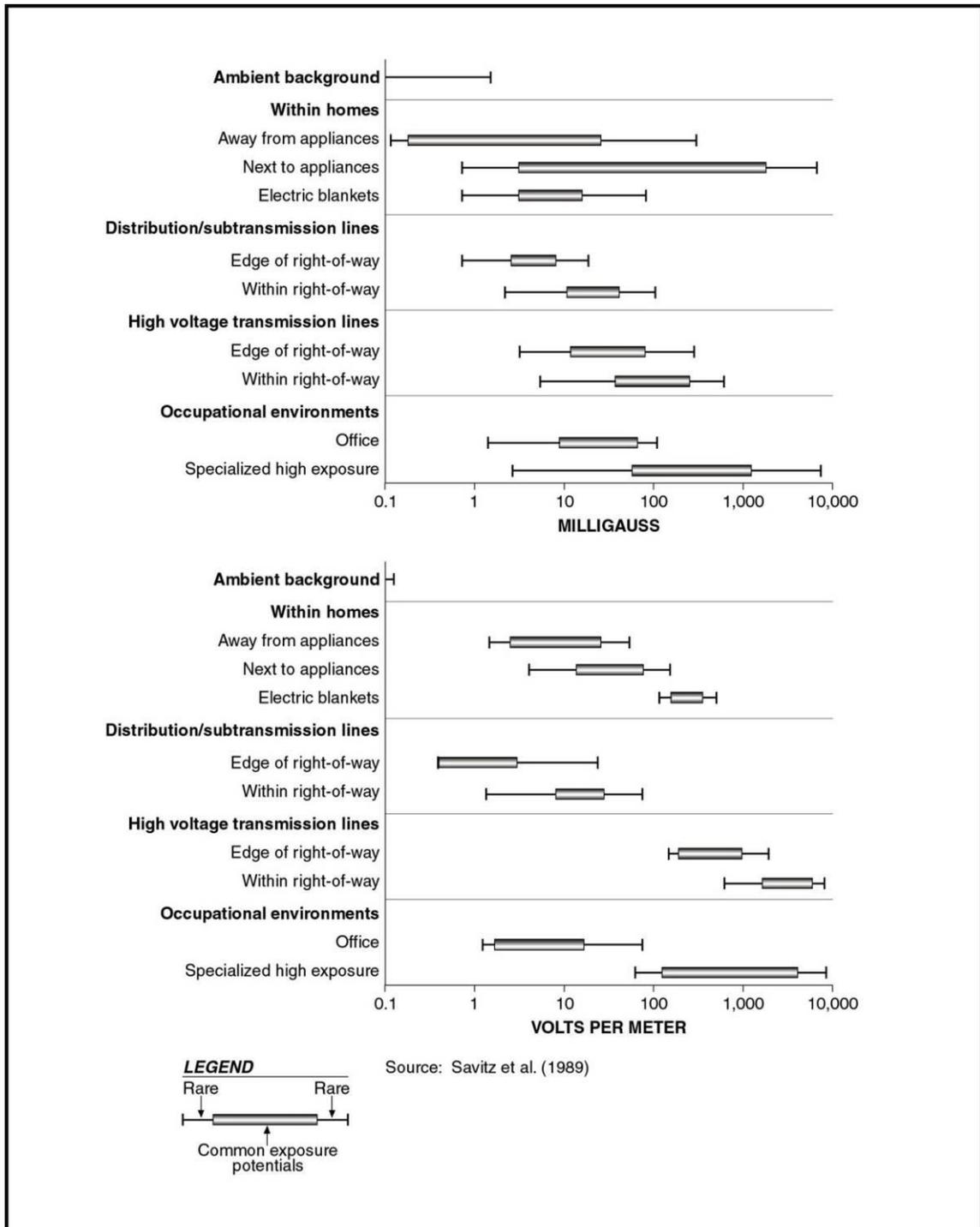


Figure 2. Electric- and magnetic-field levels in the environment.

