Carbon Debt Analysis

HDR completed a carbon debt analysis for the North Stonington, Connecticut (Project). This analysis compares the anticipated reduction in greenhouse gas (GHG) emissions from an activity compared to an associated temporary or permanent increase in GHG emissions (referred to as carbon debt). The Project will reduce GHG emissions by displacing electricity produced by natural gas-powered generation facilities with electricity produced by the photovoltaic system. Construction of the Project will require clearing 34.6 acres of forested land, thereby releasing stored carbon from the five carbon stocks of an established forest (aboveground biomass, belowground biomass, dead wood, litter and soil organic carbon) as well as preventing these trees from storing carbon over the life of the Project. The purpose of this analysis is to determine the net impact of adding solar electricity to the power grid and clearing a forested area from the Project area.

Avoided Emissions

Greenhouse gas (GHG) emissions displaced by the Project are calculated by using output emission rates for natural gas for the state of Connecticut. The output emission rates are obtained from the USEPA's Emissions and Generation Resource Integrated Database (eGRID) 2019 data[1]. The output emission rate for natural gas is not specific to peak load output; however, it is considered representative because it is anticipated that the operation of the photovoltaic system will displace the production of electricity using natural gas facilities. Total GHG emissions are expressed as carbon dioxide equivalent (CO_2e), which represents the cumulative impact of multiple greenhouse gases taking into account varying global warming potential, expressed as the amount of CO_2 that would create the same amount of warming. This analysis is not a lifecycle GHG emissions analysis and does not consider all upstream, operational and downstream effects of the Project or existing power generation resources on the regional grid.

Based on these estimations, the Project will displace 5,583 metric tons of CO_2e in the first year of operation. Over the 40-year expected life of the Project approximately 202,859 metric tons of CO_2e will be avoided.

Loss of Carbon Sequestration

Land use changes associated with the project, specifically the clearing of 34.6 acres of forested land, will cause an initial release of stored carbon at the time the forest is cleared. Clearing the forests releases the carbon that has already been stored by the forest system in the form of biomass (in four different stocks) and soil organic carbon. When the forest is cleared, the stored carbon is released. This value was calculated using a United States Environmental Protection Agency (USEPA) conversion factor of 126.57 metric tons CO_2 per acre of forest cleared.[2] Using

[1] Emissions & Generation Resource Integrated Database (eGRID). (2021, February 23). Retrieved from https://www.epa.gov/egrid/data-explorer.

[2] "Greenhouse Gases Equivalencies Calculator - Calculations and References." EPA, Environmental Protection Agency, 18 Dec. 2018, www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references.

