Memorandum

To: Aileen Kenney
Vice President of Permitting,
Deepwater Wind

Date: June 22, 2017
Revised October 24, 2017

Project #: 42256.00

From: Susan Moberg PWS, CFM

Re: DWW Solar, Simsbury CT – Carbon Debt Analysis

VHB provided services to DWW Solar LLC (DWW) that included performing a carbon debt analysis for DWW's proposed solar installation in Simsbury, Connecticut (the Project). The purpose of this analysis was to determine when the Project will have a net improvement in greenhouse gas (GHG) emissions compared to the loss of 30 acres of trees. Approximately 151 acres of the 289-acre Project Site is forested; proposed tree clearing represents 19.9 percent of the Project Site's forested areas and 10.4 percent of the total Project Site (see Figure: Tree Clearing Plan). This analysis also accounted for the emissions associated with upstream activities of the solar photovoltaic (PV) system, and the emission benefits of land use conversion from active agriculture to warm season grasses.

Methodology and Assumptions

The analysis relied upon US Environmental Protection Agency (US EPA) conversion factors to identify the amount of carbon sequestered in one year by one acre of average U.S. forest: 0.85 metric tons (MT) CO_2, the carbon stock in one acre of average U.S. forest: 76 MT CO_2, and the carbon stock in one acre of cropland after one year of growth, including soil organic carbon: 17.43 MT CO_2.[1]

To calculate GHG emissions associated with upstream activities of the Project's system components, this analysis utilized a study from the National Renewable Energy Laboratory (NREL) that estimated total life cycle emissions of solar photovoltaic (PV) systems to be approximately 40 g CO_2eq/kWh, and that upstream activities account for up to 70 percent of these emissions (28 g CO_2eq/kWh).[2] This analysis used the upper limit of this quantification to arrive at a conservative estimate for associated emissions. Upstream activities of solar PV systems include:

- Raw materials extraction;
- Materials production;
- Module manufacture;
- System/plant component manufacture; and
- Installation/plant construction.

To estimate emissions avoided by converting 130.6 acres of land from active agriculture (i.e., zucchini, tobacco, and corn) to warm season grasses, this analysis used emissions estimates specific to Hartford County provided by

---

[1] US EPA. (2017). *Greenhouse Gases Equivalencies Calculator - Calculations and References*. Retrieved 23 October 2017, from https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

[2] NREL. (2013). *Life Cycle Greenhouse Gas Emissions from Solar Photovoltaics.* Retrieved 19 October 2017, from https://www.nrel.gov/docs/fy13osti/56487.pdf

100 Great Meadow Road
Suite 200
Wethersfield, CT 06109-2377
P 860.807.4300

Michigan State University's US Cropland Greenhouse Gas Calculator.[3] This tool accounts for emissions associated with farming activities such as soil tillage, fuel consumption, and fertilizer use. Soybean crop was used as a proxy for all agricultural production at the Project Site so as not to overestimate the benefits of avoiding such activities. Soybean crop has the lowest overall emissions per acre per year among all available inputs within the tool (i.e., corn, wheat, soybean, switchgrass, silage, and oats). For reference, estimated GHG emissions per year for soybean production is 0.15 MT CO_2eq/acre compared to 0.40 MT CO_2eq/acre for corn production. To estimate the sequestration benefits of grasslands, this analysis referred to a study from Iowa State University that quantified the average annual benefit to be 0.91 MT CO_2/acre.[4]

Estimated emissions generated, avoided, or sequestered were extended over a 30-year period – the assumed lifetime of the Project. This period is consistent with the NREL study on the life-cycle of solar PV systems.

Findings

The carbon debt of the Project is estimated to be 41,373.79 MT CO_2eq over a period of 30 years. This figure includes:

- Tree removal (30-year sequestration loss): 765 MT CO_2;
- Tree removal (one-time release of carbon stock): 2,280 MT CO_2;
- Cropland conversion (30-year emission avoidance and 30-year sequestration): (4,142.05) MT CO_2eq;
- Cropland conversion (one-time release of carbon stock): 2,276.79 MT CO_2; and
- Upstream activities of solar PV system: 40,194.05 MT CO_2eq.

The Project is expected to produce 47,850.06 MWh of energy in its first year of operation.[5] Using emission factors provided by the US EPA specific to the Project's eGrid region (NPCC New England),[6] the estimated annual emission offset of the Project is anticipated to be 12,523.03 MT CO_2eq. Attachment A provides greenhouse gas equivalencies for this estimated offset. For example, the Project's estimated annual emission offset is equivalent to 2682 passenger vehicles driven for one year and 1,352 homes' energy use for one year.[7]

Anticipating a carbon debt of 41,373.79 MT CO_2eq and annual PV production benefits of 12,523.03 MT CO_2eq, it would take the Project approximately 3.3 years to have a net improvement in GHG emissions.

[3] Michigan State University. (2017). US Cropland Greenhouse Gas Calculator. Retrieved 23 October 2017, from http://surf.kbs.msu.edu/county/CT/Hartford
[4] Iowa State University. (2011). *Incorporating Prairies into Multifunctional Landscapes*. http://www.extension.iastate.edu/Publications/PMR1007.pdf
[5] NREL. (2017). PVWatts Calculator. http://pvwatts.nrel.gov/pvwatts.php
[6] US EPA. (2014). eGrid2014v2 Summary Tables. Retrieved 23 October 2017, from https://www.epa.gov/sites/production/files/2017-02/documents/egrid2014_summarytables_v2.pdf
[7] US EPA. (2017). Greenhouse Gas Equivalencies Calculator. Retrieved 23 October 2017, from https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Equivalency Results

How are they calculated?