## Exposure Guidelines

---

### Background

Neither the federal government nor the state of Connecticut has enacted standards for electric fields or magnetic fields from power lines or other sources at power frequencies, although the CSC has developed BMPs for siting new transmission lines, as noted in a subsequent section of this report.

In the absence of any federal or state standards, EMF levels can be assessed using the exposure guidelines recommended by two international scientific organizations: 1) the International Committee on Electromagnetic Safety (ICES), and 2) the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The exposure limits set by these agencies, summarized in Table 1, were developed to protect the health and safety of both workers and the general public and are based upon comprehensive reviews and evaluations of relevant health research. These guidelines set limits to protect against the known effects of EMF exposure, which are short-term (acute) effects that can occur at very high field levels and generally cause no long-term damage or health consequences. As discussed further in the section on the *Current Status of EMF Health Research*, the review of the health research by ICNIRP and ICES led to the conclusion that there was insufficient evidence to warrant the development of standards or guidelines on the basis of hypothesized long-term adverse health effects such as cancer.

**Table 1. ICNIRP (2010) and ICES (2019) guidelines for EMF exposure at 60-Hz**

Agency	Exposure (60 Hz)	
	Electric Field	Magnetic Field
<b>ICNIRP</b>		
Occupational	8.3 kV/m	10 G (10,000 mG)
General Public	4.2 kV/m	2 G (2,000 mG)
<b>ICES</b>		
Occupational	20 kV/m	27.1 G (27,100 mG)
General Public	5 kV/m*	9.040 G (9,040 mG)

\*Within power line ROWs, the guideline is 10 kV/m.

The World Health Organization (WHO) has recommended that policy makers should adopt international exposure limit guidelines, such as those from ICNIRP or ICES, for exposure to EMF (WHO, 2007).

## **CSC EMF Best Management Practices**

---

The CSC adopted their BMP, *“EMF Best Management Practices for the Construction of Electric Transmission Lines in Connecticut,”* based on a consensus of health and scientific agencies that the scientific evidence *“reflects the lack of credible scientific evidence for a causal relationship between MF [magnetic field] exposure and adverse health effects”* (CSC, 2014, p. 3). Nevertheless, the CSC concluded that precautionary measures for the siting of new transmission lines in the state of Connecticut are appropriate and advocates *“the use of effective no-cost and low-cost technologies and management techniques on a project-specific basis to reduce MF exposure to the public while allowing for the development of efficient and cost-effective electrical transmission projects”* (CSC, 2014, p.4).

The CSC’s EMF BMP guidance (CSC, 2014) also expresses the CSC’s interest in *“evidence of any new developments in scientific research addressing MF and public health effects or changes in scientific consensus group positions regarding MF”* (p. 5). For this project, Exponent has summarized the status of current research on EMF and human health (*see* Appendix A).

Reviews of EMF health research have been completed by a number of scientific and health organizations, including the WHO in 2007 and the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) of the European Union in 2015. The SCENIHR report represents the most comprehensive review of EMF health research since the WHO report and was published subsequent to the CSC’s most recent BMP guidelines. As summarized in Appendix A, the 2015 SCENIHR report concluded that the scientific research published up to 2014 did not confirm any adverse health effects from long-term exposure to EMF at the levels experienced in our everyday environment (SCENIHR, 2015). These conclusions are consistent with those expressed in the 2007 WHO report and in reviews conducted by other organizations, as well as with the CSC BMP guidelines.

## Assessment of Project EMF

---

### The Project Site

Existing sources of EMF along the boundaries of the Project Site include the 60-Hz AC fields associated with the Eversource 23-kV overhead distribution line along Prospect Street, to which the electricity from the solar arrays will connect.

When the Project is operating EMF on the Project Site will derive from 1) the DC solar panels; 2) the DC cables connecting the solar arrays to the power inverters; 3) the power inverters that convert the DC power to AC power; and 4) the underground 23-kV interconnection and existing Eversource 23-kV distribution line along Prospect Street, to which the Project will connect. The solar panels and DC cables will produce static fields (i.e., at 0 Hertz [Hz]); the power inverters will produce AC fields at a frequency greater than 60 Hz; and the underground 23-kV interconnection and 23-kV distribution line will produce fields at a frequency of 60 Hz.

