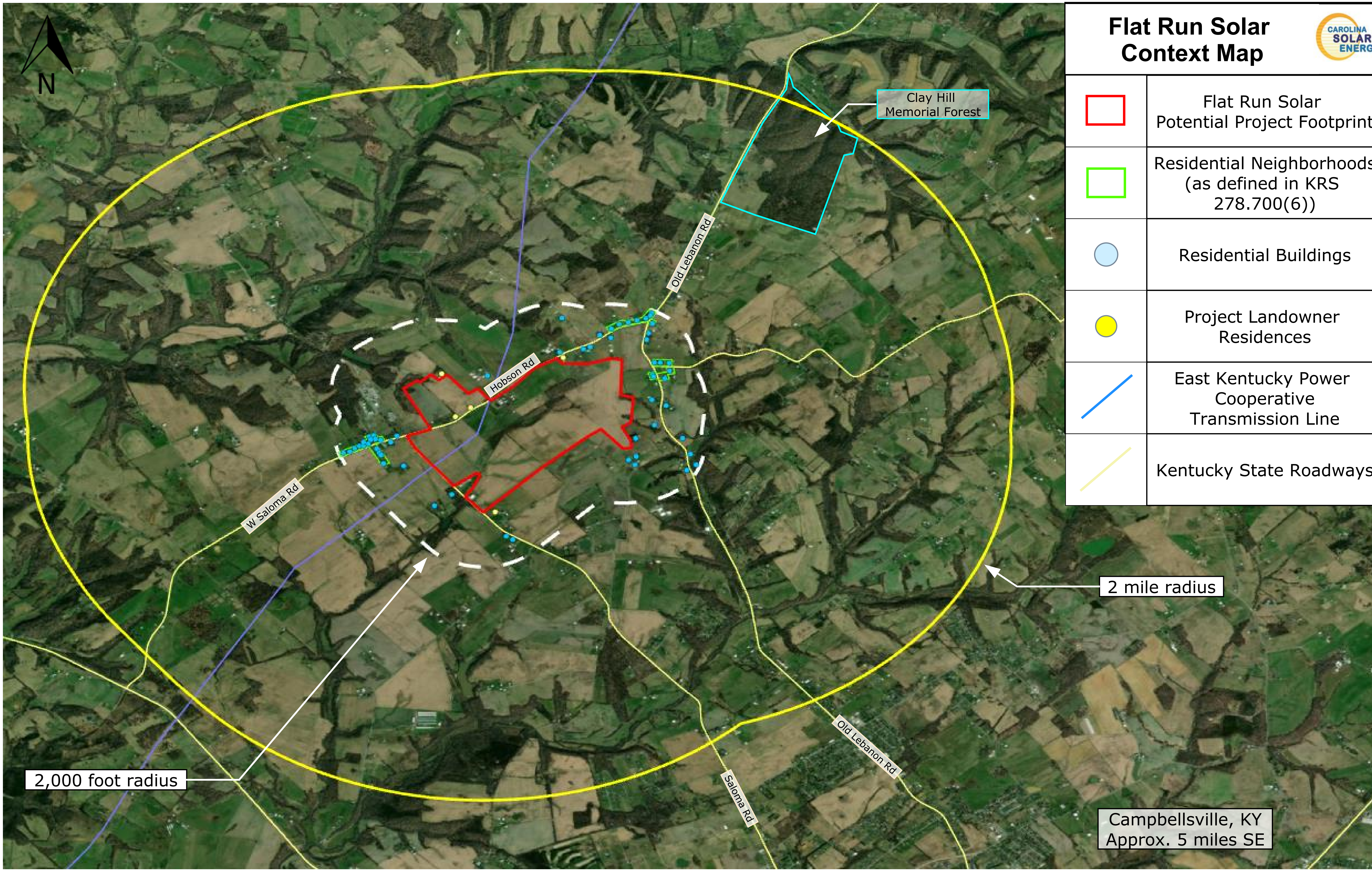
Attachment A



Flat Run Solar
Context Map
CAROLINA SOLAR ENERGY
Flat Run Solar Potential Project Footprint
Residential Neighborhoods (as defined in KRS 278.700(6))
Residential Buildings
Project Landowner Residences
East Kentucky Power Cooperative Transmission Line
Kentucky State Roadways
N
Clay Hill Memorial Forest
Old Lebanon Rd
Hobson Rd
W Saloma Rd
Saloma Rd
Old Lebanon Rd
2 mile radius
2,000 foot radius
Campbellsville, KY
Approx. 5 miles SE

Attachment B

7019 2280 0001 0518 4174

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Postmark Here
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Sent To: Mary Virginia Price
Street: 1118 Hobson Rd
City, State: Campbellsville Ky 42718

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Total Postage and Fees $ $7.00

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Sent To: Jeffrey & Kimberly Deener
Street: 139 Sanders Rd
City, State: Campbellsville Ky 42718

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Postage $ $0.55
Total Postage and Fees $ $7.00

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Sent To: Ricky Dale Shreve
Street: 2041 West Saloma Rd
City, State: Campbellsville, Ky 42718

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Postage $ $0.55
Total Postage and Fees $ $7.00

0707
25
Postmark Here
03/12/2021

Sent To: Richard Gabehart
Street: 150 Crawley Rd
City, State: Campbellsville Ky 42718

PS ... Instructions

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Postage $ $0.55
Total Postage and Fees $ $7.00

0707
25
Postmark Here
03/12/2021

Sent To: David & Deronda Eastridge
Street: 221 Hobson Rd
City, State: Campbellsville Ky 42718

PS ... Instructions

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☐ Adult Signature Restricted Delivery $ $0.00
Postage $ $0.55
Total Postage and Fees $ $7.00

0707
25
Postmark Here
03/12/2021

Sent To: Family Farm Inc Schuhmann
Street: 201 Southside
City, State: Campbellsville Ky 42718

PS Form ... Instructions

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Extra Services & Fees (check box, add fee as appropriate)	$2.85	Postmark Here
☒ Return Receipt (hardcopy)	$ $0.00	
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☐ Adult Signature Required	$ $0.00	
☐ Adult Signature Restricted Delivery	$ $0.00	
Postage $	$0.55	03/12/2021
Total Postage and Fees $	$7.00	

Sent T Richard Schuhmann

Street 266 Hobson Rd

City, S Campbellsville Ky 42718

PS Fo ... structions

7019 2280 0001 0518 4075

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Extra Services & Fees (check box, add fee as appropriate)	$2.85	Postmark Here
☒ Return Receipt (hardcopy)	$ $0.00	
☐ Return Receipt (electronic)	$ $0.00	
☐ Certified Mail Restricted Delivery	$ $0.00	
☐ Adult Signature Required	$ $0.00	
☐ Adult Signature Restricted Delivery	$ $0.00	
Postage $	$0.55	03/12/2021
Total Postage and Fees $	$7.00	

Sent T Danny & Kay Eubank

Street 292 Crawley Rd

City, S Campbellsville Ky 42718

PS F ... structions

7019 2280 0001 0518 4082

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Extra Services & Fees (check box, add fee as appropriate)	$2.85	Postmark Here
☒ Return Receipt (hardcopy)	$ $0.00	
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☐ Adult Signature Required	$ $0.00	
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Postage $	$0.55	03/12/2021
Total Postage and Fees $	$7.00	

Sent To Isidro & Veronica Noriega

Street and 347 Hobson Rd

City, State Campbellsville, Ky 42718

PS Form ... ctions

7019 2280 0001 0518 4112

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Certified Mail Fee $		Postmark Here
Extra Services & Fees (check box, add fee as appropriate)		
☒ Return Receipt (hardcopy)	$	
☐ Return Receipt (electronic)	$	
☐ Certified Mail Restricted Delivery	$	
☐ Adult Signature Required	$	
☐ Adult Signature Restricted Delivery	$	
Postage $		
Total Postage and Fees $		

Sent Paul Anthony Gunter

Stree 393 Hobson Road

City, Campbellsville Ky 42718

PS F ... structions

7019 2280 0001 0518 4099

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Extra Services & Fees (check box, add fee as appropriate)	$2.85	Postmark Here
☒ Return Receipt (hardcopy)	$ $0.00	
☐ Return Receipt (electronic)	$ $0.00	
☐ Certified Mail Restricted Delivery	$ $0.00	
☐ Adult Signature Required	$ $0.00	
☐ Adult Signature Restricted Delivery	$ $0.00	
Postage $	$0.55	03/12/2021
Total Postage and Fees $	$7.00	

Sent T Harold & Renee Osborne

Street 4484 Saloma Rd

City, S Campbellsville Ky 42718

PS Fo ... structions

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Extra Services & Fees (check box, add fee as appropriate)	$2.85	Postmark Here
☒ Return Receipt (hardcopy)	$ $0.00	
☐ Return Receipt (electronic)	$ $0.00	
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☐ Adult Signature Required	$ $0.00	
☐ Adult Signature Restricted Delivery	$ $0.00	
Postage $	$0.55	03/12/2021
Total Postage and Fees $	$7.00	

Sen Anthony Todd Gupton

Stre 5157 Saloma Road

City, Campbellsville Ky 42718

PS ... nstructions

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Extra Services & Fees *(check box, add fee as appropriate)* $2.85	25
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☐ Certified Mail Restricted Delivery $ $0.00	
☐ Adult Signature Required $ $0.00	
☐ Adult Signature Restricted Delivery $	
Postage $ $0.55	03/12/2021
Total Postage and Fees $ $7.00	

Sent T Billie Jo Akridge

Street 5175 Saloma Rd

City, S Campbellsville Ky 42718

PS Fo ... tructions

7019 2280 0001 0518 3962

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Campbellsville, KY 42718

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Certified Mail Fee $ $3.60	0707
Extra Services & Fees *(check box, add fee as appropriate)* $2.85	25
☑ Return Receipt (hardcopy) $ $0.00	
☐ Return Receipt (electronic) $ $0.00	Postmark Here
☐ Certified Mail Restricted Delivery $ $0.00	
☐ Adult Signature Required $ $0.00	
☐ Adult Signature Restricted Delivery $	
Postage $ $0.55	03/12/2021
Total Postage and Fees $ $7.00	

Danny & Pam Huber

104 Landon Lane

Campbellsville, Ky 42718

... Instructions

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Certified Mail Fee $ $3.60	0707
Extra Services & Fees *(check box, add fee as appropriate)* $2.85	25
☒ Return Receipt (hardcopy) $ $0.00	
☐ Return Receipt (electronic) $ $0.00	Postmark Here
☐ Certified Mail Restricted Delivery $ $0.00	
☐ Adult Signature Required $ $0.00	
☐ Adult Signature Restricted Delivery $	
Postage $ $0.55	03/12/2021
Total Postage and Fees $ $7.00	

Sent Colby & Gloria Deener

Stre 508 Hobson Rd

City, Campbellsville Ky 42718

PS ... nstructions

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Campbellsville, KY 42718

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Certified Mail Fee $ $3.60	0707
Extra Services & Fees *(check box, add fee as appropriate)* $2.85	25
☒ Return Receipt (hardcopy) $ $0.00	
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☐ Certified Mail Restricted Delivery $ $0.00	
☐ Adult Signature Required $ $0.00	
☐ Adult Signature Restricted Delivery $	
Postage $ $0.55	03/12/2021
Total Postage and Fees $ $7.00	

Sent Hollis Brockman

Stree 5565 Old Lebanon Rd

City, Campbellsville Ky 42718

PS F ... structions

7019 2280 0001 0518 4143

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OFFICIAL USE

Certified Mail Fee $ $3.60	0707 25
Extra Services & Fees *(check box, add fee as appropriate)* $2.85	
☒ Return Receipt (hardcopy) $ $0.00	
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☐ Certified Mail Restricted Delivery $ $0.00	
☐ Adult Signature Required $ $0.00	
☐ Adult Signature Restricted Delivery $	
Postage $ $0.55	
Total Postage and Fees $ $7.00	03/12/2021

Sent To: Keith Edward Jr & Nancy Franklin
Street: 758 Chestnut Grove Rd
City: Campbellsville Ky 42718

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Campbellsville, KY 42719
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Extra Services & Fees *(check box, add fee as appropriate)* $2.85	
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☐ Certified Mail Restricted Delivery $ $0.00	
☐ Adult Signature Required $ $0.00	
☐ Adult Signature Restricted Delivery $	
Postage $ $0.55	
Total Postage and Fees $ $7.00	03/12/2021

Sent To: Hugh & Mary Ann Garrett
Street: P O Box 113
City: Campbellsville Ky 42719

PS F... Instructions

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Extra Services & Fees *(check box, add fee as appropriate)* $2.85	
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☐ Adult Signature Required $ $0.00	
☐ Adult Signature Restricted Delivery $	
Postage $ $0.55	
Total Postage and Fees $ $7.00	03/12/2021

Sent To: Tennessee Gas Pipeline Company LLC
Street: 1380 Hobson Rd
City: Campbellsville Ky 42718

PS Fo... Instructions

Flat Run Adjoiners 5/25/2021

Number, per Attachment B, "Flat Run Solar Property Impact Study"	Owner Last Name*	Owner First name*
1	TN Gass	n/a
2	Deener	Colby
3	Deener	Colby and Gloria
4	Deener	Colby and Gloria
5	Deener	Paul Anthony
6	Noriega	Isidro and Veronica
7	Schuhmann	Family Farm INC
8	Schuhmann	Richard
9	Eastridge	David and Dernoda
10	Deener	Colby and Gloria
11	Brockman	Hollis
12	Garrnett	Hugh M and Mary Ann
13	Eubank	Danny and Kay
14	Gabehart	Richard
15	Sullivan	Chad and Carol
16	Franklin	Keith Edward Jr and Nancy
17	Sullivan	Ronald and Gwynette
18	Sullivan	Chad
19	Sullivan	Chad
20	Osborne	Harold and Renee
21	Sullivan	Ronald and Gwynette
22	Huber	Danny and Pam
23	Shreve	Ricky Dale
24	Gupton	Anthony Todd
25	Akridge	Billie Jo
26	Deener	Jeffery and Kimberly
27	Deener	Colby and Gloria

*per Taylor County PVA website

Attachment C

SOLOMON LEE VAN METER
450 OLD VINE STREET., SUITE 300
LEXINGTON, KENTUCKY 40507
(859) 221-3165

May 18, 2021

Patty Ann Price Thomas
1118 Hobson Rd. (Highway 218)
Campbellsville, KY 42718

RE: Construction and Maintenance Traffic

Dear Patty:

This letter is to confirm that you are aware that 25 acres of land belonging to Glivens and Lera Ann Sprowles, located adjacent to your property, was added to the Flat Run Solar Project in November, 2020, that on previous occasions and today you have been provided printed copies of the project site plan depicting the anticipated location of solar panels on the Sprowles property, and that you are aware of and have access to the current project site plan on the Carolina Solar Energy website (https://www.carolinasolarenergy.com/) .

This is also to confirm that I have discussed with you, and you understand that, as a result of the addition of the Sprowles property to the project, there will be additional traffic though the project entrance to be located on your property at your current driveway during construction of the project. There may also be an increased amount of maintenance traffic during the operational life of the project as a result of the Sprowles property having been added to the project.

We have discussed this today, as well as on previous occasions as to which neither of us has a specific recollection or specific notes.

This will also confirm that you are aware that, during construction of the project, the loudest noise will come from the pile driving machine. When that machine is operating closest to your house the noise level could be as loud as 95dBA, which is roughly equivalent to the level of sound created by a garbage disposal or a hair dryer.