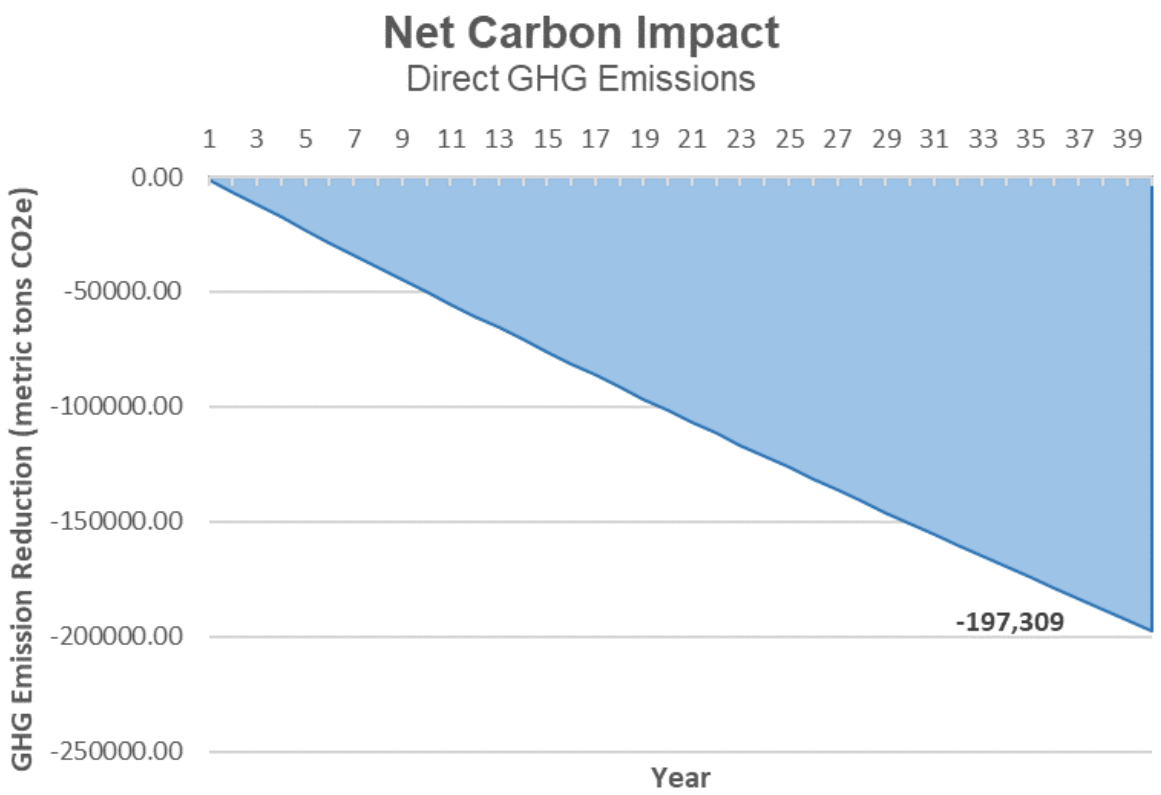
this emission factor assumes that all of the carbon stored by the forest is released and no carbon is stored by re-vegetation of the Project area. This loss occurs only once and is accounted for in the first year of the Project's life. Due to the clearing of this forested area, the Project will cause 4,374 metric tons of CO_2 to be released.

The removal of trees also results in a loss of future carbon sequestration because if the forest was not cleared, the trees would have continued to store additional carbon in the forest carbon stocks as they grew each year, in addition to the carbon the forest has already stored at the time of clearing. This value was calculated using a USEPA conversion factor of 0.85 metric tons CO_2/acre/year.[2] This emission factor is based on the average amount of carbon sequestered by U.S. forests in 2016. This loss will occur annually and is estimated to be approximately 29 metric tons of CO_2 per year. Over the 40-year life of the Project, 1,160 metric tons of CO_2 will not be sequestered.

Net Carbon Impact

Over its operational life, the Project will displace 202,859 metric tons of CO_2e and result in the loss of 5,549 metric tons of carbon sequestered. Therefore, the Project has a positive impact through a net reduction of 197,309 metric tons of CO_2e. It will take 399 days for the Project to offset its carbon debt from the operational phase of the Project.

Figure 1 – Direct Emissions, Net Carbon Impact (Solar vs Natural Gas Output)



Lifecycle Analysis Discussion

The National Renewable Energy Laboratory (NREL) recently published a harmonization of life cycle assessments (LCAs) of electricity generation technologies, including solar and natural gas[3]. NREL reviewed more than 2,100 published LCA studies on utility-scale electricity generation. The studies were screened by multiple experts using strict criteria of quality, relevance, and transparency. As a result, less than 15% of the 2,100 studies were included in the harmonization effort. The harmonization effort adjusted the estimates from published peer-reviewed literature to a consistent set of methods and assumptions specific to each technology. Harmonization did not significantly change the median value of the published data but did reduce the variability of GHG emissions estimates.