The DC solar panels, the AC power inverters, and the AC transformers will be located more than 700 feet from the boundaries of the site and the nearest residences are still further away from boundaries of the site. DC magnetic-field levels from cables connecting the solar arrays to the inverters will produce a DC magnetic field, but at the northern site boundary, would be a small fraction of earth's natural static (i.e., DC) geomagnetic field. The higher-frequency AC fields from the inverters, like the DC fields from the solar panels, generally decrease to near background levels within a few tens of feet or less. Thus, the operation of these sources would not appreciably change the EMF levels outside the Project Site (Tell et al., 2015). Furthermore, the earth's geomagnetic field with a strength of 517 mG in the Project area is about 8,000 times lower than the international ICNIRP standard for exposure of the general public to static magnetic fields (ICNIRP, 2009).

Since the 23-kV underground interconnection from the solar panels to the Eversource distribution line extends outside the Project site, the 60-Hz fields from this source was evaluated further.

## **Southern Boundary of the Project Site**

The southern end of the Project Site is bordered by Prospect Street. Several residential properties are located on the southern side of Prospect Street, approximately 75 feet from the Project Site's boundary. Based on the considerable distance of the Project Area from the southern border of the Project Site (more than 1,400 feet), the EMF from the solar panels, power inverters, and related equipment would not affect the EMF levels outside the Project Site's boundary (Tell et al., 2015), including at the residences located across Prospect Street.

The nearest residences to southern border of the Project Site also are located approximately 40 feet from the existing overhead Eversource 23-kV distribution line along Prospect Street. The Project is proposed to tap into this existing distribution line, which will not need to be recondotored or rebuilt as a result of the Project, and no new distribution lines will need to be constructed. At maximum project output, the current carried on the underground interconnection that connects to the existing distribution circuit on the north side of Prospect Street will be a weak source of magnetic fields, but no electric fields since the latter are shielded by the coverings on the underground cables, duct bank, and covering earth.

As for the effect of the Project on the magnetic field from the existing 23-kV distribution line, the electric current injected onto the existing 23-kV distribution line along Prospect Street will be less than 90 A, which would not be expected to increase the magnetic-field level outside the range typical of distribution lines (NIEHS, 2002), and also would be far below the limits on magnetic-field exposure recommended by ICNIRP and ICES as discussed in the following section.

## **Discussion**

Based upon the considerable distance of the Project Area from the majority of the residences located nearest to the Project Site, the EMF levels associated with the solar arrays and related equipment are expected to be far below the exposure limits for the general public recommended by ICNIRP and ICES at these residences. As discussed above, electric fields are easily blocked by most objects, including walls, trees, and fences, and therefore the major indoor sources of

electric fields result from the appliances and equipment inside our homes and buildings and not from outdoor sources such as the Project. The buried interconnection cables on the north side of Prospect Street will be expected to locally increase the magnetic field above the cables, similar to other buried power cables, but will not affect electric-field levels from existing aboveground sources.

The residences nearest to southern border of the Project Site are on the southern side of Prospect Street. These residences also are located approximately 40 feet, or further, from the existing 23-kV distribution line along Prospect Street. As discussed above, the Project's connection to the existing line is not expected to cause magnetic field values to exceed the typical range of values expected for such lines as shown in Figure 2 and discussed in (NIEHS, 2002). All EMF levels, both before and after the Project, will be far below the general public exposure limits recommended by ICNIRP and ICES.

Although the EMF BMP explicitly applies to transmission lines, not solar arrays or distribution lines, Exponent applied the spirit of the BMP as interpreted for a solar array or distribution line. Exponent considers the Project to be consistent with the CSC's EMF BMP for "no cost/low-cost" design to reduce magnetic-field exposure, as follows:

- The Project's solar arrays and related equipment (e.g., cables, inverters, transformers) will be sufficiently far from the Project Site's boundaries or the nearest residences such that the EMF levels from this equipment would be negligible off site.
- No new lines will be constructed. The existing 23-kV distribution line on Prospect Street will not be reconductored or rebuilt as a result of the Project.