The sum of the greenhouse gas emissions you entered above is of Carbon Dioxide Equivalent. This is equivalent to:

12,523 Metric Tons

Greenhouse gas emissions from

2,682 Passenger vehicles driven for one year	-or- 30,693,701 Miles driven by an average passenger vehicle	-or- 4,363 Tons of waste recycled instead of landfilled	-or- 624 Garbage trucks of waste recycled instead of landfilled

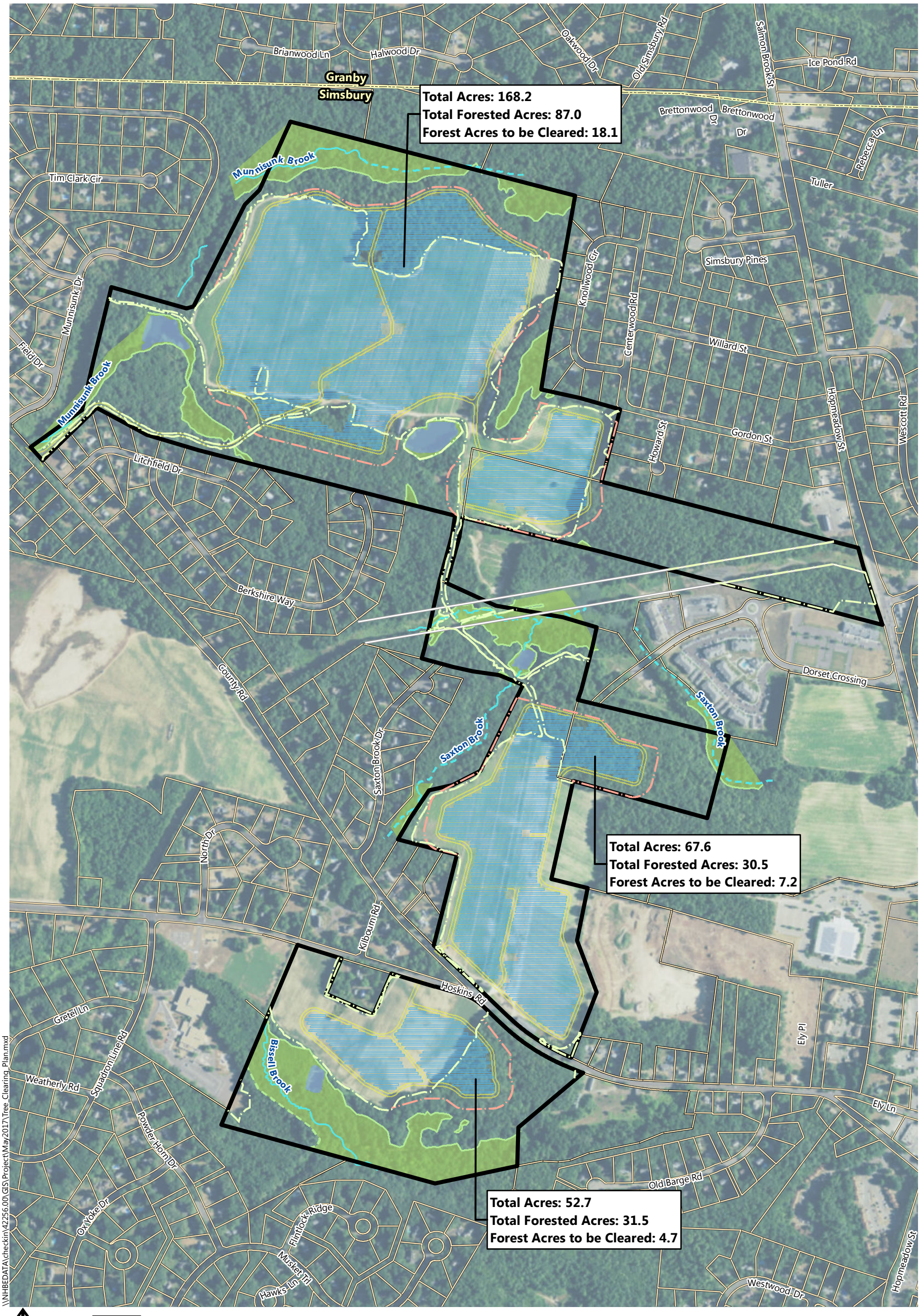
CO_2 emissions from

1,409,140 gallons of gasoline consumed	-or- 13,701,346 Pounds of coal burned	-or- 166 tanker trucks' worth of gasoline	-or- 1,352 homes' energy use for one year -or-
3.2 Wind turbines running for a year	-or- 1,877 homes' electricity use for one year	-or- 68.4 railcars' worth of coal burned	-or- 419,111 Incandescent lamps switched to LEDs -or-
28,993 barrels of oil consumed	-or- 511,938 propane cylinders used for home barbeques	-or- 0.003 coal-fired power plants in one year	

Carbon sequestered by

324,549 tree seedlings grown for 10 years	-or- 14,750 acres of U.S. forests in one year	-or- 102 acres of U.S. forests preserved from conversion to cropland in one year

June 27, 2017



Tobacco Valley Solar | Simsbury, Connecticut

Tree Clearing Map

Source: VHB, CTDEEP, ESRI

\\NHBEDATA\checkin\42256.00\GIS\Project\May2017\Tree_Clearing_Plan.mxd