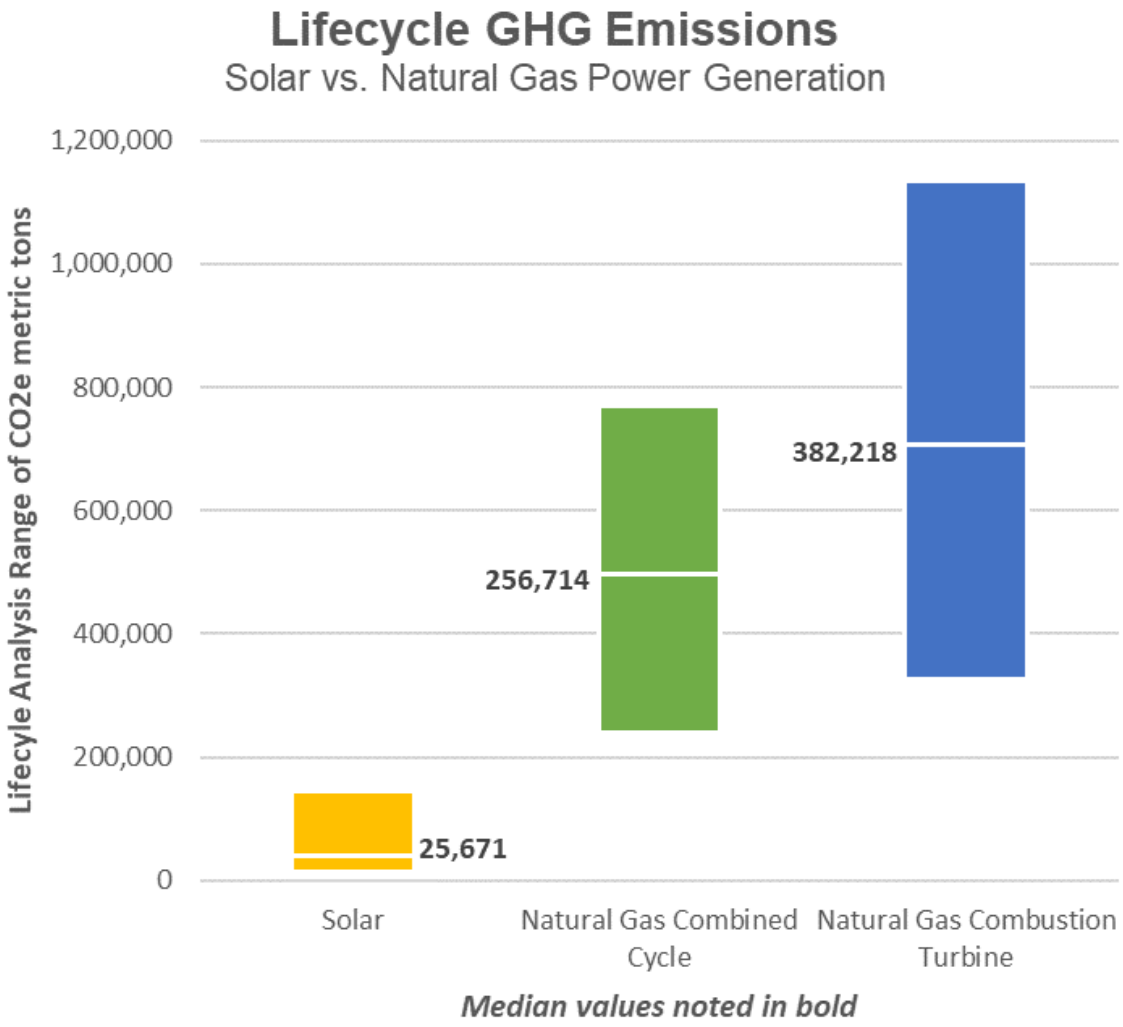
The harmonized studies employed a 'cradle-to-grave' approach to the LCA of crystalline silicon utility-scale solar panel arrays and electricity produced from conventionally produced natural gas. The LCAs included GHGs directly emitted during electricity generation, as well as indirect emissions from upstream processes such as material extraction, transportation, and plant construction, and from downstream processes such as plant decommissioning, recycling of materials, and waste disposal. The LCAs did not consider the removal of trees from a project site, as that is a site-specific factor.