## Summary

---

This report summarizes the anticipated effect on EMF levels from the development of a 3.5-MW AC solar photovoltaic generator system located on approximately 63 acres in Burlington, Connecticut. Post-development, sources of EMF within the Project Site will include DC magnetic fields from the solar panels and from the cables connecting the solar arrays to the power inverters, as well as AC fields from the power inverters and the existing 23-kV distribution line along Prospect Street.

The Project's solar arrays and related equipment in the Project Area will be sufficiently far from the Project Site's boundaries, and therefore, sufficiently far from the nearest residences such that the AC EMF levels from this equipment would be negligible off-site and far below the exposure limits for the general public recommended by ICNIRP and ICES. At the southern boundary of the Project Site, the nearest residences are located approximately 40 feet from the existing 23-kV distribution line along Prospect Street. The Project's connection to the existing distribution line, however, is not expected to increase the magnetic-field level outside the range typical of distribution lines (NIEHS, 2002) and also would be far below the limits on magnetic-field exposure recommended by ICNIRP and ICES. Based on these factors, the engineering design and other activities initiated by Burlington Solar One demonstrate compliance with the CSC's EMF BMP. Reviews of the research on EMF and human health conducted by scientific and health organizations have been consistent in their overall conclusions that long-term exposure to EMF at the levels experienced in our everyday environment has not been shown to cause or contribute to adverse health effects in adults or children. The conclusions of these reviewing organizations are consistent with the CSC BMP guidelines

## References

---

Ahlbom A, Day N, Feychting M, Roman E, Skinner J, Dockerty J, Linet M, McBride M, Michaelis J, Olsen JH, Tynes T, Verkasalo PK. A pooled analysis of magnetic fields and childhood leukaemia. *Br J Cancer* 83: 692-698, 2000.

Amoon AT, Crespi CM, Ahlbom A, Bhatnagar M, Bray I, Bunch KJ, Clavel J, Feychting M, Hemon D, Johansen C, Kreis C, Malagoli C, Marquant F, Pedersen C, Raaschou-Nielsen O, Rööslä M, Spycher BD, Sudan M, Swanson J, Tittarelli A, Tuck DM, Tynes T, Vergara X, Vinceti M, Wunsch-Filho V, Kheifets L. Proximity to overhead power lines and childhood leukaemia: an international pooled analysis. *Br J Cancer* 119: 364-373, 2018.

Bonneville Power Administration (BPA). Corona and Field Effects Computer Program. Portland, OR: Bonneville Power Administration, 1991.

Bunch KJ, Keegan TJ, Swanson J, Vincent TJ, Murphy MF. Residential distance at birth from overhead high-voltage powerlines: childhood cancer risk in Britain 1962-2008. *Br J Cancer* 110: 1402-8, 2014.

Bunch KJ, Swanson J, Vincent TJ, Murphy MF. Magnetic fields and childhood cancer: an epidemiological investigation of the effects of high-voltage underground cables. *J Radiol Prot* 35: 695-705, 2015.

Bunch KJ, Swanson J, Vincent TJ, Murphy MF. Epidemiological study of power lines and childhood cancer in the UK: further analyses. *J Radiol Prot* 36: 437-455, 2016.

Connecticut Siting Council (CSC). Petition 754 - Best Management Practices for Electric and Magnetic Fields. February 14, 2014.

Greenland S, Sheppard AR, Kaune WT, Poole C, Kelsh MA. A pooled analysis of magnetic fields, wire codes, and childhood leukemia. Childhood Leukemia-EMF Study Group. *Epidemiology* 11: 624-634, 2000.

Health Council of the Netherlands (HCN) ELF Electromagnetic Fields Committee. Electromagnetic Fields: Annual Update. Publication No. 2009/02. The Hague: Health Council of the Netherlands, 2009.