Very truly yours,

Solomon Lee Van Meter

Acknowledged and agreed:

Patty Thomas 5/18/21

PATTY ANN PRICE THOMAS (Date)

Attachment D

(Confidential)

Attachment E

Paul A. Coomes, Ph.D.
Consulting Economist
3604 Trail Ridge Road Louisville KY 40241 502.608.4797 coomes.economics@gmail.com
Emeritus Professor of Economics, University of Louisville

May 18, 2021

TO: Carson Harkrader
Horseshoe Bend Solar, LLC
400 W. Main St, Suite 503
Durham, NC 27701
www.carolinasolarenergy.com

RE: Questions from the Kentucky Public Service Commission

This is to respond to two questions from the PSC, as forwarded to me, regarding my economic analysis of the Flat Run solar project. The PSC asked as follows, with responses below:

a. Explain how the IMPLAN model was customized for Taylor County.
b. Explain why the IMPLAN model was not customized include surrounding counties.

a. I created an IMPLAN model for Taylor County by simply selecting the county from a drop-down list of Kentucky counties. The software builds such a model by loading county-specific economic data, and making the required calculations across 500+ industries and various household sectors. Without going into a long technical explanation, this involves (1) starting with a national input-output model that shows the purchases of commodities by every industry from every other industry, (2) adjusting it to reflect the availability of commodities by industry in Taylor County, and (3) also predicting household purchases of every commodity in every industry by residents of Taylor County. If the commodity is available in the County to supply all local needs, say dental services, then the model predicts households would buy all their dental services from dentists in the County. But if the commodity is not available in the County, or is not sufficiently available, then the model predicts that the good or service would need to be imported into the County to meet industrial or household demand. Generally speaking, the more a commodity is produced in the County, the higher the resultant local economic impact (multiplier) when there is an industrial expansion requiring that commodity. If most required commodities must be obtained outside the County then the associated multiplier would be very small.

b. Actually, I did experiment with adding counties, but as you will see the result in the case of a solar project was negligible. Taylor and Green counties are contiguous, and Green County supplies about 1,300 people who work in Taylor County, the most of any other county and about 11 percent of the number of workers in Taylor. However, commuting patterns data from the US Census Bureau show that 69 percent of workers in Taylor County are also Taylor County residents. The reverse is similar, with 80% of Green County workers also residents of Green County, with 10% commuting from Taylor County.

   In any case, I constructed a regional model containing both Taylor and Green counties, and simulated the economic impact of the solar project, comparing that to the result I obtained using Taylor County only. There was little difference. For example, the employment multiplier for Taylor only is 1.32, and is 1.34 for the combination of the two counties. This amounts to a difference of but 2 total jobs for the construction phase (199 vs. 201). The difference was so small I decided not to complicate the report with it.

   The economic multipliers are small whether one models one county or two. This is due to the lack of industrial linkages in the region to the solar farm construction project, and to the thinness of retail and service industries to absorb new household spending. These counties are sparsely populated, and do not support businesses that supply much of what their residents demand. Residents will travel to nearby larger cities to make major purchases of commodities, and to spend money on entertainment, travel, health care, and other services not available at home.

   As a further check I built another model, this time of Taylor and the five contiguous counties – Adair, Casey, Green, Larue and Marion. I also used the latest IMPLAN economic data, now available for 2019, and updated the Taylor-only and Taylor plus Green simulations. The results are almost identical across the three models. The job multipliers for the solar farm construction phase are 1.288 for Taylor alone, 1.299 for Taylor plus Green, and 1.300 for Taylor plus the five contiguous counties. (Other economic multipliers, such as labor income and business output, are also consistently in that small range). Based on the best impact analysis tools available, there is no material difference in the predicted regional impacts when zooming out to adjacent counties.

Attachment F

gai consultants

Louisville Office
9850 Von Allmen Court
Suite 201
Louisville, Kentucky 40241

T 502.213.9620

May 26, 2021

Project R200785.02, Tasks 001 and 002

Mr. Tyler Boquet-Caron
Solar Developer
Flat Run Solar, LLC
400 West Main Street, Suite 503
Durham, North Carolina 27701-3295

Response to Comments
Sound Evaluation-Supplemental Information
Flat Run Solar Project
Taylor County, Kentucky

Dear Mr. Bouquet-Caron:

GAI Consultants, Inc. (GAI) is responding to your emailed review comments dated May 18, 2021 regarding the Flat Run Solar Project in Taylor County, Kentucky. GAI has prepared the following information to be deemed as supplemental to our submitted Sound and Traffic Evaluation Report dated March 19, 2021. For ease of review, we are providing your comments in italics followed by our responses.

Request 1

Comment: *Provide the noise level generated at the source and at increments of 100 feet up to 1,000 feet for central inverters and string inverters.*

Response: See Tables 1 and 2 below.

Table 1
Source: Central Inverters

Distance (ft.)	dBA
50	61.2
100	55.1
200	49.1
300	45.6
400	43.1
500	41.2
600	39.6
700	38.2
800	37.1
900	36.1
1,000	35.1

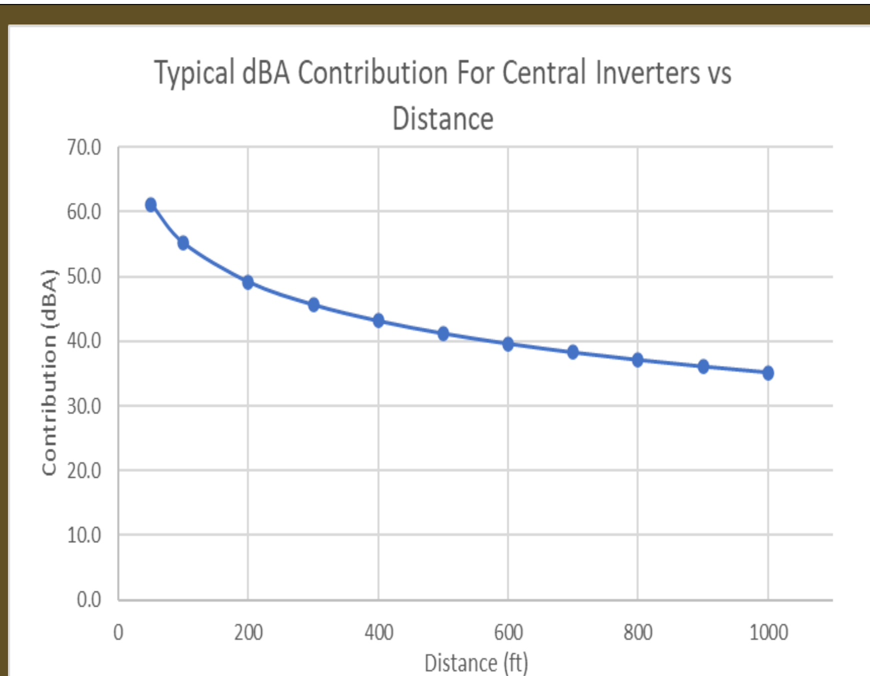
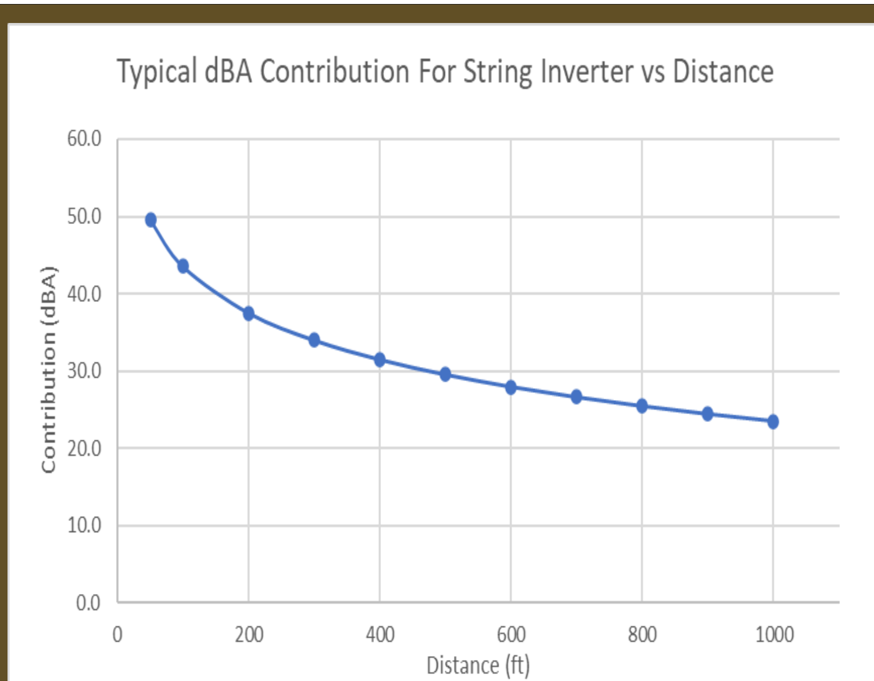


Table 2

Source: String Inverters (Optional)

Distance (ft.)	dBA
50	49.6
100	43.5
200	37.5
300	34.0
400	31.5
500	29.6
600	28.0
700	26.6
800	25.5
900	24.5
1,000	23.5



Request 2

Comment: *Attachment F assesses the projected volume of vehicular traffic during construction in the context of the local road system. "Construction of the Flat Run facility is expected to take eight to 12 months, with working hours from 7 AM to 9 PM daily…up to 150 workers are anticipated to be on-site each day…up to 15 trucks (Class 9) are anticipated to deliver components daily, with trucks weighing approximately 20 tons each…a distribution of the anticipated 165 daily vehicles during construction is shown in Figure 6." For purposes of comparing projected construction traffic to existing roadway traffic counts shown in Figure 4 (which are based on AADT which measures the number of trips in both directions), we believe the 165 daily vehicles cited above should be counted as 330 daily trips?*

Response: Yes, we anticipate the 165 daily vehicles will generate 330 daily trips.

GAI thanks you in advance for your review of this additional information. Should you have questions or comments, please contact me at 859.795.3492 or s.dodson@gaiconsultants.com.

Sincerely,

GAI Consultants, Inc.

Sharon L. Dodson
Project Manager

Ryan P. Hurt, P.E., MBA
Senior Project Manager, Associate
KY P.E. No. 31014

RPH:SLD/mms

Attachment G

(1) The Purpose of this plan is for a Power Generation Permit for review and approval by the Kentucky State Siting Board to construct a solar energy system. All information shown is for planning purposes only.
(2) No lighting is proposed for the array area. The Interconnection Substation will have some lighting.
(3) Site will be surrounded by 6' tall chain link fence with three strands of barbed wire or similar to meet National Electric Code requirements. The proposed access gate will be will be locked with a standard keyed or combination lock. Emergency personnel will be provided a key or combination for access.

CAROLINA SOLAR ENERGY

Carolina Solar Energy
400 W Main St
Durham, NC 27701
Suite 503

Flat Run
55 MWAC

ISSUE
05.27.21
05.26.21
04.26.21
03.15.21
02.17.21

PROJECT
Flat Run

DRAWN BY
CJ

DESCRIPTION
Array Layout

a

01

Attachment H

Carolina Solar Energy
400 W Main St
Durham, NC 27701
Suite 503

DESCRIPTION
Project landowner residences

CLIENT
KY PSC

DRAWN BY
TC

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PROJECT
Flat Run Solar

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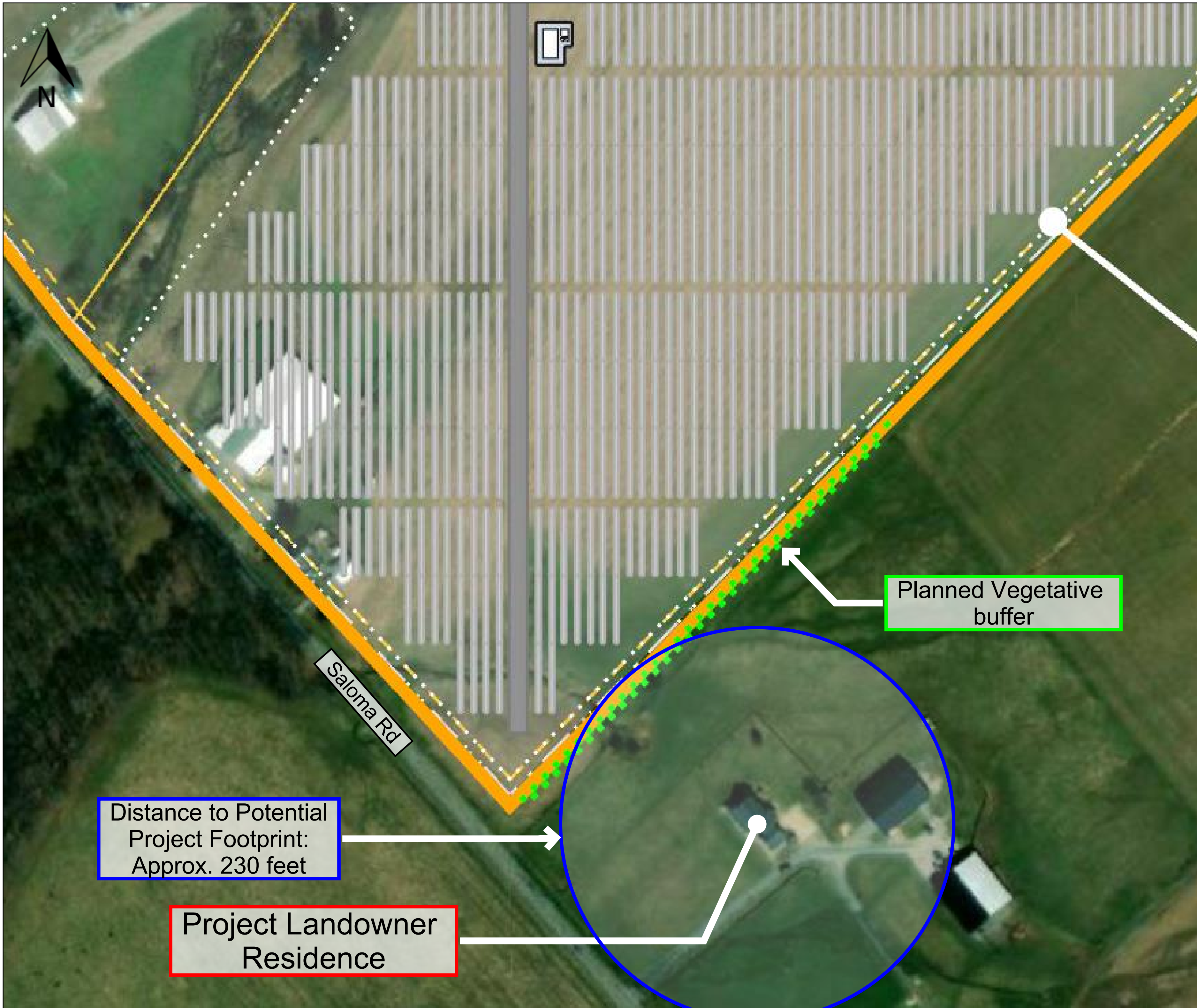
01



Carolina Solar Energy
400 W Main St
Durham, NC 27701
Suite 503

DESCRIPTION
Project landowner residences

CLIENT
KY PSC

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5.26.2021

PROJECT
Flat Run Solar

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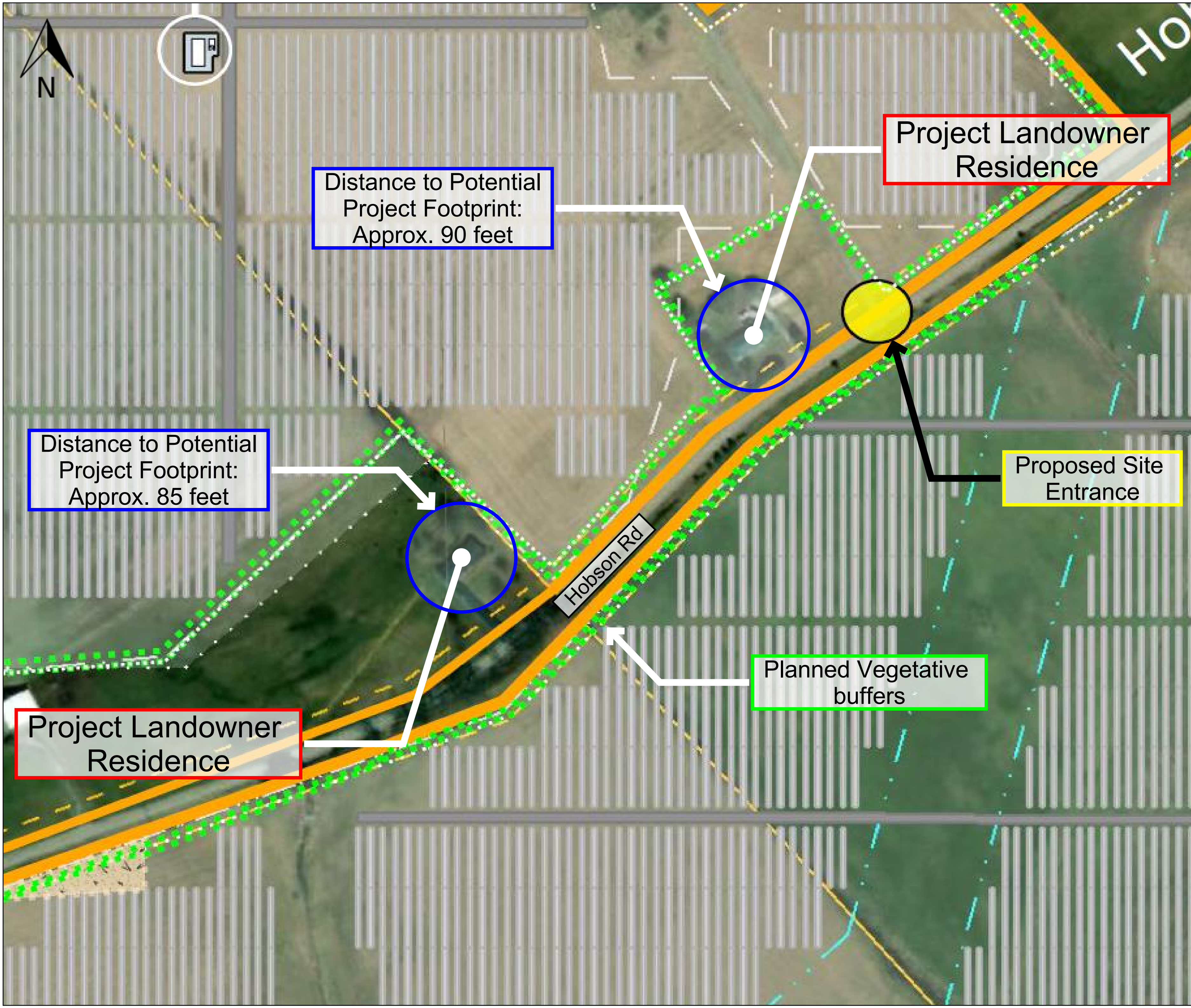
02