The harmonized lifecycle greenhouse gas emission value of crystalline silicon solar panels ranged from 26 grams CO_2e per kWh (g CO_2e/kWh) to 183 g CO_2e/kWh with a median value of 45 g CO_2e/kWh. The Project is anticipated to produce 570,475 MWh of power over its 40-year life. Therefore, based on the NREL harmonization median value, the Project will result in 25,671,000 kilograms (kg) CO_2e over its lifetime. The harmonized lifecycle greenhouse gas emission value of electricity produced from conventionally produced natural gas ranged from 310 g CO_2e/kWh to 990 g CO_2e/kWh with a median value of 450 g CO_2e/kWh and 670 g CO_2e/kWh for combined cycle plants and combustion turbine plants, respectively. It is assumed for comparison purposes that a natural gas plant would produce an equivalent amount of power over a 40-year operational life as the Project. Based on the median value, a combined cycle natural gas plant would result in 256,714,000 kg CO_2e over its lifetime, and a combustion turbine plant would result in 382,218,000 kg CO_2e over its lifetime.

The lowest estimated lifecycle value for electricity produced from conventionally produced natural gas is higher (310 g CO_2e/kWh) than the highest estimated lifecycle value for electricity produced from crystalline silicon solar panels (183 g CO_2e/kWh). From an LCA perspective based on NREL harmonized numbers, the solar panel array would result in 90% fewer CO_2e emissions compared to a combined cycle natural gas plant and 93% fewer CO_2e emissions than a combustion turbine natural gas plant, as shown in Figure 2.

[3] "Lifecycle Assessment Harmonization." NREL, National Renewable Energy Laboratory, https://www.nrel.gov/analysis/life-cycle-assessment.html.

Figure 2 – Lifecycle Assessment of Natural Gas vs. Solar Electricity Production



The NREL harmonization studies did not include the loss of carbon sequestration due to land use changes. It is conservatively assumed that the construction of a natural gas power plant would result in no land use changes. If the land use change impacts associated with the Project (described above in the Loss of Carbon Sequestration section) are added to the NREL LCA number for the Project, then the Project would result in 30,045,000 kg CO_2e over its lifetime. This value is 88% lower than the NREL LCA number for a combined cycle natural gas plant and 92% lower than the NREL LCA number for a combustion turbine natural gas plant.

HDR **CARBON DEBT ANALYSIS** DATA INPUTS

Client: Silicon Ranch
Project Name: North Stonington Solar Project
Date: 02.02.2022

Project Information

Project City	State	Zip Code
North Stonington	CT	06359

Energy Output in Year 1 of Operation
15,700 MWh

Energy Output in Project Lifetime
570,475 MWh

Expected Useful Life
40 years

Acres of Forested Land Removed due to Project Construction
34.56 acres

HDR **CARBON DEBT ANALYSIS** CALCULATIONS

Client: Silicon Ranch
Project Name: North Stonington Solar Project
Date: 02.02.2022

Loss of Carbon Sequestration - Annual

Forested Project Area (acres)	Carbon Sequestered by US Forest [1] (metric tons CO_2/acre forest/year)	Loss of Carbon Sequestration (metric tons CO_2/year)
34.56	0.85	29.38

[1] Source: "Greenhouse Gases Equivalencies Calculator - Calculations and References." EPA, Environmental Protection Agency, 18 Dec. 2018, www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references. This factor represents an average for U.S. forests in 2016 and may change in the future if the carbon stock significantly changes.

Avoided Emissions - Annual

Annual Production (MWh/year)	State	Output Emission Rate [1] (lb/MWh)	Avoided Emissions (metric tons CO_2e/year)
15,700	Connecticut	783.96	5,582.86

[1] The output emission rate reflects the average emission rate from natural gas electricity production in Connecticut, as calculated by the EPA's Emissions and Generation Resource Integrated Database (eGRID) for the year 2019.