Institute of Electrical and Electronics Engineers (IEEE). IEEE Recommended Practice for Instrumentation: Specifications for Magnetic Flux Density and Electric Field Strength Meters - 10 Hz to 3 kHz (IEEE Std. 1308-1994, Reaffirmed 2010). New York: IEEE, 1994/2010.

Institute of Electrical and Electronics Engineers (IEEE). IEEE recommended practice for measurements and computations of electric, magnetic, and electromagnetic fields with respect to human exposure to such fields, 0 Hz to 100 kHz. (IEEE Standard C95.3.1-2010). New York: IEEE, 2010.

Institute of Electrical and Electronics Engineers (IEEE). Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines (IEEE Std. -644-2019). New York: IEEE, 2019.

Institute of Electrical and Electronics Engineers (IEEE). IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 0 kHz to 300 GHz. (C95.1-2019). New York, NY: IEEE, 2019.

International Agency for Research on Cancer (IARC). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Volume 80: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields. Lyon, France: IARC Press, 2002.

International Commission on Non-ionizing Radiation Protection (ICNIRP). ICNIRP Guidelines on Limits of Exposure to Static Magnetic Fields. Health Physics 96(4):504-514; 2009.

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

National Radiological Protection Board (NRPB). Review of the Scientific Evidence for Limiting Exposure to Electromagnetic Fields (0-300 GHz). Chilton, UK: National Radiological Protection Board, 2004.

Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Opinion on Potential Health Effects of Exposure to Electromagnetic Fields (EMF). Brussels, Belgium: European Commission, 2015.

Sermage-Faure C, Demoury C, Rudant J, Goujon-Bellec S, Guyot-Goubin A, Deschamps F, Hemon D, Clavel J. Childhood leukaemia close to high-voltage power lines--the Geocap study, 2002-2007. Br J Cancer 108: 1899-1906, 2013.

Siemens Industry Inc., Siemens Power Technologies International (Siemens PTI). System Impact Study Report for QP892 Solar Project. Report Number R042-20. May 14, 2020.

Swedish Radiation Safety Authority (SSM). Research 2016:15. Recent Research on EMF and Health Risk - Eleventh report from SSM's Scientific Council on Electromagnetic Fields, 2016. Including Thirteen years of electromagnetic field research monitored by SSM's Scientific Council on EMF and health: How has the evidence changed over time? Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2016.

Swedish Radiation Safety Authority (SSM). Research 2018:09. Recent Research on EMF and Health Risk - Twelfth report from SSM's Scientific Council on Electromagnetic Fields, 2017. Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2018.

Swedish Radiation Safety Authority (SSM). Research 2019:08. Recent Research on EMF and Health Risk – Thirteenth Report from SSM's Scientific Council on Electromagnetic Fields, 2018. Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2019.

Swedish Radiation Safety Authority (SSM). Research 2020:04. Recent Research on EMF and Health Risk – Fourteenth Report from SSM's Scientific Council on Electromagnetic Fields, 2019. Stockholm, Sweden: Swedish Radiation Safety Authority (SSM), 2020.

Tell TA, Hooper HC, Sias GG, Mezei G, Hung P, Kavet R. Electromagnetic fields associated with commercial solar photovoltaic electric power generating facilities. *J Occup Environ Hyg* 12: 795-803, 2015.

World Health Organization (WHO). Environmental Health Criteria 238: Extremely Low Frequency (ELF) Fields. Geneva, Switzerland: World Health Organization, 2007.

