

Permanent Daytime and Nighttime Sound Monitoring System Protocol

Evergreen Solar, Devens, MA
December 3, 2009

Purpose. A monitoring system for continuously evaluating the status of compliance with the Devens Enterprise Commission (DEC) ongoing 43-dBA daytime and 38-dBA nighttime limits¹ on sound produced by Evergreen Solar equipment.

General features.

1. The system will be permanent, and will operate 24 hr/day, 7 days/wk, under all anticipated weather conditions.
2. Microphones are to be located at two (2) pole locations. One microphone will be located near the VOC compound along the rear service driveway. A second microphone will be located near the Cooling Towers, also along the rear service driveway.
3. Microphones to be mounted 30 to 35 feet above service drive grade at each pole.
4. One pole or a nearby location will be outfitted with a weather station to collect wind speed (mph), wind direction and precipitation amounts. Wet and dry bulb temperatures at the facility are currently and will continue to be recorded by the Facility Management System (FMS).

Acoustical requirements.

1. *System Accuracy:*
 - American National Standards Institute (ANSI) S1.4 Type 1 precision sound measurement instrumentation system.
 - Octave and 1/3-octave band filtering shall be ANSI Standard S1.11-2004 (R2009), Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters, Class 0 or 1.
2. *Frequency Range:* Measurement frequency range shall be at least 12.5 Hz to 12,500 Hz.
3. *Dynamic Range:* Dynamic range of the microphone and analysis system shall be at least 25 dBA to 120 dBA, when measured with slow response. Automatic switching is permitted. The expected system noise floor shall be stated.
4. *Data Measured:* A-weighted and un-weighted slow sound level meter response sound pressure level.
5. *Calibration:* Daily, the system shall be electronically calibrated. The monitoring system manufacturer shall provide a description and instructions on this feature. Annually, the system microphone shall be pressure calibrated using a sound level calibrator with levels traceable to the National Institute of Standards and Technology (NIST).

¹ 974 CMR 4.05. Applicable sound limits apply at nearest points on surrounding residential properties, the nearest of which is Dunroven Farm (a/k/a the R1 location).

6. *Data processing:*

- Data processing may occur in equipment located either at each pole and/or at central location inside or outside of the facility.
- Octave band, 1/3-octave band, and A-weighted analysis shall be provided. One-third octave, full octave, and A-weighted L₉₀ sound pressure levels must be measured separately. The A-weighted L₉₀ must not be computed from one-third or full octave band L₉₀s.
- The system shall measure and provide the L90 sound level with sample period of 20 minutes for the purpose of demonstrating compliance. Starting March 1, 2010, EGS will take measurements at both 5 and 20 minute periods. During any subsequent period of violation, they will report 20 minute compliance data along with 5 minute data for the analysis of the period of violation.
- The system shall be used to monitor compliance with DEC daytime and nighttime sound level limits at all surrounding residential property lines:
 - (a) A-weight reference limits:
 - 66 dBA at the VOC reference microphone during the day to ensure conformance at all surrounding residential property lines with the DEC 43 dBA daytime limit.
 - 61 dBA at the VOC reference microphone during the night to ensure conformance at all surrounding residential property lines with the DEC 38 dBA nighttime limit.
 - 61 dBA at the CT reference microphone during the day to ensure conformance at all surrounding residential property lines with the DEC 43 dBA daytime limit.
 - 56 dBA at the CT reference microphone during the night to ensure conformance at all surrounding residential property lines with the DEC 38 dBA nighttime limit.
 - (b) constant tones as defined by 974 CMR 4.05, section 3(c)(7) based on measured slow 1/3-octave band 90th percentile sound level; and
 - (c) Low frequency reference limits (16 and 31.5 Hz full octave band sound level as defined by 974 CMR 4.05, section 4(a)(2)):
 - 78 and 73 dB in the 16 and 31.5 Hz octave bands respectively at the VOC reference microphone to ensure conformance (day and night) at all surrounding residential property lines.
 - 78 and 74 dB in the 16 and 31.5 Hz octave bands respectively at the CT reference microphone to ensure conformance (day and night) at all surrounding residential property lines.
 - (d) The calculation of reference limits as summarized in Appendix A shall be revisited under available seasonal conditions that have the potential to produce to the lowest ambient noise conditions with a minimum of ambient intrusions, to verify accuracy. Such conditions may become available in the late spring to early summer (Mid-May to Mid-July, 2010). Such measurements shall be coordinated with the DEC. Any alteration/adjustment of the delta values is at the sole discretion of the DEC.