Carolina Solar Energy
400 W Main St
Durham, NC 27701
Suite 503

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Flat Run Solar

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03

Carolina Solar Energy
400 W Main St
Durham, NC 27701
Suite 503

DESCRIPTION
Project landowner residences

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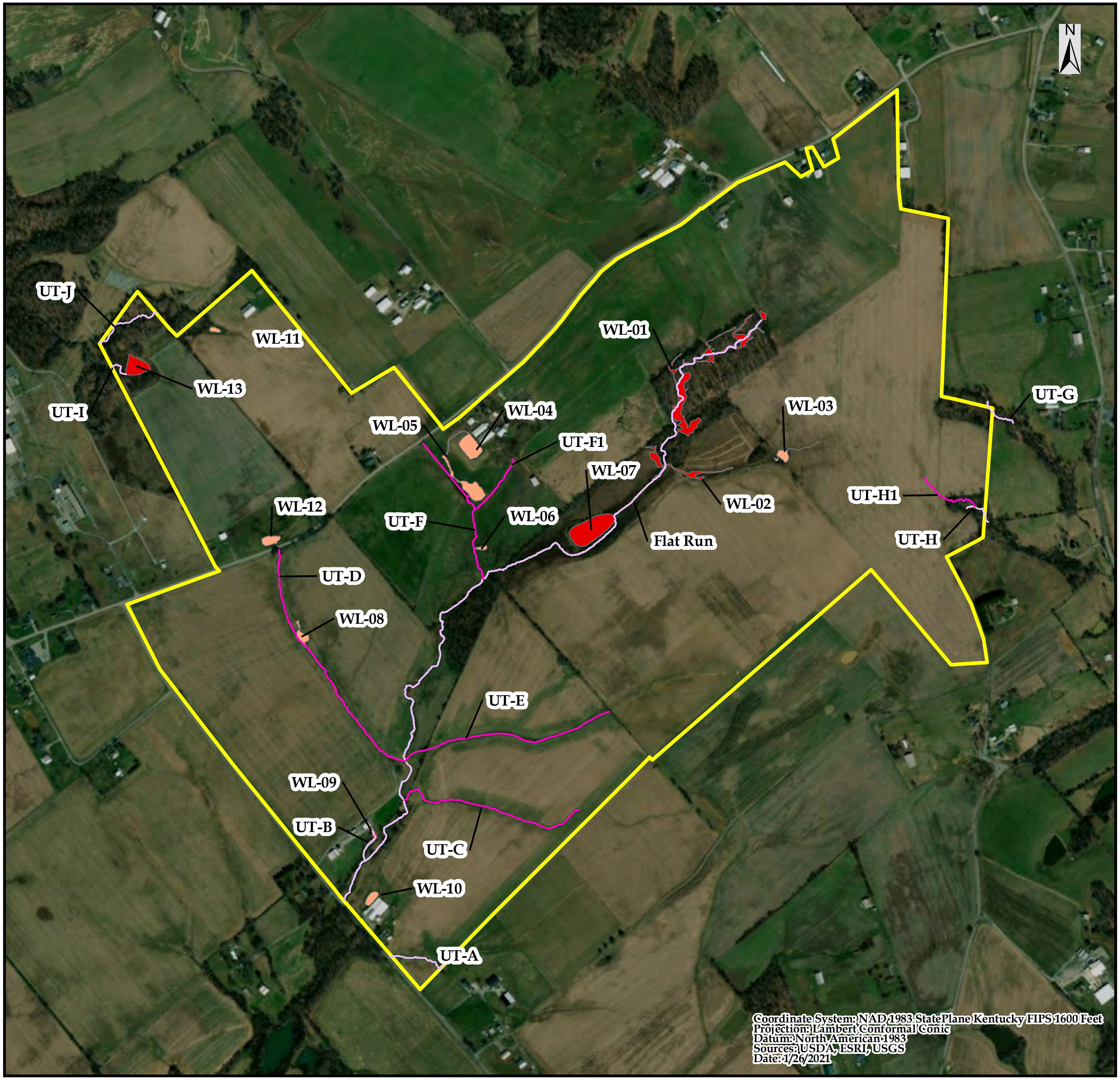
04

Attachment I



COPPERHEAD
ENVIRONMENTAL CONSULTING

Prepared for:

Flat Run Solar, LLC

FIGURE 4:
Wetland and Stream Delineation Map
at the Proposed
Flat Run Solar Farm
Taylor County, Kentucky

Legend

- Ephemeral Stream
- Intermittent Stream
- Isolated Wetland
- Jurisdictional Wetland
- Study Area

0 1,000 2,000
Feet

Scale: 1 in = 1,000 ft

Prepared by :
Copperhead Environmental Consulting, Inc.
471 Main Street
P.O. Box 73
Paint Lick, Kentucky 40461

Drawn by:	MRT	Date: 1/26/2021
Checked by:	EB	Revision: 02

Attachment J

STUDY OF ACOUSTIC AND EMF LEVELS FROM SOLAR PHOTOVOLTAIC PROJECTS

Prepared for:
Massachusetts Clean Energy Center
9th Floor
55 Summer Street
Boston, MA 02110

Prepared by:
Tech Environmental, Inc.
303 Wyman Street, Suite 295
Waltham, MA 02451

FOCUSED KNOWLEDGE. REAL SOLUTIONS.

STUDY OF ACOUSTIC AND EMF LEVELS FROM SOLAR PHOTOVOLTAIC PROJECTS

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December 17, 2012

ACKNOWLEDGEMENTS

The study team would like to thank the owners and managers of the four project sites for participating in this study and their cooperation in gaining access to the sites, operational data, and system specifications.

We would also like to thank Bram Claeys of the Massachusetts Department of Energy Resources as well as Elizabeth Kennedy and Peter McPhee of the Massachusetts Clean Energy Center for their thorough and insightful review of this study.

EXECUTIVE SUMMARY

Sound pressure level and electromagnetic field (EMF) measurements were made at three utility-scale sites with solar photovoltaic (PV) arrays with a capacity range of 1,000 to 3,500 kW (DC at STC) under a full-load condition (sunny skies and the sun at an approximate 40^{o} azimuth). Measurements were taken at set distances from the inverter pads and along the fenced boundary that encloses the PV array. Measurements were also made at set distances back from the fenced boundary. Broadband and 1/3-octave band sound levels were measured, along with the time variation of equipment sound levels.

EMF measurements were also made at one residential PV installation with a capacity of 8.6 kW under a partial-load condition. PV array operation is related to the intensity of solar insolation. Less sunshine results in lower sound and EMF levels from the equipment, and no sound or EMF is produced at night when no power is produced. A description of acoustic terms and metrics is provided in Appendix A, and EMF terms and metrics are presented in Appendix B. These appendices provide useful information for interpreting the results in this report and placing them in context, relative to other sound and EMF sources.

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 at set back distances of 50 to 150 feet from the boundary. Average L_{eq} sound levels at a distance of 10 feet from the inverter face varied over the range of 48 dBA to 61 dBA for Site 2 and Site 3 Inverters[1], and were higher in the range of 59 to 72 dBA for Site 1 Inverters. Along the axis perpendicular to the plane of the inverter face and at distances of 10 to 30 feet, sound levels were 4 to 13 dBA higher compared to levels at the same distance along the axis parallel to the inverter face. At 150 feet from the inverter pad, sound levels approached background levels. Sound level measurements generally followed the hemispherical wave spreading law (-6 dB per doubling of distance).

The time domain analysis reveals that 0.1-second L_{eq} sound levels at a distance of 10 feet from an inverter pad generally varied over a range of 2 to 6 dBA, and no recurring pattern in the rise and fall of the inverter sound levels with time was detected. The passage of clouds across the face of the sun caused cooling fans in the inverters to briefly turn off and sound levels to drop 4 dBA.

[1] The same make of inverters were used at Sites 2 and 3.

The 1/3-octave band frequency spectrum of inverter sound at the close distance of 10 feet shows energy peaks in several mid-frequency and high-frequency bands, depending on the inverter model. Tonal sound was found to occur in harmonic pairs: 63/125 Hz; 315/630 Hz; 3,150/6,300 Hz; and 5,000/10,000 Hz. The high frequency peaks produce the characteristic "ringing noise" or high-frequency buzz heard when one stands close to an operating inverter. The tonal sound was not, however, audible at distances of 50 to 150 feet beyond the PV array boundary, and these tonal peaks do not appear in the background sound spectrum. All low-frequency sound from the inverters below 40 Hz is inaudible, at all distances.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has a recommended electric field level exposure limit of 4,200 Volts/meter (V/m) for the general public. At the utility scale sites, electric field levels along the fenced PV array boundary, and at the locations set back 50 to 150 feet from the boundary, were not elevated above background levels (< 5 V/m). Electric fields near the inverters were also not elevated above background levels (< 5 V/m). At the residential site, indoor electric fields in the rooms closest to the roof-mounted panels and at locations near the inverters were not elevated above background levels (< 5 V/m).

The International Commission on Non-Ionizing Radiation Protection has a recommended magnetic field level exposure limit of 833 milli-Gauss (mG) for the general public. At the utility scale sites, magnetic field levels along the fenced PV array boundary were in the very low range of 0.2 to 0.4 mG. Magnetic field levels at the locations 50 to 150 feet from the fenced array boundary were not elevated above background levels (<0.2 mG). There are significant magnetic fields at locations a few feet from these utility-scale inverters, in the range of 150 to 500 mG. At a distance of 150 feet from the inverters, these fields drop back to very low levels of 0.5 mG or less, and in many cases to background levels (<0.2 mG). The variation of magnetic field with distance generally shows the field strength is proportional to the inverse cube of the distance from equipment.

At the residential site, indoor magnetic field levels in the rooms closest to the roof-mounted panels were in the low range of 0.2 to 1.4 mG. There are low-level magnetic fields at locations a few feet from the inverters, in the range of 6 to 10 mG. At a distance of no more than 9 feet from the inverters, these fields dropped back to the background level at this residential site of 0.2 mG. Due to the relatively high background level in the residential site basement where the inverters were housed, the relationship of magnetic field strength to distance from the inverters could not be discerned.

TABLE OF CONTENTS

1.0 INTRODUCTION

The goal of this study is to conduct measurements at several ground-mounted PV arrays in Massachusetts to determine the sound pressure levels and electromagnetic field (EMF) levels generated by PV arrays and the equipment pads holding inverters and small transformers. This information will be used to inform local decision-makers and the public about the acoustic and EMF levels in the vicinity of PV projects.

Measurements were made at three utility-scale sites having PV arrays with a capacity range of 1,000 to 3,500 kW (DC at STC), with weather conditions consisting of sunny skies and the sun at approximately 40^{o} azimuth. Measurements were also made at one residential[2] PV installation with a capacity of 8.6 kW under a partial-load condition. Sound level and EMF data were collected at set distances from the inverter pads and along the fenced boundary of the PV array. Measurements were also made at set distances back from the fenced boundary. Broadband and 1/3-octave band sound levels were measured, along with the time variation of equipment sound levels. Figure 1 shows a schematic map of a typical utility scale PV array containing four inverter pads and a fenced boundary. The orange stars show typical measurement locations around the fenced boundary of the array and at fixed set back distances of 50 feet, 100 feet, and 150 feet from the boundary. The green stars represent typical measurement locations at three set back distances from inverters on two of the equipment pads. At each equipment pad that was sampled, sound level measurements were made in two directions: along an axis parallel to the inverter face and along an axis perpendicular to the inverter face. Figure 2 illustrates a sound meter setup along the axis perpendicular to (90^{o} from) an inverter face.

Section 2.0 of this report describes the measurement methods and locations, while Section 3.0 presents the measurement results in detail for the four sites. Study conclusions are given in Section 4.0. A description of acoustic terms and metrics is provided in Appendix A, and EMF terms and metrics are presented in Appendix B. These appendices provide useful information for interpreting the results in this report and placing them in context, relative to other sound and EMF sources.

[2] Only EMF measurements were made at the residential site.

Figure 1. Schematic Map of Sound and EMF Measurement Locations at a Solar Photovoltaic (PV) Array

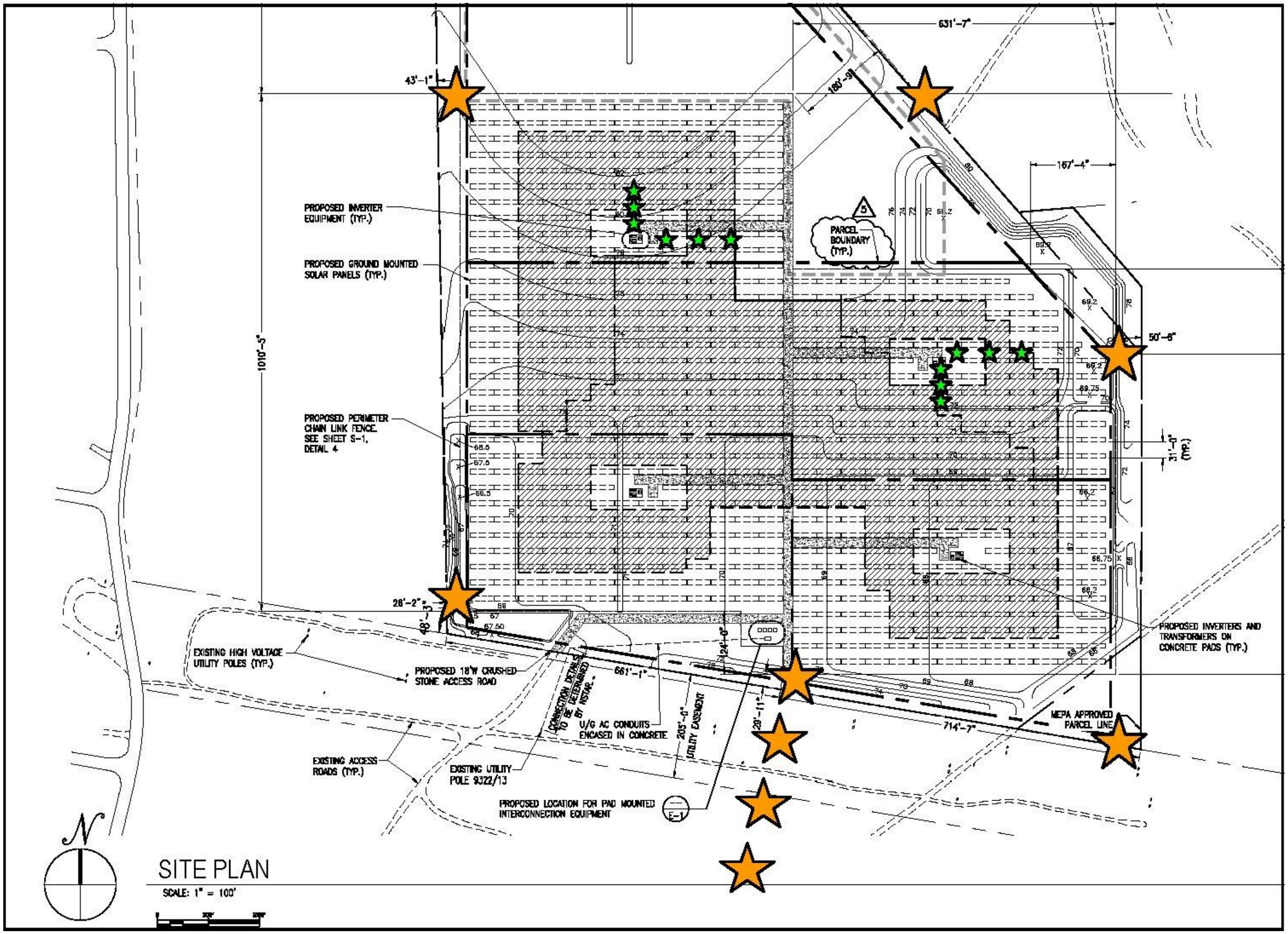


Figure 2. Sound Level Meter on the Axis Perpendicular to the Face of an Inverter at a Solar Photovoltaic (PV) Array

2.0 MEASUREMENT METHODS AND LOCATIONS

Sound pressure and EMF levels were measured along the fenced boundary of each PV array, at three set back distances from the boundary, and at fixed distances from equipment pads housing inverters and transformers (see Figures 1 and 2). Sound levels were measured with a tripod-mounted ANSI Type 1 sound meter, a Bruel & Kjaer Model 2250 meter, equipped with a large 7-inch ACO-Pacific WS7-80T 175 mm (7-inch) wind screen that is oversize and specially designed to screen out wind flow noise. An experimental study of wind-induced noise and windscreen attenuation effects by Hessler[3] found that the WS7-80T windscreen keeps wind-induced noise at the infrasound frequency band of 16 Hz to no more than 42 dB for moderate across-the–microphone wind speeds. That minimal level of wind-induced noise is 8 to 20 dB below the 16-Hz levels measured in this study.