## **Appendix A**

---

### **Current Status of EMF Health Research**

## Reviews of EMF by Scientific and Health Organizations

Since the late 1970s, researchers have examined whether EMF from man-made sources can cause short- or long-term health effects in humans using a variety of study designs and techniques. This large amount of research has subsequently been reviewed by multidisciplinary scientific expert panels, assembled by national and international scientific and health organizations, to draw conclusions about EMF exposure in the general public. Organizations that convened expert panels to conduct reviews of EMF research include the International Agency for Research on Cancer (IARC, 2002), the National Radiological Protection Board (NRPB, 2004), the WHO (WHO, 2007), the Health Council of the Netherlands (HCN, 2009), SCENIHR (SCENIHR, 2015), and the Swedish Radiation Safety Authority (SSM, 2016, 2018, 2019, 2020). As discussed above, ICNIRP and ICES also reviewed the relevant health research when developing recommended exposure guidelines.

When conducting reviews of scientific research, expert panels consider all the evidence on a particular issue in a systematic and thorough manner to evaluate whether the overall data present a logically coherent and consistent picture. This is often referred to as a *weight-of-evidence review*, in which all research studies are considered together, giving more weight to studies of higher quality and using an established analytic framework to arrive at a conclusion about possible causality between an exposure and disease. The weight-of-evidence review process helps to ensure that studies with a given result are not selectively chosen from the overall body of research to advocate for or suppress a preconceived idea of an adverse effect.

The reviews published by scientific and health organizations, including those listed above, have been consistent in their overall conclusions. None of the reviewing organizations have concluded that long-term exposure to EMF at the levels experienced in our everyday environment causes or contributes to adverse health effects in adults or children. The current guidance from the WHO on its website states that “[b]ased on a recent in-depth review of the

*scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields.”<sup>2</sup>*

As noted previously, the only confirmed relationship between EMF exposure and adverse biological or health effects occurs at very high exposure levels to which neither electrical workers nor the general public could be exposed. If the current density or electric field induced by an extremely strong magnetic field exceeds a certain threshold, excitation of muscles and nerves is possible. Similarly, strong electric fields can induce charges on the surface of the body that can lead to small shocks (i.e., micro shocks). These short-term, acute effects cause no long-term damage or health consequences. ICES and ICNIRP have developed recommended exposure guidelines (see *Exposure Guidelines* section above) for workers and the general public to protect against the occurrence of these effects.

## Childhood Leukemia

The 2007 WHO report, and much of the subsequent research on EMF, has paid particular attention to childhood leukemia because of epidemiologic associations found in some studies between this disease and high estimates of time-weighted average magnetic-field exposure (e.g., Ahlbom et al., 2000; Greenland et al., 2000).<sup>3</sup> The WHO report noted that “[c]onsistent epidemiological evidence [i.e., differences in the estimated exposures of case and control children] suggests that chronic low-intensity ELF magnetic field exposure is [statistically] associated with an increased risk of childhood leukaemia. However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted” (WHO, 2007, p. 355). The WHO concluded that reconciling the epidemiologic data on childhood leukemia and the absence of findings (i.e., no hazard or risk observed) in experimental studies through innovative research is currently the highest priority in the field of EMF research.

---

<sup>2</sup> <https://www.who.int/peh-emf/about/WhatisEMF/en/index1.html>

<sup>3</sup> Time-weighted average is the average exposure over a given specified time period (e.g., an 8-hour workday or a 24-hour day) of a person’s exposure to a chemical or physical agent.

The suggested weak statistical association between and childhood leukemia reported in some of the earlier studies has not been strengthened or substantially diminished by subsequent research, although the more recent and larger studies tend to show no overall associations with distance from power lines or measured or calculated magnetic fields (Sermage-Faure et al., 2013; Bunch et al., 2014, 2015, 2016; Amoon et al., 2018). The recent literature does not alter the previous conclusions of the WHO and other reviews that the epidemiologic evidence on magnetic fields and childhood leukemia is weak, inconsistent, and includes outstanding questions about study design or other methodological issues (WHO, 2007; HCN 2009; SCENIHR 2015; SSM 2020). The recent weight-of-evidence review released in 2015 by SCENIHR concluded that the epidemiological data on childhood leukemia and EMF exposure continued to “*prevent a causal interpretation*” and that “*no mechanisms have been identified and no support is existing from experimental studies that could explain these findings*” (SCENIHR, 2015, p. 7).