Net Avoided Emissions - Annual

Avoided Emissions (metric tons CO_2e/year)	Loss of Carbon Sequestration (metric tons CO_2/year)	Net Avoided Emissions[1] (metric tons CO_2e/year)
5,582.86	29.38	5,553.49

[1] Net Avoided Emissions represents the difference between Avoided Emissions and Total Loss of Carbon Sequestration. A positive number indicates a net reduction; a negative number indicates a net increase.

Loss of Sequestered Carbon - Land Clearing

Forested Project Area (acres)	Carbon Sequestration Lost Due to Conversion of Forest to Clearing [1] (metric tons CO_2/acre)	Carbon Sequestration Lost Due to Converting Land Use from Forested to Project Use (metric tons CO_2e)
34.56	126.57	4,374.37

[1] Source: "Greenhouse Gases Equivalencies Calculator - Calculations and References." EPA, Environmental Protection Agency, 18 Dec. 2018, www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references. This factor represents the one-time loss of sequestered carbon in aboveground, belowground, dead wood, and litter biomass, as well as mineral soils. The factor assumes no carbon is sequestered by vegetation on cleared land (such as grass).

Avoided Emissions - Project Lifetime

Project Lifetime Production (MWh)	State	Output Emission Rate [1] (lb/MWh)	Avoided Emissions (metric tons CO_2e/Project Life)
570,475	Connecticut	783.96	202,858.81

[1] The output emission rate reflects the average emission rate from natural gas electricity production in Connecticut, as calculated by the EPA's Emissions and Generation Resource Integrated Database (eGRID) for the year 2019.

Net Avoided Emissions - Lifetime

Project Lifespan (years)	Avoided Emissions (metric tons CO_2e/Project Life)	Total Loss of Carbon Sequestration[1] (metric tons CO_2/Project Life)	Net Avoided Emissions[2] (metric tons CO_2e/Project Life)
40	202,858.81	5,549.41	197,309.39

[1] The Total Loss of Carbon Sequestration represents but the one time carbon loss resulting from land clearing and the annual loss from incremental forest sequestration.

[2] Net Avoided Emissions represents the difference between Avoided Emissions and Total Loss of Carbon Sequestration. A positive number indicates a net reduction; a negative number indicates a net increase.

HDR **CARBON DEBT ANALYSIS** CALCULATIONS

Client: Silicon Ranch
Project Name: North Stonington Solar Project
Date: 02.02.2022

LCA GHG Emissions - Crystalline Silicon Solar Panels

LCA Value	Grams CO2e per kWh	Lifecycle 'Cradle to Grave' Emissions (metric tons CO_2/lifetime)
Low	26	14,832
Median	45	25,671
High	183	104,397

[1] Source: Lifecycle Assessment Harmonization." NREL, National Renewable Energy Laboratory, https://www.nrel.gov/analysis/life-cycle-

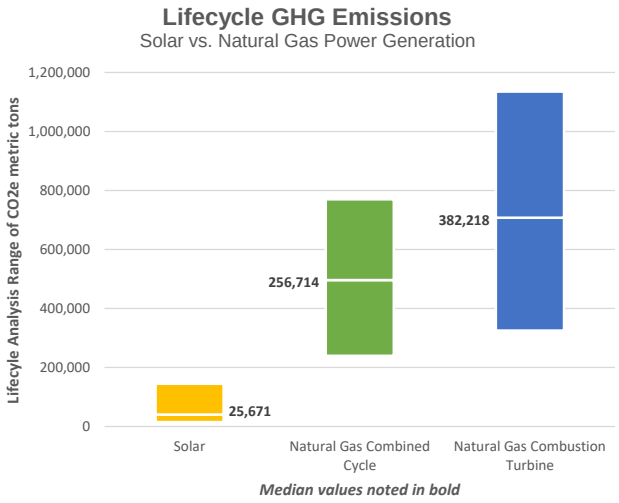
LCA GHG Emissions - Combined Cycle Natural Gas