The B&K Model 2250 measures 1/3-octave bands down to 6.3 Hz, well into the infrasonic range, and up to 20,000 Hz, the upper threshold of human hearing. The sound meter first recorded short-term (1-minute L_{eq} and L_{90}) broadband sound levels (in A-weighted decibels, dBA) at the established survey points. Then the sound meter was placed at the nearest measurement distance to each equipment pad to record a 10-minute time series of broadband and 1/3-octave band L_{eq} sound levels (in decibels, dB) at 0.1-second intervals. The L_{90} sound level removes intermittent noise and thus is lower than the L_{eq} sound level in the tables of results provided in Section 3.

EMF levels of both the magnetic field (in milliGauss, mG) and the electric field (in Volts/meter, V/m) were measured using a pair of Trifield Model 100XE EMF Meters. These instruments perform three-axis sampling simultaneously, enabling rapid survey of an area. The Trifield meters have a range for magnetic fields of 0.2 to 10,000 mG, and for electric fields from 5 to 1,000 V/m. EMF measurements were taken at the same survey points as the sound level measurements.

Measurements were made along the fenced boundary around each PV array at four to six evenly-spaced locations (depending on the size of the array), and at three additional locations set back 50 feet, 100 feet, and 150 feet from the boundary. At each equipment pad that was sampled, sound level

[3] Hessler, G., Hessler, D., Brandstatt, P., and Bay, K., "Experimental study to determine wind-induced noise and windscreen attenuation effects on microphone response for environmental wind turbine and other applications", Noise Control Eng. J., 56(4), 2008.

measurements were made in two directions: parallel to the inverter face, and perpendicular to the equipment face. The closest sound monitoring location was selected at a distance "1X" where the inverter or transformer sound was clearly audible above background levels. The closest EMF monitoring location was selected at a distance "1X" where magnetic field levels were approximately 500 mG, a level that is below the ICNIRP-recommended[4] human exposure limit of 833 mG (see Appendix B). Additional sampling points were then placed at distances[5] of 2X, 3X, and at 150 feet from the equipment pad, in the two orthogonal directions. There were a total of eight monitoring locations for each equipment pad, and seven to nine locations for the PV array boundary.

Measurements were made on October 11, 17, 22 and 26, 2012 around 12:30 p.m. EDT, the time of peak solar azimuth, and only on days for which clear skies were forecast to maximize solar insolation to the PV array. The peak solar azimuth in southern Massachusetts was approximately 40^{o} azimuth on these dates. Consistent with standard industry practice, background levels of sound and EMF were measured at representative sites outside the fenced boundary of the PV array and far enough away to not be influenced by it or any other significant nearby source. The background levels presented for each site were made at distances of 50 feet, 100 feet, and 150 feet from the fenced boundary around the PV array (see Figure 1).

[4] International Commission on Non-Ionizing Radiation Protection.

[5] Location 2X is twice the distance from the equipment as location 1X; Location 3X is three times that distance.

3.0 MEASUREMENT RESULTS

Sound and EMF measurements were made at the following four PV arrays, presented in the following sections:

Site 1 – Achusnet ADM, Wareham, MA
Site 2 – Southborough Solar, Southborough, MA
Site 3 – Norfolk Solar, Norfolk, MA
Site 4 – Residential PV array owned by Massachusetts Audubon Society, Sharon, MA

3.1 Site 1 – Achusnet ADM

Facility Location:	27 Charlotte Furnace Road, Wareham, MA
Facility Owner:	Borrego Solar Systems, Inc.
System Capacity:	3,500 kW
Power Output During Monitoring:	3,500 kW
No. & Size Inverters:	(7) 500-kW inverters
Date Measured:	Thursday October 11, 2012
Cloud Cover:	0%
Winds:	West 10-12 mph
Ground:	Open area between cranberry bogs, no buildings or vegetation.
Background Sound:	Mean value L_{eq} of 46.4 dBA (range of 45.6 to 47.0 dBA). Mean value of L_{90} 43.9 dBA (range of 41.6 to 45.4 dBA). Sources included highway traffic on I-495 (to the south), earthmoving equipment to the east, birds and other natural sounds.
Background EMF:	None (< 0.2 mG and < 5 V/m) except along southern boundary from hi-voltage power lines overhead, and near the eastern boundary from low-voltage power lines overhead.

The solar photovoltaic array is in a flat area between cranberry bogs east of Charlotte Furnace Road in Wareham and the boundary of the array is fenced. The surrounding area has no buildings or vegetation. There are four equipment pads within the PV array, each housing one or two inverters. Measurements were made at two equipment pads: 1) the Northwest Pad, which contains two inverters and a small transformer, and 2) the Northeast Pad, which has one inverter and a small transformer. The sound and EMF measurements made at Site 1 are summarized in Tables 1 through 3. Figures 3 and 4 present a time series graph of 0.1-second L_{eq} sound levels at the nearest measurement location

(1X) for the Northwest and Northeast Equipment Pads, while Figure 5 provides the corresponding 1/3-octave band spectra for the sound level measurements at those same locations along with the spectrum for background sound levels.

Sound Levels

Background sound levels varied over time and space across the site. Highway traffic noise was the primary background sound source and higher levels were measured for locations on the south side of the site closer to the highway. Variable background sound was also produced by trucking activity to the east of the PV array, where sand excavated during the PV array's construction and stored in large piles was being loaded with heavy equipment into dump trucks and hauled away. Background sound levels varied over a range of 6 dBA. Background mean value L_{eq} and L_{90} levels were 46.4 dBA and 43.9 dBA, respectively. The PV array was inaudible outside of the fenced boundary, and was also inaudible everywhere along the boundary except at the North East boundary location where a faint inverter hum could be heard. Broadband sound levels at the locations set back 50 to 150 feet from the boundary are not elevated above background levels.

L_{eq} sound levels at a distance of 10 feet from the inverter face on the North West Pad (which holds two 500-kW inverters) were 68.6 to 72.7 dBA and at the same distance from the North East Pad (which holds only one 500-kW inverter) were lower at 59.8 to 66.0 dBA. Along the axis perpendicular to the inverter face measured sound levels were 4 to 6 dBA higher than at the same distance along the axis parallel to the inverter face. The sound levels generally declined with distance following the hemispherical wave spreading law (approximately -6 dB per doubling of distance) and at a distance of 150 feet all inverter sounds approached background sound levels. Due to the layout of the solar panels, the measurements made perpendicular to the inverter face and at a distance of 150 feet were blocked from a clear line of sight to the inverter pad by many rows of solar panels, which acted as sound barriers.

The time domain analysis presented in Figures 3 and 4 reveal that 0.1-second L_{eq} sound levels at the close distance of 10 feet generally varied 3 to 4 dBA at the North West Pad and 2 to 3 dBA at the North East Pad. The graphs show no recurring pattern in the rise and fall of the inverter sound levels over the measurement period of ten minutes. The inverters registered full 500-kW capacity during both 10-minute monitoring periods.

The frequency spectrum of equipment sound at the close distance of 10 feet (Figure 5) shows energy peaks in four 1/3-octave bands, which are most pronounced for the North West Pad: 315 Hz, 630 Hz, 3,150 Hz, and 6,300 Hz. The two higher frequency peaks produce the characteristic "ringing noise" or high-frequency buzz heard when one stands close to an operating inverter. The second frequency peak in each pair is a first-harmonic tone (6,300 Hz being twice the frequency of 3,150 Hz). The tonal sound exhibited by Figure 5 is not, however, audible at distances of 50 to 150 feet beyond the PV array boundary, and these tonal peaks do not appear in the background sound spectrum shown in Figure 5. The dashed line in Figure 5 is the ISO 226 hearing threshold and it reveals that low-frequency sound from the inverters below 40 Hz is inaudible, even at a close distance. The background sound spectrum is smooth except for a broad peak around 800 Hz caused by distant highway traffic noise and a peak at 8,000 Hz that represents song birds.

Electric Fields

Electric field levels along the PV array boundary, and at the locations set back 50 to 150 feet from the boundary, are not elevated above background levels (< 5 V/m). The one measurement at 5.0 V/m in Table 1 was caused by the field around a nearby low-voltage power line overhead. Electric fields near the inverters are also not elevated above background levels (< 5 V/m). The one measurement at 10.0 V/m in Table 3 was caused by the meter being close to the front face of a solar panel at the 150-foot set back distance.

Magnetic Fields

Magnetic field levels along the PV array boundary and 50 feet from the boundary were in the very low range of 0.2 to 0.3 mG, except at the southern end of the boundary that is close to overhead high-voltage power lines, owned by the local utility and not connected to the project, where levels of 0.7 to 3 mG were measured, caused by those hi-voltage power lines. Magnetic field levels at the location 100 feet from the boundary were elevated by a low-voltage power line overhead. At 150 feet from the boundary, the magnetic field is not elevated above background levels (<0.2 mG).

Table 3 reveals that there are significant magnetic fields at locations a few feet from inverters, around 500 mG. These levels drop back to 0.2 to 0.5 mG at distances of 150 feet from the inverters. The variation of magnetic field with distance shown in Table 3 generally shows the field strength is proportional to the inverse cube of the distance from equipment. Following that law, the magnetic field at 5 feet of 500 mG should decline to 0.02 mG (< 0.2 mG) at 150 feet. The measured levels of 0.1 to 0.5 mG at 150 feet listed in Table 3 are likely caused by small-scale magnetic fields setup around the PV cells and connecting cables near the sampling locations.

TABLE 1

SOUND AND EMF LEVELS MEASURED AT SITE 1
PV ARRAY BOUNDARY

Boundary Location	L_{90} Level (dBA)	L_{eq} Level (dBA)	Magnetic Field (mG)	Electric Field (V/m)
North West Boundary	39.1	42.5	< 0.2	< 5
South West Boundary	43.6	44.7	1.8	< 5
South Center Boundary	44.8	48.1	3.0	< 5
South East Boundary	44.0	45.6	0.7	< 5
North East Boundary	42.2	43.9	< 0.2	< 5
North Center Boundary	43.4	44.3	0.3	< 5
Background Mean Values	43.9	46.4	< 0.2	< 5
Set back 50 feet from Boundary	41.6	47.0	0.2	< 5
Set back 100 feet from Boundary	45.4	46.7	0.4	5.0
Set back 150 feet from Boundary	44.7	45.6	< 0.2	< 5

TABLE 2

SOUND LEVELS MEASURED AT SITE 1
EQUIPMENT PADS

Equipment Pad / Direction / Distance	**L_{90} Level (dBA)**	**L_{eq} Level (dBA)**
North West Pad / Parallel to Inverter Face / 10 feet	67.6	68.6
North West Pad / Parallel to Inverter Face / 20 feet	61.8	63.1
North West Pad / Parallel to Inverter Face / 30 feet	58.8	60.6
North West Pad / Parallel to Inverter Face / 150 feet	45.2	46.0
North West Pad / Perpendicular to Inverter Face / 10 feet	71.8	72.7
North West Pad / Perpendicular to Inverter Face / 20 feet	63.5	64.8
North West Pad / Perpendicular to Inverter Face / 30 feet	59.5	62.3
North West Pad / Perpendicular to Inverter Face / 150 feet	41.8	43.0
North East Pad / Parallel to Inverter Face / 10 feet	59.1	59.8
North East Pad / Parallel to Inverter Face / 20 feet	55.4	56.2
North East Pad / Parallel to Inverter Face / 30 feet	54.8	55.7
North East Pad / Parallel to Inverter Face / 150 feet	43.4	44.0
North East Pad / Perpendicular to Inverter Face / 10 feet	65.5	66.0
North East Pad / Perpendicular to Inverter Face / 20 feet	59.8	60.2
North East Pad / Perpendicular to Inverter Face / 30 feet	56.3	56.9
North East Pad / Perpendicular to Inverter Face / 150 feet	41.0	43.6

TABLE 3

EMF LEVELS MEASURED AT SITE 1
EQUIPMENT PADS

Equipment Pad / Direction / Distance	Magnetic Field (mG)	Electric Field (V/m)
North West Pad / Parallel to Inverter Face / 5 feet 3 inches	500	< 5
North West Pad / Parallel to Inverter Face / 10 feet 6 inches	10.5	< 5
North West Pad / Parallel to Inverter Face / 15 feet 9 inches	2.75	< 5
North West Pad / Parallel to Inverter Face / 150 feet	0.2	< 5
North West Pad / Perpendicular to Inverter Face / 4 feet	500	< 5
North West Pad / Perpendicular to Inverter Face / 8 feet	200	< 5
North West Pad / Perpendicular to Inverter Face / 12 feet	6.5	< 5
North West Pad / Perpendicular to Inverter Face / 150 feet	0.5	< 5
North East Pad / Parallel to Inverter Face / 3 feet 10 inches	500	< 5
North East Pad / Parallel to Inverter Face / 7 feet 8 inches	30	< 5
North East Pad / Parallel to Inverter Face / 11 feet 10 inches	4.5	< 5
North East Pad / Parallel to Inverter Face / 150 feet	0.2	10.0
North East Pad / Perpendicular to Inverter Face / 7 feet 6 inches	500	< 5
North East Pad / Perpendicular to Inverter Face / 15 feet	10	< 5
North East Pad / Perpendicular to Inverter Face / 22 feet 6 inches	2.1	< 5
North East Pad / Perpendicular to Inverter Face / 150 feet	0.1	< 5

Figure 3. Time Variation of Sound Levels (Leq) at a Distance of 10 Feet from the Inverter Pads for Site #1