7. *Data collection:*

When a reference limit is exceeded, the following will be collected, disseminated to the DEC in accordance with item #8, and stored for the sample time interval:

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- (a) Audio wave file (wav or mp3)
- (b) A-weight L_{90} (20-minute) sound level
- (c) One-third-octave band L_{90} (20-minute) spectrum.
- (d) 16 and 31.5 Hz octave band L_{90} (20-minute) sound levels.
- Record for later recall and study:
 - (a) All A-weight L_{90} sound levels for each sample time period
 - (b) All wind speed, direction, and the presence of precipitation for all sample time periods.
 - (c) All 16 and 31.5 Hz octave band L_{90} sound levels.
 - (d) All system overloads or malfunctions as a guide to evaluating potentially invalid data.
 - (e) FMS data for cooling tower fan speeds, NOX fan speeds, and VOC fan speeds. Other data regarding equipment and activities, other than cooling and remediation equipment, that might affect sound levels at reference locations, such as construction, site maintenance, etc.

8. *Reporting:* report to the DEC the following:

- All A-weight L_{90} (20-minute) sound level collected daily for the first 30 days of permanent monitoring, bi-weekly for the next 30 days, and on a monthly basis thereafter. Daily reporting shall also be provided to the DEC for the months of July and August of 2010. Starting March 1, 2010, EGS will take measurements at both 5 and 20 minute periods. During any subsequent period of violation, they will report 20 minute compliance data along with 5 minute data for the analysis of the period of violation.
- 16 and 31.5 Hz octave band L_{90} (20-minute) sound levels collected on a monthly basis.
- If the A-weighted sound level, or the 16 or 31.5 Hz octave band sound level exceeds the limits in item 6, or if a tonal condition is detected, report the following, within 24 hours of the event, for the subject time sample:
 - a) Audio wave file (wav or mp3)
 - b) A-weight L_{90} (20-minute) sound level
 - c) One-third-octave band L_{90} (20-minute) spectrum.
 - d) 16 and 31.5 Hz octave band L_{90} (20-minute) sound levels.
- A-weight L_{90} (5 minute) sound level data collected over the same period. These data will be distributed in a digital graphical PDF format for the required time periods showing time (5minute intervals) on the x axis and A-weighted sound pressure level (dBA) on the y axis and wind speed and precipitation on the second y axis. Each graph will plot A-weight L_{90} (5

minute) measurements at R1, R5 and R7 locations, in addition to 16 and 31.5 Hz octave band L90 levels at R1.

Appendix A

On the basis of measurements prior to ES construction, the background was determined to be 33 dBA during nighttime hours. Accordingly, the DEC nighttime limit is 38 dBA. This implies that the facility sound level on its own, without background present, must not exceed 37 dBA.

The lowest background sound level measured during the day was 38 dBA. Accordingly, the daytime limit is 43 dBA (38 dBA + 5 dBA = 43 dBA). This implies that the facility sound level on its own during the day, without background present, must not exceed 42 dBA.

VOC Reference

At 12:00 PM, Saturday, September 5, 2009, the sound level measured at R1 was 37 dBA (see Table A-1). At this time, the facility was operating under normal conditions and insect-corrected measured sound levels were below the DEC nighttime limit of 38 dBA. Presented below are two methods for determining sound level limits at the VOC reference location currently known as R5. These methods employ two assumptions about the background sound. These assumptions are needed as background sound, i.e. sound not produced by Evergreen Solar, cannot be separated from Evergreen sound measured at R1.

- First, let us assume that all of the sound measured was produced by Evergreen, that is background sound was less than 27 dBA (note that $27 + 37 = 37$ dBA).
- At this time, the sound level at the VOC reference was 60 dBA. The delta is $60 - 37 = 23$ dBA.
- When Evergreen is 37 dBA at R1, the VOC reference sound level must not exceed $37 + 23 = 60$ dBA.
- **Hence, 60 dBA is the VOC reference limit under the assumption that Evergreen was the only source of sound and background was 27 dBA or less.**

Let us consider an alternative view of these data. When 37 dBA was measured at R1, suppose the background sound level was in fact 33 dBA—the lowest background sound level reported in the permitting document.