LCA Value	Grams CO2e per kWh	Lifecycle 'Cradle to Grave' Emissions (metric tons CO_2/lifetime)
Low	420	239,599
Median	450	256,714
High	480	273,828

LCA GHG Emissions - Combustion Turbine Natural Gas

LCA Value	Grams CO2e per kWh	Lifecycle 'Cradle to Grave' Emissions (metric tons CO_2/lifetime)
Low	570	325,171
Median	670	382,218
High	750	427,856

LCA Value	Solar	Natural Gas Combined Cycle	Natural Gas Combustion Turbine	% Reduction
Low	14,832	239,599	325,171	-93.8%
Median	25,671	256,714	382,218	-90.0%
High	104,397	273,828	427,856	-61.9%



HDR **CARBON DEBT ANALYSIS** CALCULATIONS

Client: Silicon Ranch
Project Name: North Stonington Solar Project
Date: 02.02.2022

Year	Annual Output (MWh)	Avoided Emissions	Land Use Impact	Net Annual Impact	Net Cumulative Impact
1	15,700	-5582.864	4403.75	-1179.11	-1179.11
2	15621.5	-5554.95	29.38	-5525.57	-6704.69
3	15543.39	-5527.175	29.38	-5497.80	-12202.49
4	15465.68	-5499.539	29.38	-5470.16	-17672.65
5	15388.35	-5472.041	29.38	-5442.67	-23115.31
6	15311.41	-5444.681	29.38	-5415.31	-28530.62
7	15234.85	-5417.458	29.38	-5388.08	-33918.70
8	15158.67	-5390.37	29.38	-5360.99	-39279.70
9	15082.88	-5363.419	29.38	-5334.04	-44613.74
10	15007.47	-5336.601	29.38	-5307.23	-49920.96
11	14932.43	-5309.918	29.38	-5280.54	-55201.51
12	14857.77	-5283.369	29.38	-5253.99	-60455.50
13	14783.48	-5256.952	29.38	-5227.58	-65683.07
14	14709.56	-5230.667	29.38	-5201.29	-70884.37
15	14636.01	-5204.514	29.38	-5175.14	-76059.50
16	14562.83	-5178.491	29.38	-5149.12	-81208.62
17	14490.02	-5152.599	29.38	-5123.22	-86331.84
18	14417.57	-5126.836	29.38	-5097.46	-91429.30
19	14345.48	-5101.202	29.38	-5071.83	-96501.13
20	14273.75	-5075.696	29.38	-5046.32	-101547.45
21	14202.38	-5050.317	29.38	-5020.94	-106568.39
22	14131.37	-5025.066	29.38	-4995.69	-111564.08
23	14060.72	-4999.94	29.38	-4970.56	-116534.64
24	13990.41	-4974.941	29.38	-4945.56	-121480.21
25	13920.46	-4950.066	29.38	-4920.69	-126400.90
26	13850.86	-4925.316	29.38	-4895.94	-131296.84
27	13781.6	-4900.689	29.38	-4871.31	-136168.15
28	13712.7	-4876.186	29.38	-4846.81	-141014.96
29	13644.13	-4851.805	29.38	-4822.43	-145837.39
30	13575.91	-4827.546	29.38	-4798.17	-150635.56
31	13508.03	-4803.408	29.38	-4774.03	-155409.59
32	13440.49	-4779.391	29.38	-4750.01	-160159.60
33	13373.29	-4755.494	29.38	-4726.12	-164885.72
34	13306.42	-4731.716	29.38	-4702.34	-169588.06
35	13239.89	-4708.058	29.38	-4678.68	-174266.74
36	13173.69	-4684.518	29.38	-4655.14	-178921.89
37	13107.82	-4661.095	29.38	-4631.72	-183553.61
38	13042.28	-4637.789	29.38	-4608.41	-188162.02
39	12977.07	-4614.601	29.38	-4585.22	-192747.24
40	12912.19	-4591.528	29.38	-4562.15	-197309.39
Lifetime Output:	**570,475**	**-202,859**	**5,549**	**-197,309**	