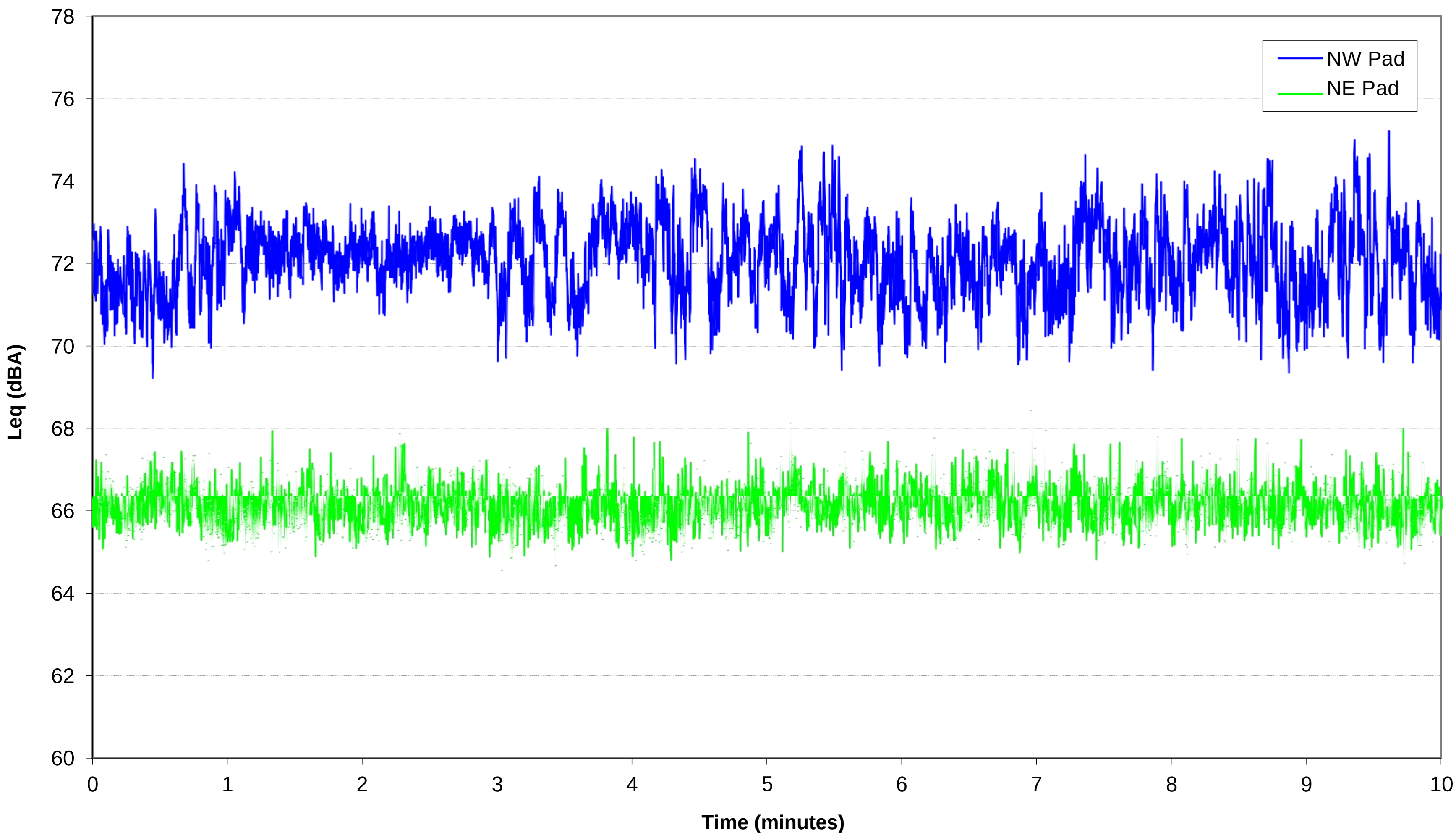


Figure 4. Time Variation of Sound Levels (Leq) at a Distance of 10 Feet from the Inverter Pads for Site #1 - First 10 Seconds of Measurements

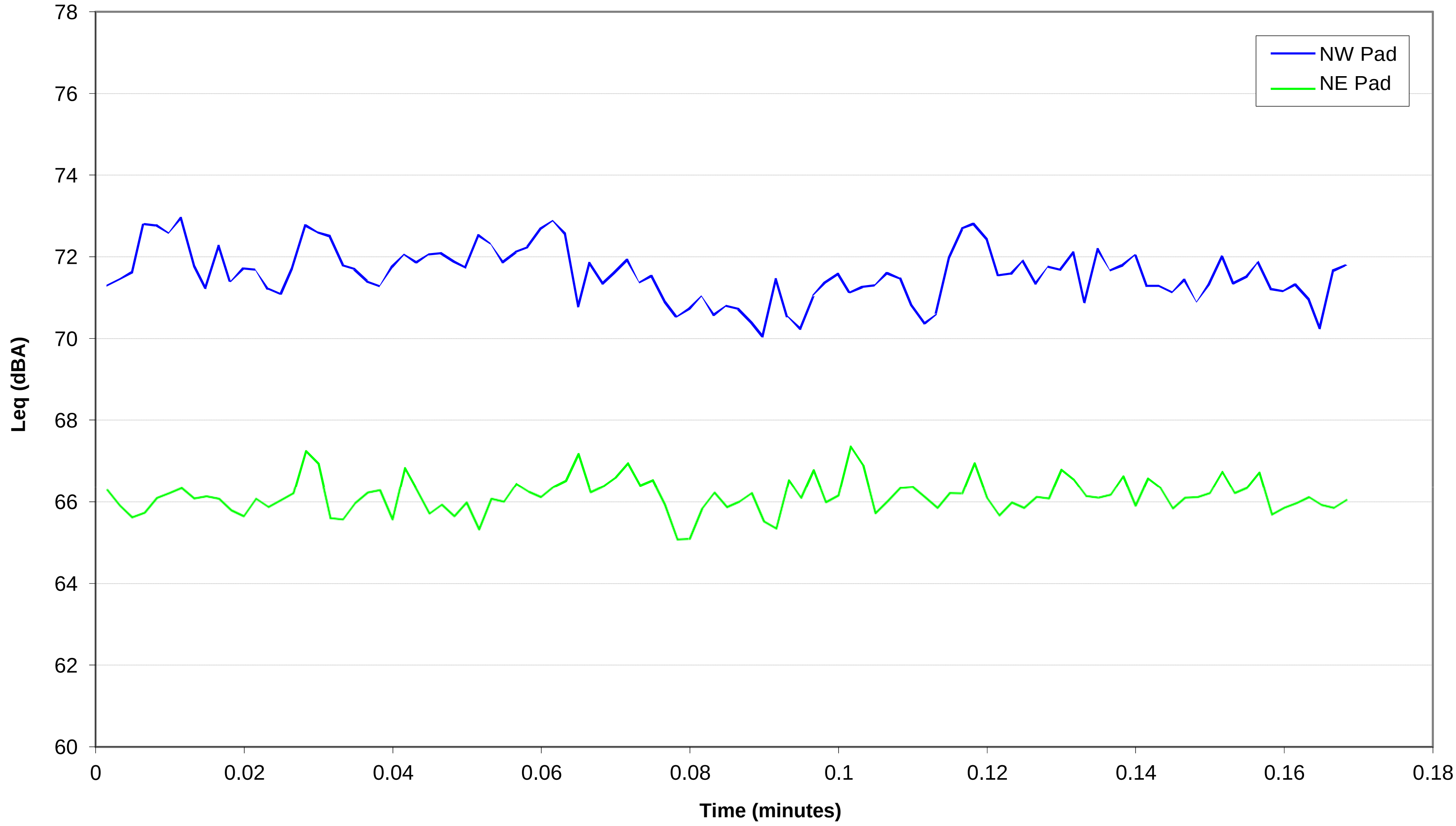
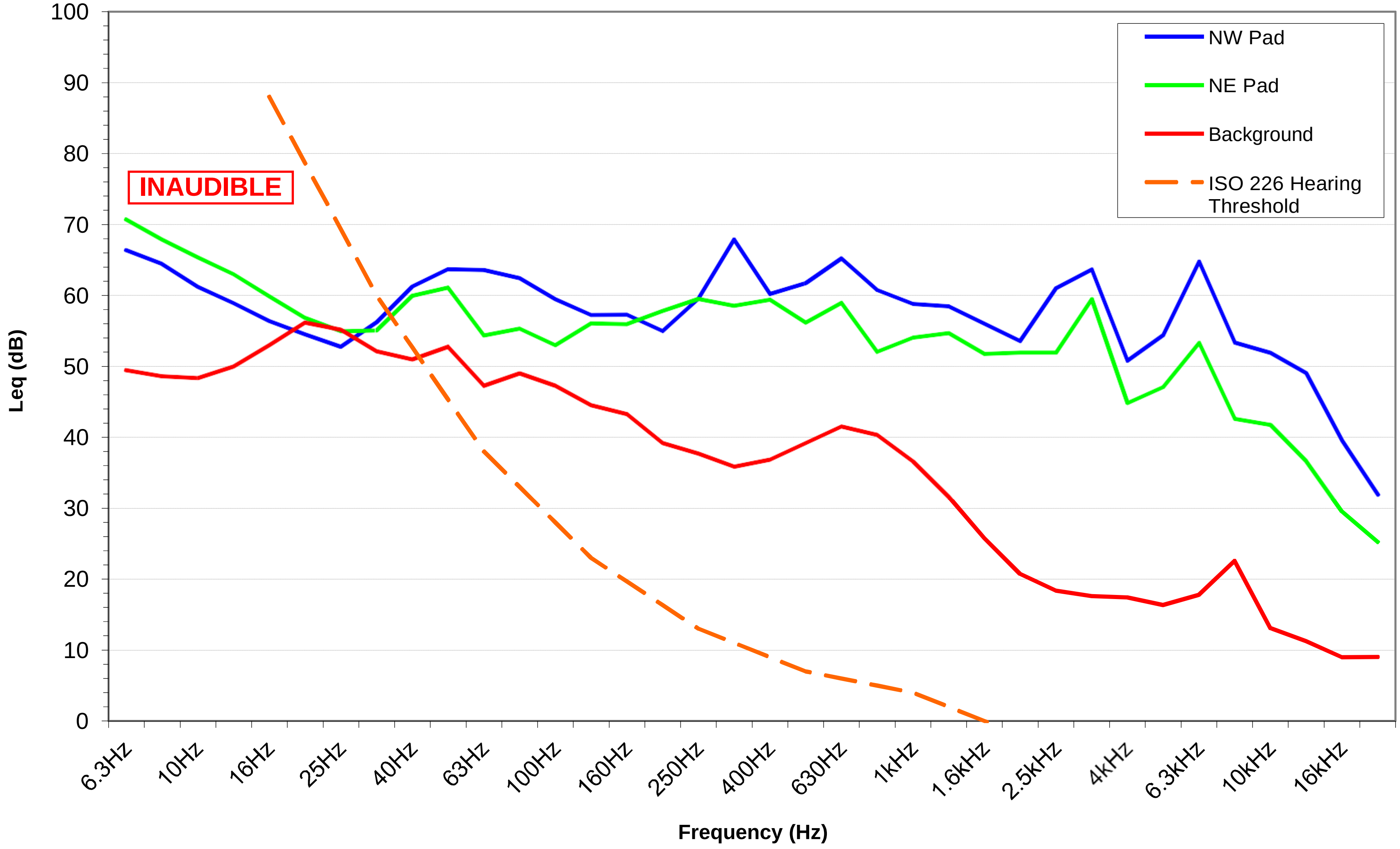


Figure 5. Frequency Spectrum of Sound Levels (Leq) at a Distance of 10 Feet from the Inverter Pads for Site #1



3.2 Site 2 – Southborough Solar

Facility Location:	146 Cordaville Road, Southborough, MA
Facility Owner:	Southborough Solar, LLC
System Capacity:	1,000 kW
Power Output During Monitoring:	1,000 kW
No. & Size Inverters:	(2) 500-kW inverters
Date Measured:	Wednesday October 17, 2012
Cloud Cover:	5% (high, thin cirrus)
Winds:	Northwest 3-5 mph
Ground:	Wooded areas and wetlands surround the PV array, and a building is located to the south where the inverters are housed.
Background Sound:	Mean value L_{eq} of 53.1 dBA (range of 51.0 to 55.9 dBA). Mean value L_{90} of 49.6 dBA (range of 48.6 to 50.3 dBA). Sources included roadway traffic on Cordaville Road (to the west) and Route 9 (to the north) and natural sounds.
Background EMF:	None (< 0.2 mG and < 5 V/m).

The solar photovoltaic array is in a cleared area of land east of Cordaville Road in Southborough and the boundary of the array is fenced. The array is surrounded by wetlands and woods. The two inverters are not within the PV array; instead they are located on a single pad at the southeast corner of the building that lies south of the PV array. Measurements were made at the one equipment pad housing the two inverters. Due to the close proximity of wetlands to the fenced boundary for the PV array, it was not possible to obtain measurements 50 to 150 feet from the boundary. Instead, measurements were taken 50 to 150 feet set back from the property boundary of the site near where the inverter pad is located. The sound and EMF measurements made at Site 2 are summarized in Tables 4 through 6. Figures 6 and 7 present a time series graph of 0.1-second L_{eq} sound levels at the nearest measurement location (1X) for the equipment pad, while Figure 8 provides the corresponding 1/3-octave band spectra for the sound level measurements at those same locations along with the spectrum for background sound levels.

<u>Sound Levels</u>

Background sound levels varied over time and space across the site, depending on the distance from Cordaville Road, which carries heavy traffic volumes. Roadway traffic noise was the primary background sound source and higher levels were measured for locations on the west side of the site closer to Cordaville Road. Background sound levels varied over a range of 5 to 7 dBA. The background mean value L_{eq} and L_{90} levels were 53.1 dBA and 49.6 dBA, respectively. The inverters were inaudible at a distance of 50 feet outside of the site boundary. Broadband sound levels at the locations set back 50 to 150 feet from the boundary are not elevated above background levels.

L_{eq} sound levels at a distance of 10 feet from the inverter face on the equipment pad (which holds two 500-kW inverters) were 48.1 to 60.8 dBA. Along the axis perpendicular to the inverter face, measured sound levels were 10 to 13 dBA higher than at the same distance along the axis parallel to the inverter face. The sound levels did not follow the expected hemispherical wave spreading law (approximately -6 dB per doubling of distance) and declined at a lower rate with increasing distance due to the relatively high background sound levels from nearby roadway traffic. At a distance of 150 feet, all inverter sounds were below background sound levels.

The time domain analysis presented in Figures 6 and 7 reveal that 0.1-second L_{eq} sound levels at the close distance of 10 feet generally varied 5 to 6 dBA. The graphs show no recurring pattern in the rise and fall of the inverter sound levels over the measurement period of ten minutes. The rise and fall in inverter sound levels over several minutes is thought to be due to the passage of sheets of high thin cirrus clouds across the face of the sun during the measurements. The inverters registered full 500-kW capacity during both 10-minute monitoring periods.

The frequency spectrum of equipment sound at the close distance of 10 feet (Figure 8) shows energy peaks in two 1/3-octave bands: 5,000 and 10,000 Hz. These high frequency peaks produce the characteristic "ringing noise" or high-frequency buzz heard when one stands close to an operating inverter. The second frequency peak is a first-harmonic tone (10 kHz being twice the frequency of 5 kHz). The tonal sound exhibited by Figure 8 is not, however, audible at distances of 50 to 150 feet beyond the site boundary, and these tonal peaks do not appear in the background sound spectrum shown in Figure 8. The dashed line in Figure 8 is the ISO 226 hearing threshold and it reveals that low-frequency sound from the inverters below 40 Hz is inaudible, even at a close distance. The background sound spectrum declines smoothly with increasing frequency in the audible range except for a rise around 800 to 2,000 Hz caused by nearby roadway traffic noise.

Electric Fields

Electric field levels along the PV array boundary, and at the locations set back 50 to 150 feet from the site boundary, are not elevated above background levels (< 5 V/m).

Magnetic Fields

Magnetic field levels along the PV array boundary were in the very low range of 0.2 to 0.4 mG. Magnetic field levels at the locations 50 to 150 feet from the site boundary were not elevated above background levels (<0.2 mG).

Table 6 reveals that there are significant magnetic fields at locations a few feet from inverters, in the range of 200 to 500 mG. These levels drop back to background levels (<0.2 mG) at distances of 95 to 150 feet from the inverters. The variation of magnetic field with distance shown in Table 6 generally shows the field strength is proportional to the inverse cube of the distance from equipment.