- In this case, the sound level produced by Evergreen was 35 dBA ($33 + 35$ dBA = 37 dBA).
- At this time, the sound level at the VOC reference was also 60 dBA. The delta then is $60 - 35 = 25$ dBA.
- When Evergreen is 37 dBA at R1, the VOC reference sound level must not exceed $37 + 25 = 62$ dBA.
- **Hence, 62 dBA is the VOC reference limit under the assumption that background sound was 33 dBA—the lowest measured during permitting.**

Here we have two VOC reference monitor sound level limits that correspond to Evergreen Solar sound levels of 37 dBA determined under two different assumptions about background: the first assumes background is 27 dBA or lower, the second that the background is 33 dBA—the lowest measured during permitting.

It is defensible that the background sound level does not go below the lowest measured during permitting—33 dBA. Thus the VOC reference limit should be set at 62 dBA. But it is also defensible that the background can drop below 33 dBA resulting in a lower VOC reference sound level limit. **We suggest that an average of the two cases be taken for the VOC reference limit, i.e. 61 dBA.**

Evergreen Solar - Dunroven Farm Horse Trail (R1)
Summary of 20-minute Sound Monitoring
September 5 - 7, 2009 (12 Noon to 6 PM)

Date	Start Time	Measured L ₉₀ (dBA)	L ₉₀ (dBA) Insect Sounds Removed	VOC REF R5 (Avg)	CT REF R7 (Avg)	VOC - Meas.	CT REF - Meas.
Saturday, September 05, 2009	12:01 PM	38.8	37	59.8	56.0	22	19
	12:21 PM	38.5	38	59.7	56.6	22	19
	12:41 PM	38.7	38	59.7	53.8	22	16
	1:01 PM	40.6	39	59.7	53.9	21	15
	1:21 PM	40.1	38	59.8	53.6	22	15
	1:41 PM	40.5	39	59.9	53.9	21	15
	2:01 PM	40.8	39	59.7	53.7	20	14
	2:21 PM	40.3	39	59.8	53.8	21	15
	2:41 PM	40.9	39	59.8	53.9	21	15
	3:01 PM	40.2	39	59.9	53.7	21	15
	3:21 PM	41.3	39	59.9	54.0	21	15
	3:41 PM	40.2	39	59.9	53.8	21	15
	4:01 PM	41.0	39	60.0	53.9	21	14
	4:21 PM	41.8	40	60.0	53.8	21	14
	4:41 PM	41.2	39	60.2	53.9	21	15
5:01 PM	40.2	38	60.2	53.8	22	16	
5:21 PM	41.0	40	60.2	53.9	21	14	
5:41 PM	41.1	39	60.3	53.7	21	14	
Sunday, September 06, 2009	12:20 PM	40.4	39	59.9	56.2	21	17
	12:40 PM	39.7	38	60.0	56.3	21	17
	1:00 PM	40.2	39	60.0	56.0	22	18
	1:20 PM	40.7	39	60.1	55.7	21	17
	1:40 PM	40.1	38	60.0	55.3	21	16
	2:00 PM	40.1	38	60.0	54.4	22	16
	2:20 PM	39.6	38	59.9	53.6	22	16
	2:40 PM	39.6	38	60.0	53.7	22	16
	3:00 PM	39.6	38	60.0	53.7	22	16
	3:20 PM	39.8	38	60.1	53.6	22	16
	3:40 PM	40.1	38	60.0	53.7	22	15
	4:00 PM	39.4	38	60.1	53.6	23	16
	4:20 PM	39.9	38	60.1	53.5	22	16
	4:40 PM	40.2	38	60.1	54.0	22	16
	5:00 PM	40.0	38	60.1	54.1	22	16
5:20 PM	39.5	38	60.1	53.9	22	16	
5:40 PM	40.1	38	60.1	54.2	22	16	
Monday, September 07, 2009	12:00 PM	38.9	36	59.9	53.3	23	17
	12:20 PM	39.7	37	59.8	53.6	23	17
	12:40 PM	39.9	37	60.0	59.0	23	22
	1:00 PM	40.1	38	60.2	64.6	22	27
	1:20 PM	39.5	37	60.2	64.4	23	27
	1:40 PM	39.8	38	60.1	64.8	23	27
	2:00 PM	39.8	38	60.2	64.4	22	27
	2:20 PM	40.3	38	60.3	65.2	22	27
	2:40 PM	39.9	38	60.0	58.4	22	21
	3:23 PM	40.0	38	59.9	54.0	22	16
	3:43 PM	40.3	37	60.0	53.8	22	16
	4:03 PM	41.0	38	60.0	54.0	22	16
	4:23 PM	40.9	37	60.0	54.0	23	17
	4:43 PM	39.4	37	60.1	53.8	23	17
	5:03 PM	39.6	37	60.1	53.9	23	17
5:23 PM	39.6	37	60.1	53.8	23	17	
5:43 PM	39.0	37	60.2	53.9	23	17	

Table A-1. Evergreen Solar sound levels measured on Labor Day weekend, September 5-7, 2009.