TABLE 4

SOUND AND EMF LEVELS MEASURED AT SITE 2
PV ARRAY BOUNDARY

Boundary Location	L_{90} Level (dBA)	L_{eq} Level (dBA)	Magnetic Field (mG)	Electric Field (V/m)
North West Boundary	53.3	54.4	0.2	< 5
South West Boundary	52.4	54.4	0.2	< 5
South East Boundary	48.3	50.8	0.4	< 5
North East Boundary	46.8	49.8	< 0.2	< 5
Background Mean Values	49.6	53.1	< 0.2	< 5
Set back 50 feet from Boundary	50.3	52.3	< 0.2	< 5
Set back 100 feet from Boundary	49.9	55.9	< 0.2	< 5
Set back 150 feet from Boundary	48.6	51.0	< 0.2	< 5

TABLE 5

SOUND LEVELS MEASURED AT SITE 2 EQUIPMENT PAD

Equipment Pad / Direction / Distance	L_{90} Level (dBA)	L_{eq} Level (dBA)
Parallel to Inverter Face / 10 feet	46.7	48.1
Parallel to Inverter Face / 20 feet	44.8	46.2
Parallel to Inverter Face / 30 feet	44.3	45.6
Parallel to Inverter Face / 95 feet*	44.0	45.6
Perpendicular to Inverter Face / 10 feet	59.9	60.8
Perpendicular to Inverter Face / 20 feet	57.3	58.7
Perpendicular to Inverter Face / 30 feet	53.4	54.5
Perpendicular to Inverter Face / 150 feet	46.2	47.5

*Measurements could not be taken at 150 feet parallel to inverter face because of the close proximity of wetlands. Instead, a measurement was made at the farthest practical distance in that direction at 95 feet.

TABLE 6

EMF LEVELS MEASURED AT SITE 2
EQUIPMENT PAD

Equipment Pad / Direction / Distance	Magnetic Field (mG)	Electric Field (V/m)
Parallel to Inverter Face / 4 feet	200	< 5
Parallel to Inverter Face / 8 feet	10	< 5
Parallel to Inverter Face / 12 feet	0.8	< 5
Parallel to Inverter Face / 95 feet*	<0.2	< 5
Perpendicular to Inverter Face / 4 feet	500	< 5
Perpendicular to Inverter Face / 8 feet	25	< 5
Perpendicular to Inverter Face / 12 feet	4.5	< 5
Perpendicular to Inverter Face / 150 feet	<0.2	< 5

*Measurements could not be taken at 150 feet parallel to inverter face because of the close proximity of wetlands. Instead, a measurement was made at the farthest practical distance in that direction at 95 feet.

Figure 6. Time Variation of Sound Levels (Leq) at a Distance of 10 Feet from the Inverter Pad for Site #2

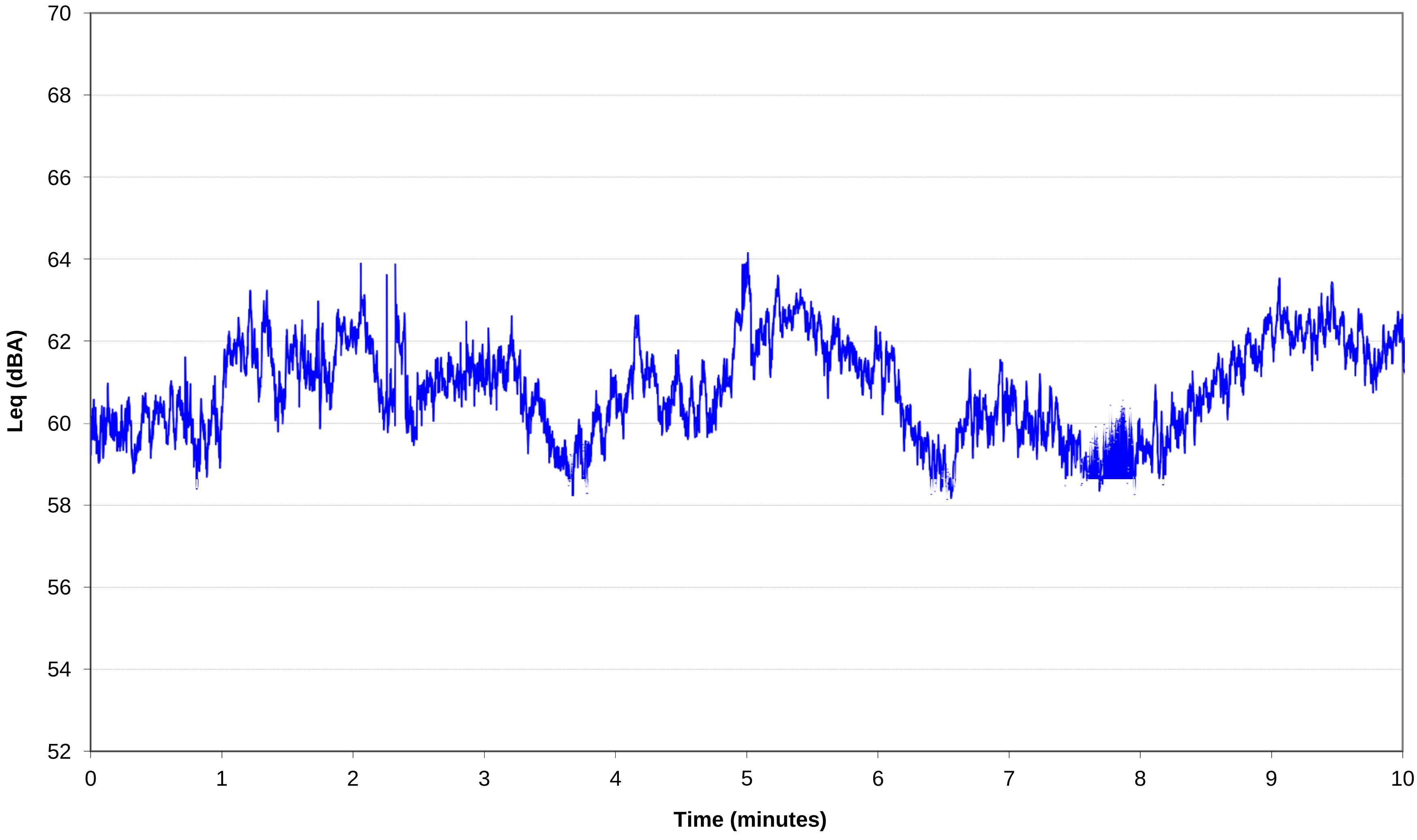


Figure 7. Time Variation of Sound Levels (Leq) at a Distance of 10 Feet from the Inverter Pad for Site #2 - First 10 Seconds of Measurements

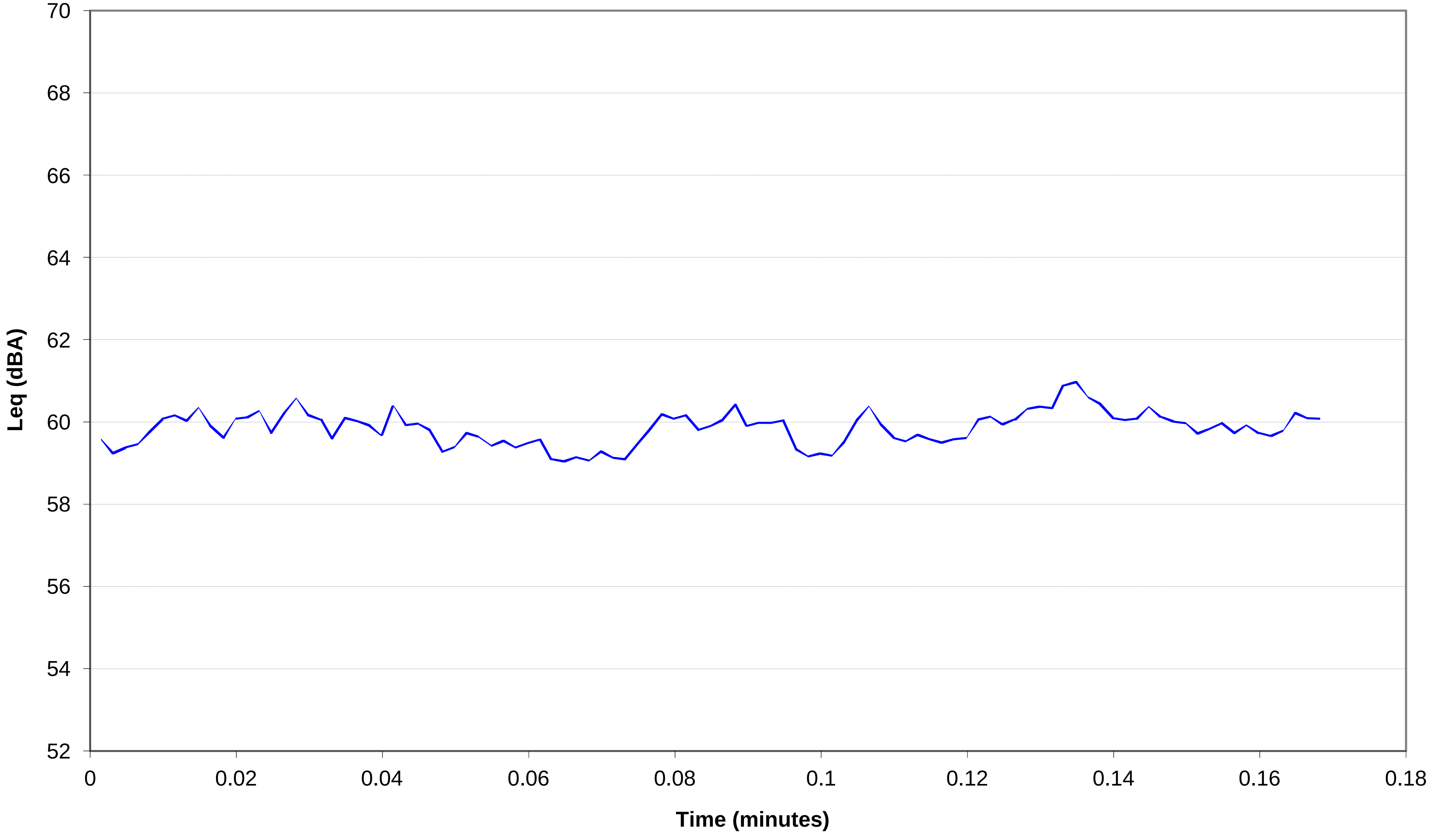
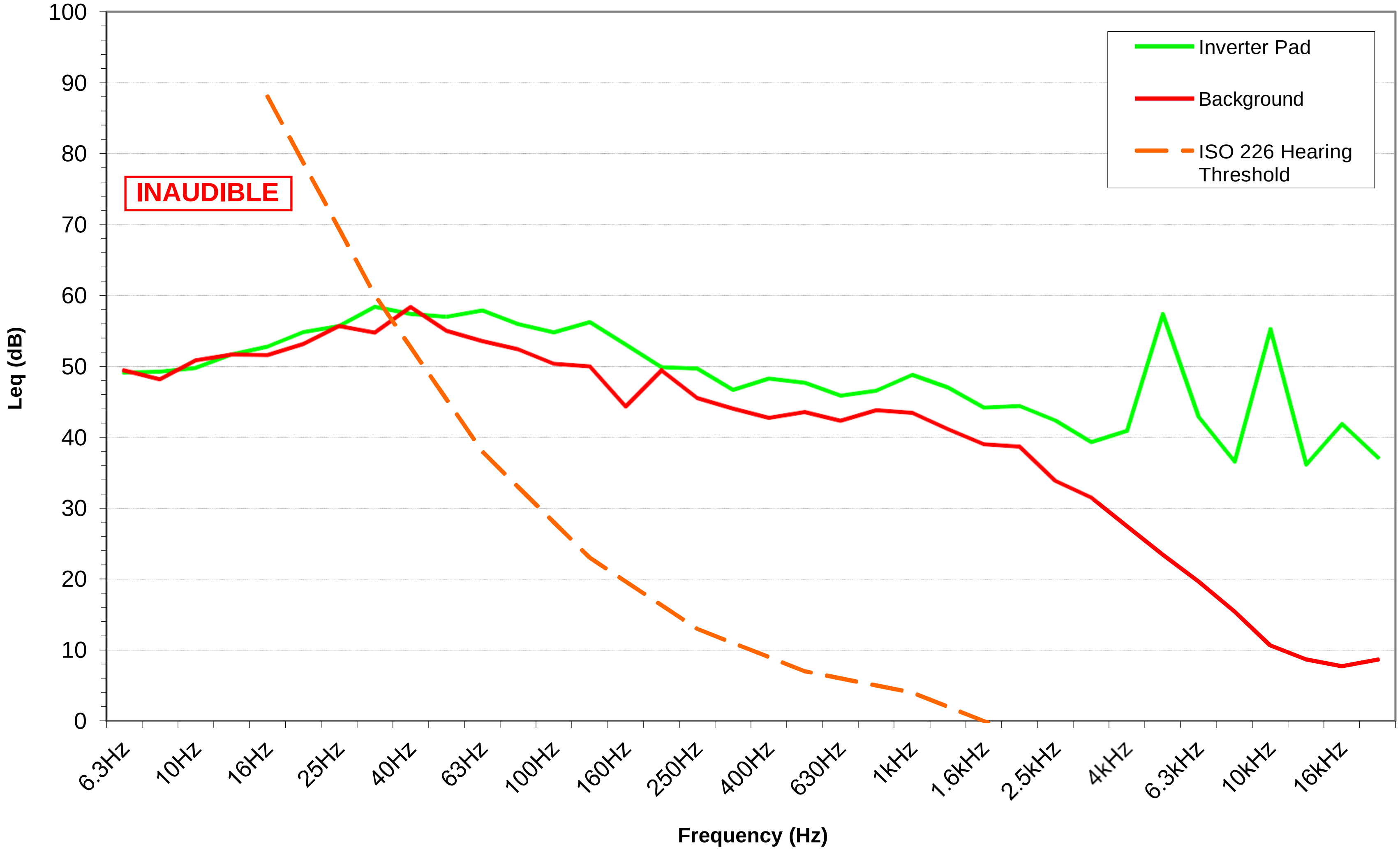


Figure 8. Frequency Spectrum of Sound Levels (Leq) at a Distance of 10 Feet from the Inverter Pad at Site #2



3.3 Site 3 – Norfolk Solar

Facility Location: 33 Medway Branch Road, Norfolk, MA
Facility Owner: Constellation Solar Massachusetts, LLC
System Capacity: 1,375 kW
Power Output During Monitoring: 1,200 to 1,375 kW
No. & Size Inverters: (2) 500-kW inverters and (1) 375-kW inverter
Date Measured: Monday October 22, 2012
Sky Cover: 10% (passing small cumulus clouds)
Winds: West 10-12 mph
Ground: One PV array sits high on top of the closed landfill with grass cover and no surrounding vegetation. The other, larger PV array is in a wooded area on relatively flat ground. Measurements were made at the larger PV array.
Background Sound: Mean value L_{eq} of 45.3 dBA (range of 43.1 to 47.5 dBA). Mean value L_{90} of 42.5 dBA (range of 42.1 to 43.2 dBA). Sources included distant traffic noise and natural sounds.
Background EMF: None (< 0.2 mG and < 5 V/m).

There are two solar photovoltaic arrays on the land of the Town of the Norfolk Department of Public Works. One array sits on top of a capped landfill and has a single equipment pad with one inverter. The second, and larger, array is in a cleared flat area east of the capped landfill and has a single equipment pad housing two inverters. The boundaries of the PV arrays are fenced. The surrounding area has only grass cover or low vegetation. Measurements were made at the larger PV array and at the equipment pad housing two inverters with a capacity of 875 kW. The sound and EMF measurements made at Site 3 are summarized in Tables 7 through 9. Figures 9 and 10 present a time series graph of 0.1-second L_{eq} sound levels at the nearest measurement location (1X) for the equipment pad, while Figure 11 provides the corresponding 1/3-octave band spectra for the sound level measurements at those same locations along with the spectrum for background sound levels.

<u>Sound Levels</u>

Background sound levels were fairly constant across the site and distant roadway traffic was the primary background sound source. The background mean value L_{eq} and L_{90} levels were 45.3 dBA and 42.5 dBA, respectively. The PV array was inaudible outside of the fenced boundary except at the South East boundary location where a faint inverter hum could be heard. Broadband sound levels at the locations set back 50 to 150 feet from the boundary are not elevated above background levels.

L_{eq} sound levels at a distance of 10 feet from the inverter face on the equipment pad (which holds two inverters) were 54.8 to 60.9 dBA. Along the axis perpendicular to the inverter face measured sound levels were 6 to 7 dBA higher than at the same distance along the axis parallel to the inverter face. The sound levels generally followed the expected hemispherical wave spreading law (approximately -6 dB per doubling of distance). At a distance of 150 feet, all inverter sounds were below background sound levels.

The time domain analysis presented in Figures 9 and 10 reveal that 0.1-second L_{eq} sound levels at the close distance of 10 feet generally varied 3 to 4 dBA. The graphs show no recurring pattern in the rise and fall of the inverter sound levels over the measurement period of ten minutes. Between 7 and 9 minutes into the 10-minute measurement, clouds passed over the face of the sun, power production dropped, and the inverter cooling fans turned off for a brief period, as shown by the abrupt 4 dBA drop in sound level in Figure 9.

The frequency spectrum of equipment sound at the close distance of 10 feet (Figure 11) shows energy peaks in four 1/3-octave bands: 63, 125, 5,000 and 10,000 Hz. The high frequency peaks produce the characteristic "ringing noise" or high-frequency buzz heard when one stands close to an operating inverter. The second frequency peak in each pair is a first-harmonic tone (10 kHz being twice the frequency of 5 kHz). The tonal sound exhibited by Figure 11 is not, however, audible at distances of 50 to 150 feet beyond the site boundary, and these tonal peaks do not appear in the background sound spectrum shown in Figure 11. The dashed line in Figure 11 is the ISO 226 hearing threshold and it reveals that low-frequency sound from the inverters below 40 Hz is inaudible, even at a close distance. The background sound spectrum declines smoothly with increasing frequency in the audible range except for a slight rise around 800 to 2,000 Hz caused by distant roadway traffic noise.

Electric Fields

Electric field levels along the PV array boundary, and at the locations set back 50 to 150 feet from the site boundary, are not elevated above background levels (< 5 V/m).

Magnetic Fields

Magnetic field levels along the PV array boundary were in the very low range, at or below 0.2 mG. Magnetic field levels at the locations 50 to 150 feet from the site boundary were not elevated above background levels (<0.2 mG).

Table 9 reveals that there are significant magnetic fields at locations a few feet from inverters, in the range of 150 to 500 mG. These levels drop back to levels of 0.4 mG in the perpendicular direction and to background levels (<0.2 mG) in the parallel direction at 150 feet from the inverters. The variation of magnetic field with distance shown in Table 9 generally shows the field strength is proportional to the inverse cube of the distance from equipment.

TABLE 7

SOUND AND EMF LEVELS MEASURED AT SITE 3
PV ARRAY BOUNDARY

Boundary Location	L_{90} Level (dBA)	L_{eq} Level (dBA)	Magnetic Field (mG)	Electric Field (V/m)
North West Boundary	46.2	48.3	< 0.2	< 5
South West Boundary	48.9	50.6	< 0.2	< 5
South East Boundary	43.3	44.3	0.2	< 5
North East Boundary	43.9	46.1	< 0.2	< 5
Background Mean Values	42.5	45.3	< 0.2	< 5
Set back 50 feet from Boundary	43.2	47.5	< 0.2	< 5
Set back 100 feet from Boundary	42.2	45.4	< 0.2	< 5
Set back 150 feet from Boundary	42.1	43.1	< 0.2	< 5

TABLE 8

SOUND LEVELS MEASURED AT SITE 3 EQUIPMENT PAD

Equipment Pad / Direction / Distance	L_{90} Level (dBA)	L_{eq} Level (dBA)
Perpendicular to Inverter Face / 10 feet	59.7	60.9
Perpendicular to Inverter Face / 20 feet	57.3	58.6
Perpendicular to Inverter Face / 30 feet	49.4	50.1
Perpendicular to Inverter Face / 150 feet	43.9	47.0
Parallel to Inverter Face / 10 feet	53.9	54.8
Parallel to Inverter Face / 20 feet	50.6	51.3
Parallel to Inverter Face / 30 feet	45.5	48.0
Parallel to Inverter Face / 150 feet	41.8	43.7

TABLE 9

EMF LEVELS MEASURED AT SITE 3 EQUIPMENT PAD

Equipment Pad / Direction / Distance	Magnetic Field (mG)	Electric Field (V/m)
Parallel to Inverter Face / 3 feet	150	< 5
Parallel to Inverter Face / 6 feet	10	< 5
Parallel to Inverter Face / 9 feet	5	< 5
Parallel to Inverter Face / 150 feet	< 0.2	< 5
Perpendicular to Inverter Face / 3 feet	500	< 5
Perpendicular to Inverter Face / 6 feet	200	< 5
Perpendicular to Inverter Face / 9 feet	80	< 5
Perpendicular to Inverter Face / 150 feet	0.4	< 5

Figure 9. Time Variation of Sound Levels (Leq) at a Distance of 10 Feet from the Inverter Pad for Site #3

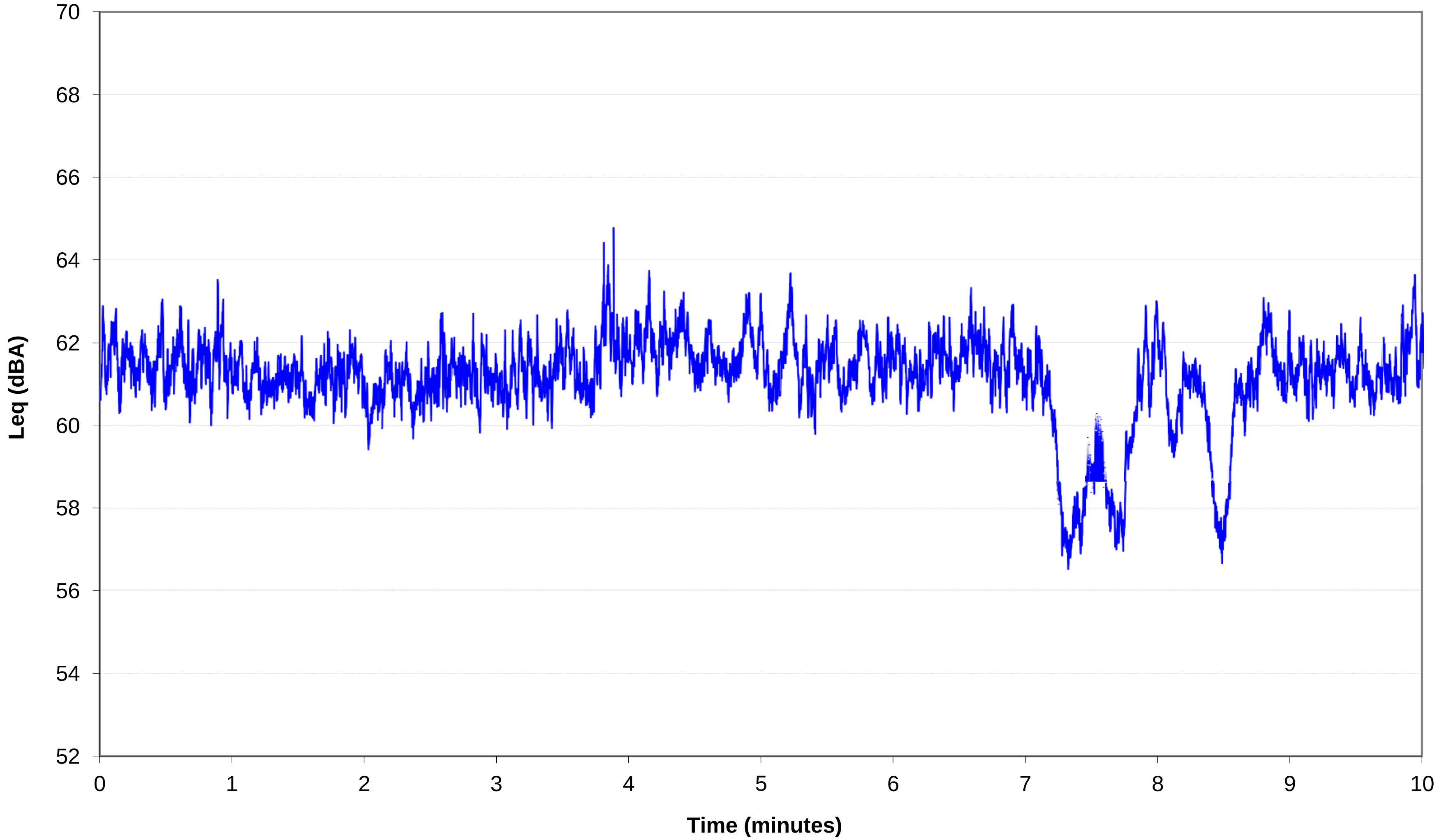


Figure 10. Time Variation of Sound Levels (Leq) at a Distance of 10 Feet from the Inverter Pad for Site #3 - First 10 Seconds of Measurements

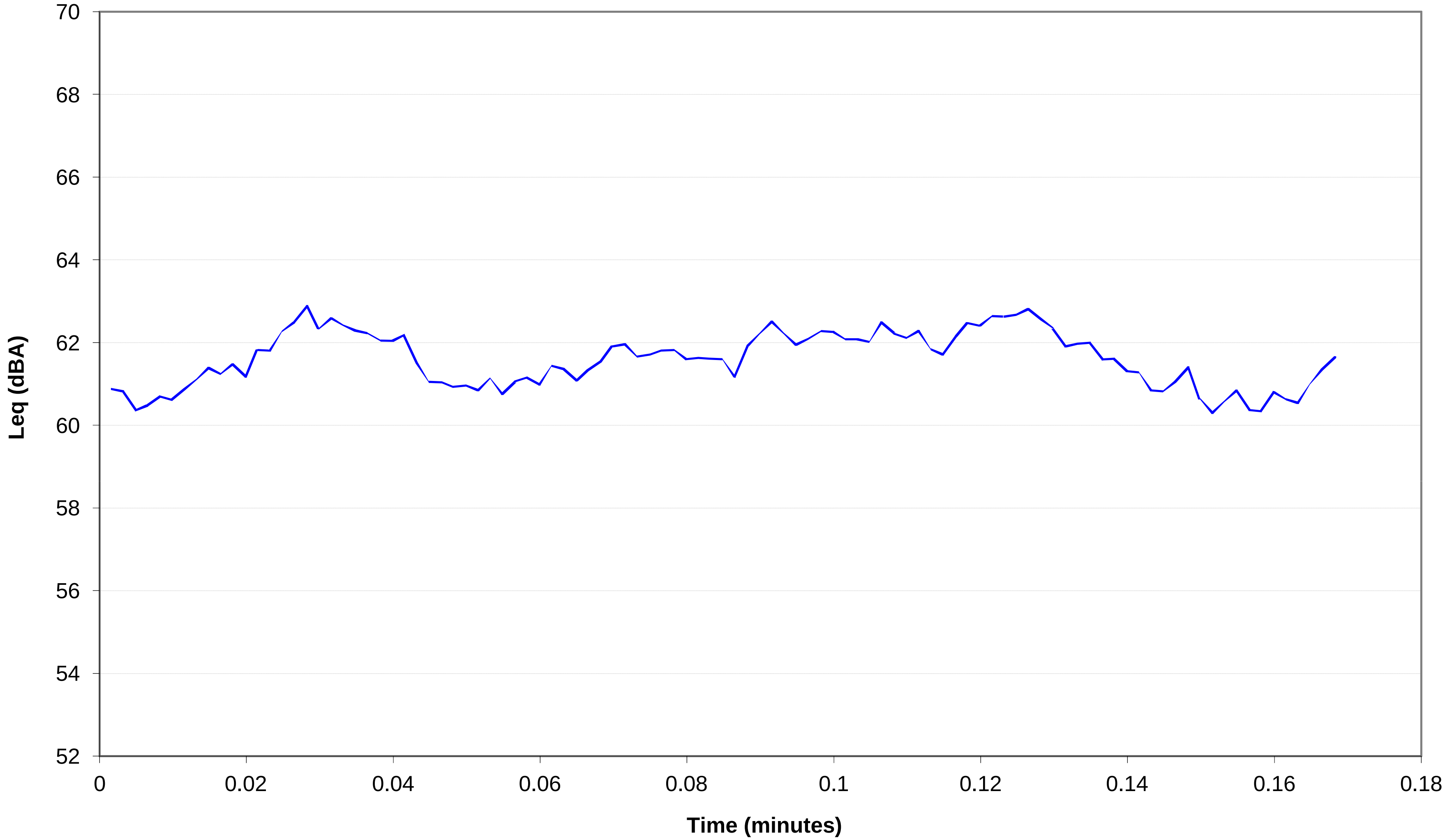
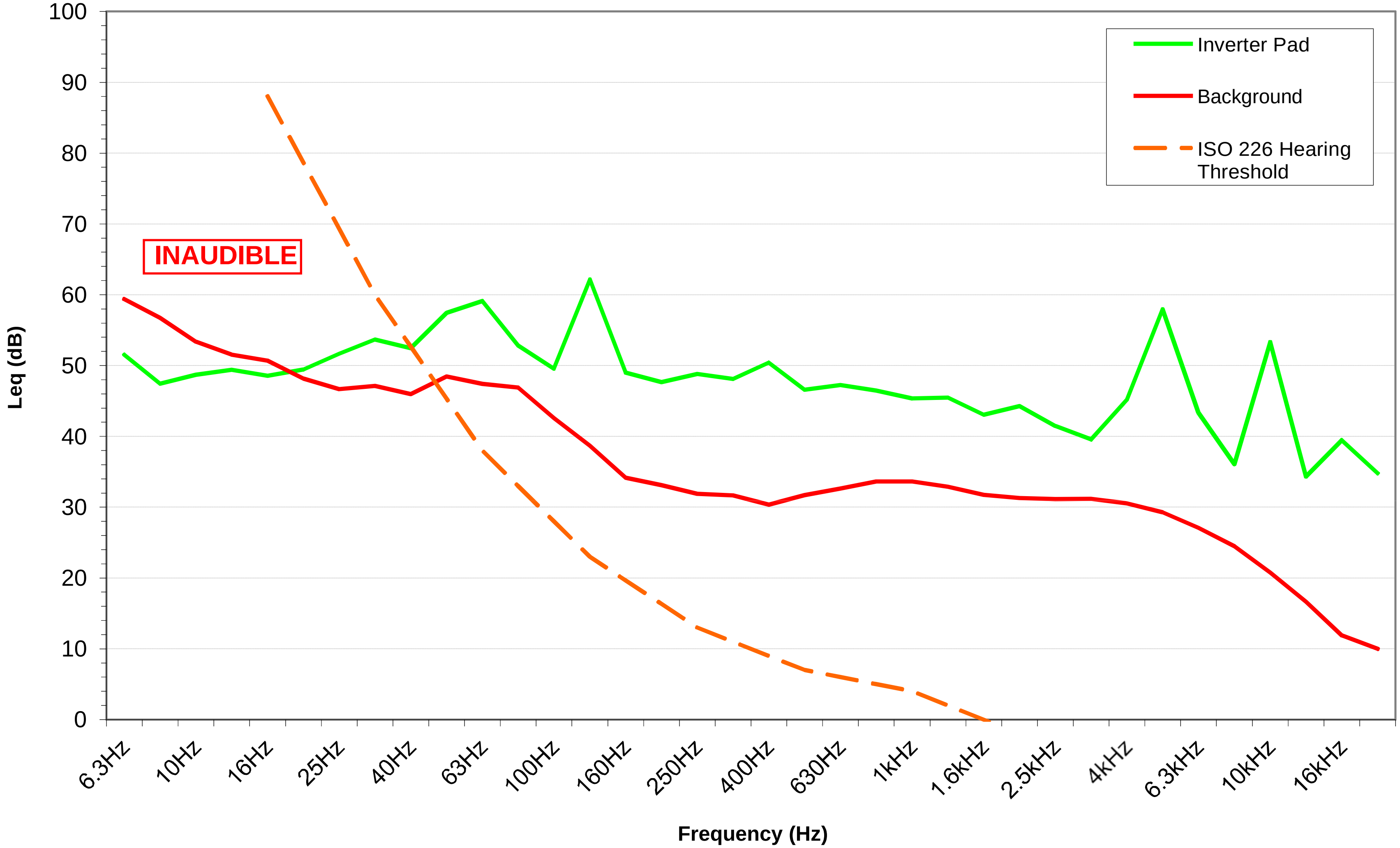


Figure 11. Frequency Spectrum of Sound Levels (Leq) at a Distance of 10 Feet from the Inverter Pad at Site #3



3.4 Site 4 – Residential Solar at Mass. Audubon Society in Sharon

Facility Location:	Moose Hill Sanctuary, 293 Moose Hill Road, Sharon, MA
Facility Owner:	Massachusetts Audubon Society
System Capacity:	8.6 kW
Power Output During Monitoring:	4.2 kW
No. & Size Inverters:	(1) 5-kW inverter and (1) 3.6-kW inverter
Date Measured:	Friday October 26, 2012
Sky Cover:	50% (scattered clouds)
Winds:	Northwest 0-3 mph
Ground:	(42) Evergreen solar panels are mounted on the pitched roof of the two-story building and face south. The ground around the site is cleared and opens to the south with surrounding woods at a distance.
Background EMF:	None in occupied rooms (< 0.2 mG and < 5 V/m). In the basement storage space where the inverters were housed, a background magnetic field of 2 mG was present and the background electric field was < 5 V/m.