On the basis of measurements prior to ES construction, the background was determined to be 38 dBA during daytime hours, 5 dBA higher than during the night. Thus, the DEC daytime limit is 43 dBA. Accordingly, sound levels at the VOC reference monitor are permitted to be 5 dBA higher than at night, i.e. the daytime limit on sound levels at the VOC reference monitor should not exceed 66 dBA.

CT Reference

The maximum cooling tower speed during daytime operation is 80% as the Evergreen systems are now set. On October 4, 2009, the sound level at R1 with the cooling tower operating at 80% was 42 dBA, 1 dBA less than the daytime limit of 43 dBA.

- Let us assume that all of the sound measured at R1 was produced by Evergreen, that is background sound was less than 32 dBA (note that $32 + 42 = 42$ dBA).
- At this time, the sound level at the CT reference was 60 dBA. The delta is $60 - 42 = 18$ dBA.
- When Evergreen is 42 dBA at R1, the CT reference sound level must not exceed $42 + 18 = 60$ dBA.
- **Hence, 60 dBA is the daytime CT reference limit under the assumption that Evergreen was the only source of sound and background was 32 dBA or less.**

Let us consider an alternative view of these data. When 42 dBA was measured at R1, suppose the background sound level was in fact 33 dBA—the lowest background sound level reported in the permitting document.

- In this case, the sound level produced by Evergreen was 41 dBA ($33 + 41$ dBA = 42 dBA).
- At this time, the sound level at the CT reference was 60 dBA. The delta then is $60 - 41 = 19$ dBA.
- When Evergreen is 42 dBA at R1, the CT reference sound level must not exceed $42 + 19 = 61$ dBA.
- **Hence, 61 dBA is the CT reference limit under the assumption that background sound was 33 dBA—the lowest measured during permitting.**

Here we have two daytime CT reference sound level limits determined under two different assumptions about background: the first assumes background is 32 dBA or lower, the second that the background is 33 dBA—the lowest measured during permitting. The associated daytime limits are 60 and 61 dBA at the CT reference location. The nighttime limits would be 5 dBA lower, i.e. 55 and 56 dBA respectively.

We have a third observation from the data for 12:00, Tuesday, September 5, 2009 in Table A-1. At this time, the insect-corrected sound level measured at R1 was 37 dBA; the sound level measured at the CT reference location was 56 dBA. **As it was more likely that the background sound level was 33 dBA (the lowest measured during permitting) than 32 dBA, the higher day/night levels are recommended as limits for sound measured at the CT reference monitor location, i.e. 61 dBA during the day and 56 dBA during the night.**

Low Frequency Reference Limits (Day and Night)

Table A-2 presents low 16 and 31 Hz octave band sound levels measured at high CT speeds at R1 and R7. The differences are determined between these two locations in the bands reported and the corresponding CT reference monitor low frequency sound levels are provided.

CT	NOX	R1--Dunroven Farm		R7 (High) CT Reference Monitor		Differences	
		16 Hz	31 Hz	16 Hz	31 Hz	16 Hz	31 Hz
100	N	56	68	68	76	12	8
80	N	57	62	70	71	13	9
Average						13	9
DEC Limits						65	65
R7 CT reference limit						78	74

Table A-2. CT low frequency noise limits.

The corresponding limits for the VOC reference location are provided in Table A-3 based on sound levels measured on October 11, 2009.

CT	NOX	R1--Dunroven Farm		R7 (High) CT Reference Monitor		Differences	
		16 Hz	31 Hz	16 Hz	31 Hz	16 Hz	31 Hz
N	80	52	55	65	63	13	8
DEC Limits						65	65
R5 VOC reference limits						78	73

Table A-3. **VOC** Low frequency noise limits

Note that conditions during October 11 were not conducive for measurements because of gusty winds and rail activity. Hence, the estimate CT and VOC reference limits are likely lower than required and should be reevaluated as conditions permit.