EMF measurements were made inside the headquarters building of the Massachusetts Audubon Moose Hill Sanctuary. No sound measurements were made for this residential sized solar installation. The EMF measurements were made in rooms on the second floor of the building, the closest locations occupants have to the roof-mounted panels. Measurements were also made at the inverters inside the basement of the building, in a space not readily accessible to the public. The EMF measurements made at Site 4 are summarized in Tables 10 and 11.

Electric Fields

Electric field levels in the rooms on the top floor, nearest the roof-mounted solar panels are not elevated above background levels (< 5 V/m). In the basement, electric fields near the inverters (3 feet) are not elevated above background levels (< 5 V/m).

Magnetic Fields

Magnetic field levels in the rooms on the top floor, nearest the roof-mounted solar panels were in the very low range of 0.2 to 1.4 mG. Table 11 reveals that there are low-level magnetic fields at locations a few feet from inverters, around 6 to 10 mG. These levels dropped back to a floor of 2 mG at a distance of 6 to 9 feet from the inverters. Nearby electrical lines and other equipment in the basement created a background of 2 mG in the space where the inverters were housed.

TABLE 10

EMF LEVELS MEASURED INSIDE THE RESIDENTIAL BUILDING, TOP FLOOR AT SITE 4

Boundary Location	Magnetic Field (mG)	Electric Field (V/m)
North West Room	0.9	< 5
South West Room	1.4	< 5
South East Room	0.2	< 5
North East Room	0.5	< 5

TABLE 11

EMF LEVELS MEASURED INSIDE THE RESIDENTIAL BUILDING, BASEMENT AT SITE 4

Equipment Pad / Direction / Distance	Magnetic Field (mG)	Electric Field (V/m)
Parallel to Inverter Face / 3 feet	10	< 5
Parallel to Inverter Face / 6 feet	6	< 5
Parallel to Inverter Face / 9 feet	2	< 5
Parallel to Inverter Face / 15 feet	2	< 5
Perpendicular to Inverter Face / 3 feet	6	< 5
Perpendicular to Inverter Face / 6 feet	2	< 5
Perpendicular to Inverter Face / 9 feet	2	< 5
Perpendicular to Inverter Face / 15 feet	2	< 5

4.0 CONCLUSIONS

Sound pressure level and electromagnetic field (EMF) measurements were made at three utility-scale PV arrays with a capacity range of 1,000 to 3,500 kW under a full-load condition with sunny skies and the sun at approximately 40^{o} azimuth. Measurements were taken at set distances from the inverter pads and along the fenced boundary of the PV array. Measurements were also made at set distances back from the boundary. Broadband and 1/3-octave band sound levels were measured, along with the time variation of sound levels from the equipment.

EMF Measurements were also made at one residential[6] PV installation with a capacity of 8.6 kW under a partial-load condition. PV array operation is related to the intensity of solar insolation. Less sunshine results in lower sound and EMF levels from the equipment, and no sound or EMF is produced at night when no power is produced. A description of acoustic terms and metrics is provided in Appendix A, and EMF terms and metrics are presented in Appendix B. These appendices provide useful information for interpreting the results in this report and placing them in context, relative to other sound and EMF sources.

Sound Levels

At the utility scale sites, 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 along the boundary. Any sound from the PV array and equipment was inaudible and sound levels are at background levels at set back distances of 50 to 150 feet from the boundary.

Average L_{eq} sound levels at a distance of 10 feet from the inverter face varied over the range of 48 dBA to 61 dBA for Site 2 and Site 3 Inverters[7], and were higher in the range of 59 to 72 dBA for Site 1 Inverters. Along the axis perpendicular to the plane of the inverter face and at distances of 10 to 30 feet, sound levels were 4 to 13 dBA higher compared to levels at the same distance along the axis parallel to the plane of the inverter face. At a distance of 150 feet from the inverter pad, sound levels

[6] Only EMF measurements were made at the residential site.

[7] The same make of inverters were used at Sites 2 and 3.

approached background levels. Sound level measurements generally followed the hemispherical wave spreading law (-6 dB per doubling of distance).

The time domain analysis reveals that 0.1-second L_{eq} sound levels at a distance of 10 feet from an inverter pad generally varied over a range of 2 to 6 dBA, and no recurring pattern in the rise and fall of the inverter sound levels with time was detected. The passage of clouds across the face of the sun caused cooling fans in the inverters to briefly turn off and sound levels to drop 4 dBA.

The 1/3-octave band frequency spectrum of equipment sound at the close distance of 10 feet shows energy peaks in several mid-frequency and high-frequency bands, depending on the inverter model. Tonal sound was found to occur in harmonic pairs: 63/125 Hz; 315/630 Hz; 3,150/6,300 Hz; and 5,000/10,000 Hz. The high frequency peaks produce the characteristic “ringing noise” or high-frequency buzz heard when one stands close to an operating inverter. The tonal sound was not, however, audible at distances of 50 to 150 feet beyond the PV array boundary, and these tonal peaks do not appear in the background sound spectrum. All low-frequency sound from the inverters below 40 Hz is inaudible, at all distances.

Electric Fields

The International Commission on Non-Ionizing Radiation Protection has a recommended exposure limit of 4,200 V/m for the general public. At the utility scale sites, electric field levels along the fenced PV array boundary, and at the locations set back 50 to 150 feet from the boundary, were not elevated above background levels (< 5 V/m). Electric fields near the inverters were also not elevated above background levels (< 5 V/m).

At the residential site, indoor electric fields in the rooms closest to the roof-mounted panels and at locations near the inverters were not elevated above background levels (< 5 V/m).

Magnetic Fields

The International Commission on Non-Ionizing Radiation Protection has a recommended exposure limit of 833 mG for the general public. At the utility scale sites, magnetic field levels along the fenced PV array boundary were in the very low range of 0.2 to 0.4 mG. Magnetic field levels at the locations

50 to 150 feet from the array boundary were not elevated above background levels (<0.2 mG). There are significant magnetic fields at locations a few feet from inverters, in the range of 150 to 500 mG. At a distance of 150 feet from these utility-scale inverters, these fields drop back to very low levels of 0.5 mG or less, and in many cases to background levels (<0.2 mG). The variation of magnetic field with distance generally shows the field strength is proportional to the inverse cube of the distance from equipment.

At the residential site, indoor magnetic field levels in the rooms closest to the roof-mounted panels were in the low range of 0.2 to 1.4 mG. There are low-level magnetic fields at locations a few feet from the inverters, in the range of 6 to 10 mG. At a distance of no more than 9 feet from the inverters, these fields dropped back to the background level at the residential site of 2 mG. Due to the relatively high background level in the residential site basement where the inverters were housed, the relationship of magnetic field strength to distance from the inverters could not be discerned.

APPENDIX A
ACOUSTIC TERMS AND METRICS

All sounds originate with a source – a human voice, vehicles on a roadway, or an airplane overhead. The sound energy moves from the source to a person's ears as sound waves, which are minute variations in air pressure. The loudness of a sound depends on the **sound pressure level**[8], which has units of decibel (dB). The **decibel scale** is logarithmic to accommodate the wide range of sound intensities to which the human ear is subjected. On this scale, the quietest sound we can hear is 0 dB, while the loudest is 120 dB. Every 10-dB increase is perceived as a doubling of loudness. Most sounds we hear in our daily lives have sound pressure levels in the range of 30 dB to 90 dB.

A property of the decibel scale is that the numerical values of two separate sounds do not directly add. For example, if a sound of 70 dB is added to another sound of 70 dB, the total is only a 3-decibel increase (or 73 dB) on the decibel scale, not a doubling to 140 dB. In terms of sound perception, 3 dB is the minimum change most people can detect. In terms of the human perception of sound, a halving or doubling of loudness requires changes in the sound pressure level of about 10 dB; 3 dB is the minimum perceptible change for **broadband** sounds, i.e. sounds that include all frequencies. Typical sound levels associated with various activities and environments are presented in Table A-1. The existing sound levels at a PV project site are determined primarily by the proximity to roads and highways, the source of traffic noise. Sound exposure in a community is commonly expressed in terms of the **A-weighted sound level (dBA)**; A-weighting approximates the frequency response of the human ear and correlates well with people's perception of loudness.

The level of most sounds change from moment to moment. Some are sharp impulses lasting one second or less, while others rise and fall over much longer periods of time. There are various measures of sound pressure designed for different purposes. The equivalent sound level $\mathbf{L_{eq}}$ is the steady-state sound level over a period of time that has the same acoustic energy as the fluctuating sounds that actually occurred during that same period. It is commonly referred to as the energy-average sound

[8] The sound pressure level is defined as $20*\log_{10}(P/P_o)$ where P is the sound pressure and P_o is the reference pressure of 20 micro-Pascals (20 μPa), which by definition corresponds to 0 dB.

level and it includes in its measure all of the sound we hear. EPA has determined that the $\mathbf{L_{eq}}$ average sound level correlates best with how people perceive and react to sound.[9]

To establish the background sound level in an area, the $\mathbf{L_{90}}$ metric, which is the sound level exceeded 90% of the time, is typically used. The $\mathbf{L_{90}}$ can be thought of as the level representing the quietest 10% of any time interval. The $\mathbf{L_{90}}$ is a broadband sound pressure measure. By definition, the $\mathbf{L_{90}}$ metric will filter out brief, loud sounds, such as intermittent traffic on a nearby roadway.

Sound pressure level measurements typically include an analysis of the sound spectrum into its various frequency components to determine tonal characteristics. The unit of frequency is **Hertz (Hz)**, measuring the cycles per second of the sound pressure waves. In the physiology of human hearing, every octave jump of a tone corresponds to a doubling of the sound frequency in Hz. For example, Middle-C on a piano has a frequency of approximately 260 Hz. High-C, one octave above, has a frequency of approximately 520 Hz. The hearing range for most people is 20 Hz to 20,000 Hz. In acoustic studies, the sound spectrum is divided into **octave bands** with center frequencies that are an octave apart, or 1/3-octave bands with center frequencies that are 1/3 of an octave apart. There are 11 whole octave bands centered in the audible range from 20 to 20,000 Hz. For the extended frequency range of 6.3 Hz to 20,000 Hz used in this study, there are 36 1/3-octave bands.

Low-frequency sound generally refers to sounds below 250 Hz in frequency, which is close to the tone of Middle-C on a piano. **Infrasound** is low-frequency sound at frequencies below 20 Hz, a sound wave oscillating only 20 cycles per second. For comparison, the lowest key on a piano produces a tone of 28 Hz, and human speech is in the range of 500 to 2,000 Hz. The hearing threshold for infrasound at 16 Hz is 90 decibels (dB).[10] We are enveloped in naturally occurring infrasound, which is inaudible. Infrasound is always present in the outdoor environment due to sounds generated by air turbulence, shoreline waves, motor vehicle traffic and distant aircraft.

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[9] U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," Publication EPA-550/9-74-004.

[10] International Standards Organization, ISO 226:2003.

TABLE A-1

VARIOUS INDOOR AND OUTDOOR SOUND LEVELS

Outdoor Sound Levels	Sound Pressure (μPa)		Sound Level (dBA)	Indoor Sound Levels
	6,324,555	-	110	Rock Band at 5 m
Jet Over-Flight at 300 m		-	105	
	2,000,000	-	100	Inside New York Subway Train
Gas Lawn Mower at 1 m		-	95	
	632,456	-	90	Food Blender at 1 m
Diesel Truck at 15 m		-	85	
Noisy Urban Area--Daytime	200,000	-	80	Garbage Disposal at 1 m
		-	75	Shouting at 1 m
Gas Lawn Mower at 30 m	63,246	-	70	Vacuum Cleaner at 3 m
Suburban Commercial Area		-	65	Normal Speech at 1 m
Quiet Urban Area -- Daytime	20,000	-	60	
		-	55	Quiet Conversation at 1m
Quiet Urban Area--Nighttime	6,325	-	50	Dishwasher Next Room
		-	45	
Suburban Area--Nighttime	2,000	-	40	Empty Theater or Library
		-	35	
Rural Area--Nighttime	632	-	30	Quiet Bedroom at Night
		-	25	Empty Concert Hall
Rustling Leaves	200	-	20	Average Whisper
		-	15	Broadcast and Recording Studios
	63	-	10	
		-	5	Human Breathing
Reference Pressure Level	20	-	0	Threshold of Hearing

Notes:
μPa - Micropascals describe sound pressure levels (force/area).
dBA - A-weighted decibels describe sound pressure on a logarithmic scale with respect to 20 μPa.

APPENDIX B

EMF TERMS AND METRICS

An electromagnetic field (**EMF**) is the combination of an **electric field** and a **magnetic field**. The electric field is produced by stationary charges, and the magnetic field by moving charges (currents). From a classical physics perspective, the electromagnetic field can be regarded as a smooth, continuous field, propagated in a wavelike manner. From the perspective of quantum field theory, the field is seen as quantized, being composed of individual particles (photons).

EMFs are present everywhere in our environment but are invisible to the human eye. For example, electric fields are produced by the local build-up of electric charges in the atmosphere associated with thunderstorms, and the earth's magnetic field causes a compass needle to orient in a North-South direction and is used for navigation. Besides natural sources, the electromagnetic spectrum also includes fields generated by man-made sources. For example, the electricity that comes out of every power socket has associated low frequency EMFs. A photovoltaic (PV) project generates low-frequency EMFs from inverters (that convert DC-current to AC-current), transformers (that step-up the PV project voltage), and current-carrying cables. The EMFs from PV project components are classified as "non-ionizing radiation," because the electromagnetic waves have low-energy quanta incapable of breaking chemical bonds in objects through which they pass.

The strength of the **electric field** is measured in volts per meter (**V/m**). Any electrical wire that is charged will produce an associated electric field. This field exists even when there is no current flowing. The higher the voltage, the stronger the electric field at a given distance from the wire. Magnetic fields arise from the motion of electric charges. The strength of the **magnetic field** is measured by the magnetic flux density in milli-Gauss (**mG**). In contrast to electric fields, a magnetic field is only produced once a device is switched on and current flows. The higher the current, the greater the strength of the magnetic field produced at a given distance. EMFs are strongest close to a source, and their strength rapidly diminishes with distance from it. Field strength is generally proportional to the inverse cube of the distance.

Typical household fixtures and appliances produce both types of fields. For example, at a distance of one foot from a fluorescent light, electric and magnetic fields of 50 V/m and 2 mG, respectively, are measured. At a distance of 1 inch from the power cord for an operating personal computer, fields of 40 V/m and 1 mG, respectively, are detected.

There are no federal, State or local regulatory exposure limits for electric or magnetic fields that apply to solar photovoltaic arrays. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has recommended exposure limits of 4,200 V/m and 833 mG for the general public. ICNIRP is an organization of 15,000 scientists in 40 nations who specialize in radiation protection, and their recommendations are routinely used in EMF exposure studies.

Attachment K

Barry Smith
County Judge/Executive
tcjudgeexec@taylorcounty.us

Magistrates:

James Jones - 1st Dist.
John D. Gaines - 2nd Dist.
Tommy Corbin - 3rd Dist.

Melissa W. Williams
County Treasurer
treasurer@taylorcounty.us

Magistrates:

Zuel Yarberry - 4th Dist.
Derrick Bright - 5th Dist.
Richard A. Phillips - 6th Dist.

OFFICE OF THE JUDGE/EXECUTIVE

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March 23, 2021

Flat Run Solar, LLC
c/o Carolina Solar
400 W. Main Street, Suite 503
Durham, NC 27701

RE: Taylor County Solar Project

Dear Mr. Harkrader:

This is to confirm that Taylor County has no planning and zoning ordinance or jurisdiction. We have no noise ordinance applicable to the proposed Flat Run Solar project to be located here in Taylor County.

Sincerely,

Barry Smith
Taylor County Judge Executive